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(ALL TIMES IN THIS BULLETIN ARE UTC)

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SPORT AVIATION / BALLOONS

ADDENDUMS and CORRECTIONS

None

(ALL TIMES IN THIS BULLETIN ARE UTC)

MESSAGE FROM THE CHIEF INSPECTOR OF AIR ACCIDENTS

This is the fifth publication of the AAIB Bulletin in its revised format, the first having been published in September 2005. When the September Bulletin was published I included the following in my opening message:-

> As well as investigating accidents and incidents and making safety recommendations to prevent a recurrence the AAIB has a role to inform and educate. This can only be achieved if we continue to attract as wide a readership as possible. I hope that this new format will achieve this aim. I would welcome comments on the new format which should be directed to **enquiries@aaib.gov.uk**

Since September I have received some very positive feedback and some suggestions for further improvement, which we are considering. We continue to seek to reach as wide a readership as possible and so I again repeat my invitation for comments.

On the 15th November, the report into the accident to Pegasus Quik, G-STYX was published and on the 15th December the report into the serious incident involving Boeing 757, G-CPER was published. The report into the accident involving Fairey Britten-Norman Trislander, G-BEVT will be published on 11th January 2006. These reports are available in hard copy from the AAIB or they can be downloaded and printed from the AAIB website. www.aaib.gov.uk

The AAIB continues to respond to an increasing number of reportable accidents and incidents. In order to manage the increased activity we have recruited additional staff during the past year and we have also made a significant investment in new facilities. These are to include state-of-the-art Flight Recorder laboratories and improved accommodation to meet our growing international commitments. The new building is scheduled for completion in the summer of 2006.

The staff at the AAIB join me in wishing everyone in aviation a very safe and successful 2006.

David King

INCIDENT

Aircraft Type and Registration:	Boeing 747-132, N481EV
No & Type of Engines:	4 Pratt & Whitney JT9D-7F Series turbofan engines
Category:	1.1
Year of Manufacture:	1970
Date & Time (UTC):	24 April 2004 at 1048 hrs
Location:	Airborne near the Compton VOR beacon
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	About 16,000 hours (of which 4,000 were on type) Last 90 days - 116 hours Last 28 days - 53 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was carrying out a cargo flight from Ramstein in Germany to Wright Field in New York State. Shortly after reaching a cruising level of FL360, the left outboard engine ran down and could not be restarted. It was decided to return to Ramstein and the aircraft descended to FL210 and took up an easterly heading. The crew determined that the three remaining engines were not producing the selected thrust and declared an emergency requesting a diversion to London Heathrow Airport. The aircraft was radar vectored onto the final approach track for Runway 27R and the commander completed a successful approach to a safe landing. Significant thrust was available and used during the final stages of the approach and the aircraft was taxied under its own power. Three safety recommendations were made and one was re-iterated.

History of the flight

The crew of two pilots and a flight engineer travelled from their hotel by taxi to Ramstein airport on the morning of the flight. The journey took approximately 25 minutes and followed a rest period of 24 hours. On arrival at the aircraft, a ground engineer who had carried out the pre-flight inspection and had signed the technical log met the crew. There were no deferred defects and the aircraft was loaded with cargo, which had been distributed and secured in the cargo bay.

The flight engineer (FE) performed an external inspection and checked the security and loading of the cargo. A second flight engineer was being re-positioned back to the USA and was being carried as a passenger. Having completed the refuel, the FE ensured the doors were secure and then joined the pilots, who had been carrying out their cockpit checks.

For the climb and the transit across northern Europe the weather was good with clear skies and no forecast precipitation. Engine start and taxi were normal and the aircraft departed from Runway 27 at Ramstein on schedule at 0905 hrs with the aircraft commander as the Pilot Flying (PF) and the co-pilot performing the role of Pilot Not Flying (PNF). Whilst the initial climb seemed normal, as altitude increased the rate of climb appeared to be slower than would be expected for the gross mass of the aircraft of 290 tonnes. No cloud was encountered and two of the three air conditioning packs were supplying the pressurisation as normal. The cruising level of FL360 was reached 33 minutes after takeoff and all engine parameters were normal with the autopilot engaged. A cruise speed of 0.84 Mach was selected and the crew prepared to obtain their Oceanic clearance when something, which was not identified by the crew members, made all three of them look at the Engine Instrument Display System (EIDS). The No 1 engine EPR (Engine Pressure Ratio) started to reduce and the co-pilot saw it initially stagnate in the mid-range before reducing further. The fuel flow increased although the figure could not be recalled.

In accordance with the operator's Standard Operating Procedures (SOPs), the commander instructed the FE to check the engine indications, from which he confirmed that the engine had failed and the engine shut down drill was performed in accordance with the abnormal check list. Air Traffic Control at the London Area Control Centre (LACC) was informed of the engine failure and a descent to FL310 was requested and approved. When level at FL310 and when instructed by the commander, the FE attempted to re-start the No 1 engine, but this was not successful. The FE then contacted the operator's Maintenance Control and was instructed to return to Ramstein where maintenance support was available. The co-pilot advised the LACC of the intended change in routing and a 180º left turn was approved with a descent to FL210. The commander carried out the descent using the autopilot in the vertical speed mode during which he became aware that the thrust levers were positioned in the "number six position", well forward of the normal position for such a descent, yet the EPR indications were at idle. When the aircraft was levelled at FL210, the air speed began to decrease significantly which the co-pilot drew to the attention of the commander. The crew discussed the anomaly of the forward thrust lever position and low engine power indications and recorded the engine EPRs as: '#1 eng 0.704, #2eng 1.124, #3eng 1.206 and #4eng 1.149'. The commander asked the FE to check that the igniters and fuel heat were on. He confirmed that they were and that the fuel temperature was normal. The FE then sought advice from Maintenance Control regarding what the problem might be and what action could be taken. Maintenance Control was unable to offer any solutions and the crew agreed that if normal thrust were not available, an immediate diversion to London Heathrow would be the safest option.

The LACC was informed that the crew were declaring an 'emergency', and requesting an immediate diversion to London Heathrow. The controller asked the co-pilot to confirm they were declaring a 'MAYDAY', to which she responded "YES WE ARE DECLARING AN EMERGENCY". Transponder code 7700 was allocated and set and the LACC began planning the routing and vertical profile for the aircraft to land at Heathrow.

The commander was seen by the co-pilot to advance the Nos 2 and 4 thrust levers one at a time but the EPRs remained the same with the EGTs increasing to approximately 890ºC with no detectable corresponding forward acceleration. Further operation of the thrust levers was considered but the commander did not wish to compound his problems by possibly flaming out the remaining engines. He decided that from the aircraft's current position, he would be able visually to manage the descent of the aircraft to Heathrow. The crew had clearly seen Heathrow as they passed abeam it and it was clear of cloud. They were not familiar with the location of the major UK airports but having seen Heathrow, they had noted its size and could visually locate its position. The LACC allocated a discreet frequency for the sole use of the aircraft and radar vectored it in a continuous descending right turn back towards Heathrow. Although initially the crew were concerned that the radar headings to the south were taking them away from Heathrow, the controller continued their turn back towards the airport. As the aircraft progressed on a northerly track, it was clear that it would be too high to join on a left base for Runway 27R which had been allocated. The controller informed the crew that the aircraft was still too high for the approach to which the co-pilot informed the controller "WE'RE JUST NOT SURE WE'RE GONNA GET ENOUGH POWER TO LAND". As the aircraft approached the point at which a left turn would normally be given to intercept the localiser, a descending 270º right turn was given by ATC which brought the aircraft onto an intercept heading for the ILS approach for Runway 27R from the north. The crew did not have available to them the approach charts for London Heathrow so the ILS frequency for and the length of Runway 27R were obtained from ATC.

The aircraft appeared to the radar controller to be establishing on the extended centre line for Runway 27L which he queried with the co-pilot. He was informed that they were going to carry out a series of 'S' turns in order to lose height and manoeuvre for the runway. Whilst the aircraft was high for a conventional approach, the commander used his knowledge of the aircraft's handling qualities and performance, in the configurations into which it would be placed, to judge an approach path such that if no thrust was available, the aircraft would touch down on the runway.

Throughout the approach, the co-pilot and FE assisted the commander by providing relevant information. Landing speeds had been calculated and the airspeed indicator bugs set. Maintaining the visual aspect envisaged by the commander, in order to achieve the necessary glide angle to reach the runway, was something that he was not able to communicate as it was a judgement exercise and not a promulgated procedure with known heights or associated speeds. A prompt from the FE for lowering the landing gear was relevant but the commander wanted to delay the action until he judged the correct point for it to be selected 'DOWN'. He used turning manoeuvres, flap and gear selections to reduce speed whilst conserving height. Only in the final stages of the approach with flaps set at 30º was thrust instinctively added to which the engines responded and the forward acceleration was detected by the crew.

The aircraft touched down at 145 kt CAS (Calibrated Air Speed) within the normal touchdown zone. Medium autobrake, spoilers and reverse thrust were used to reduce speed on the runway. After a discussion between the aircraft commander and the airport Rescue and Fire Fighting Service, the aircraft was taxied under its own power to a parking stand.

Air Traffic Control

Control of the aircraft was initially being carried out by the LACC controller who, following the run down of the

No 1 engine, managed the initial descent clearances from FL360 to FL310 and then to FL210 with the associated 180º left turn to return to Ramstein. When the controller was made aware of the problems with the remaining three engines and the fact that the pilot was declaring an emergency, she contacted the London Terminal Control Centre (LTCC) Radar Coordinator and informed him of the situation. The emergency transponder code of 7700 was allocated to the aircraft and a Radar Controller was assigned to control the aircraft using a discreet frequency. The co-pilot, who was managing the aircraft's radio telephony, was instructed to make contact on that frequency which she did and control was then passed to the LTCC.

The assigned controller took up a radar console adjacent to the TMA controller who was managing all the other aircraft in or transiting that area of the London TMA below FL200. This permitted close dialogue between the two controllers when trying to sequence the air traffic.

The Group Supervisor (GS) decided that a London Heathrow Approach Controller would be needed to handle the final vectoring of the aircraft for the landing runway, which was Runway 27R. The allocated approach controller made his way to where the TMA controller was sat and occupied the adjacent console. Shortly afterwards the approach controller was joined by the Terminal Control Watch Manager.

Having created a controlling team co-located at adjacent terminals, ATC's intention was to use 35 track miles from when the aircraft was heading 315º to radar vector it from the left base position onto the final approach. At that stage the controllers believed that the aircraft was capable of reduced thrust and not suffering a total loss of thrust on the three remaining engines. It was only when the co-pilot transmitted the warning that there may not be enough power to make the landing did the full extent of the problem become known.

At that point the aircraft appeared to stop its rate of descent and even climb slightly before continuing the descent. Given the height of the aircraft and its close proximity to Heathrow, the radar controller instructed that a 270º turn to the right should be executed to lose the excess height and speed. The flight crew accepted this instruction and the manoeuvre was flown, rolling out on an intercept heading of 305º for the extended centreline of Runway 27R. This manoeuvre took the aircraft over the centre of London.

The Heathrow Approach controller took over control of the aircraft using the same discreet frequency to avoid the flight crew having to make a frequency change. He wanted the aircraft to slow down in order to improve the accuracy of his control but also to reduce the radius of the turns being made which were large due to the aircraft's high speed. He discussed the track miles required by the flight crew to lose their height and his offer of 18 nm was agreed.

The Approach controller was still concerned at the height and speed of the aircraft in relation to the reducing track miles to run and so he verified with the co-pilot that they were making their approach to Runway 27R as it appeared on the radar display that they were aligning with 27L. The crew confirmed that they were visual with Runway 27R and were going to make 'S' turns to lose the height. The controller monitored the progress of the flight confirming several times during the final approach that the pilot was able to lose the height, which still appeared too great for the distance to run. The controller obtained a landing clearance from the tower and passed it to the crew. He also knew that the last opportunity for an orbit was at about six miles from touchdown and after that, with no thrust, the aircraft would be committed. As the aircraft rolled out of the left turn onto the final approach track at 2 nm, the controller could see that the aircraft's height and speed were reasonable and he attempted to re-assure the crew by confirming this to them and re-confirming their clearance to land.

During the handling of the emergency, there was some speculation within ATC concerning the nature of the cargo onboard the aircraft. The airline was conducting flights in support of the US military and it was not known if there were Dangerous Goods onboard.

Meteorological conditions

The synoptic situation at 1200 hrs UTC on the day of the incident showed an area of high pressure covering western Europe with generally thin Cirrus cloud over south-eastern parts of the British Isles. The area forecast gave a few shallow cumulus clouds, base 4,500 ft and scattered or broken, mainly thin cirrus clouds, in layers between 26,000 ft and 43,000 ft. The forecast surface visibility was between 20 and 30 km with no weather.

The wind at FL360 was 300º/20 kt with temperature -59ºC, dew point -66ºC and relative humidity 40%.

The weather observations for the relevant period at London Heathrow at shown in Table 1 below.

Engineering

Since the operator did not have any engineering presence in the UK, the aircraft was examined at Heathrow by an engineer from another company. Being aware of rumours that the aircraft had been parked in the Middle East during a sandstorm, one of his first priorities was to take fuel samples from all six fuel tanks. The samples were sent to the US Air Force facility at RAF Mildenhall where subsequent tests found the fuel to be to the correct specification with no abnormalities.

The engineer then inspected the engines externally and opened the cowls to check for leaks; none were found and no visible anomalies were apparent. No exceedences had been recorded by the Engine Instrument Display System so he performed a 'wet cycle' on the No 1 engine. During this he noted that there were no indications of Low Pressure Spool Speed (N_1) or Fuel Flow (FF) for this engine on the EID.

Having noted that the No 1 igniter system was inoperative, the engineer then tried to start the engine using igniter system No 2. The start was successful but there were still no indications of N_1 or FF. He replaced the N_1 tacho generator but there were still no N_1 indications so he cleaned the 'Cannon' plugs associated with N_1 and FF. During this activity, the engineer found a BITE (Built-In Test Equipment) fault on the EIDS which led

Time Hrs UTC	Mean wind direction & speed (kt)	Visibility	Clouds	Air Temp	Dew Point	QNH mb	Trend
1020	240º/02	>10 km	No significant	17º C	09ºC	1027	No change
1050	230º/05 direction variable between 150º & 280º	>10 km	Few at 4,000 ft Scattered at 30,000 ft	19º C	06ºC	1027	No change

Table 1

him to change the right-hand display unit and clean the 'Cannon' plugs for the EIDS system.

The engineer then removed the fuel filters from all four engines, despatching them to the operator's headquarters for analysis. Before despatch, he had noted that there was some particulate contamination of the No 1 engine filter, but the other three appeared clean. He did not consider that the contamination of the No 1 filter was particularly heavy (this was later confirmed by the operator's engineering department). As a precaution he checked the additional filters on the fuel control unit from this engine and found them clean. The engine was then started and run at idle, during which N_1 and FF indications were observed to be normal.

In the presence of the crew, all four engines were started and run-up to take-off power, with instrument readings being taken which were relayed to the operator's main maintenance base. Since the readings indicated normal operation and performance by all four, clearance was given for the aircraft to continue with its planned journey.

Subsequent information from the operator is that nothing in the aircraft's operating history since the incident has caused any concern over performance of any of the engines.

High altitude engine acceleration characteristics

The operator's Boeing 747 Operations Manual contains the following information regarding engine behaviour and management:

> *"Slow engine acceleration and/or slow EPR response at high altitude could be misinterpreted as lack of engine response to thrust lever movement. Due to the engine inlet air spillage at low thrust settings near idle and the possibility of false EPR indications, other engine parameters should be monitored. If engine thrust appears to be unresponsive in terms of EPR, advance the thrust lever and monitor N1, EGT and Fuel Flow increase; normally EPR should respond in approximately 15 to 20 seconds. Engine acceleration time up to one minute may be experienced. If N1, EGT and Fuel Flow do not respond normally, or if the engine has flamed out, refer to Abnormal Procedures".*

An additional note on the subject is included on the same page:

> *"NOTE: During high altitude and low gross weight cruise, the engine bleed valve may open when setting cruise thrust. When this occurs, the EPR drops .10 to .15 with an associated decrease in N1 and Fuel Flow. Moving the thrust lever two or three knobs forward of the others can normally schedule the valves closed. Once the bleed valves have closed and thrust has increased, retard the thrust lever slowly to establish desired EPR setting".*

Abnormal engine procedure

An abnormal procedure covers the *"Unscheduled thrust loss or abnormal response to thrust lever advancement"*. The procedure applies when abnormal engine indications occur with low EPR/N_1 and high EGT following thrust lever advancement from a low thrust level or when an unscheduled thrust loss occurs. The abnormal procedure is set out in the Quick Reference Handbook (QRH) and is read by the FE; allocated actions are performed by the PF and FE whilst the PNF monitors the crew actions.

When an engine enters a surge or non recoverable stall condition, the procedure requires the engine to be shut down and restarted in order to regain control of the engine. This is performed in a set sequence or flow. When at high level and adjusting thrust at cruising level or when commencing a descent the Flight Operations Manual states:

> *"If engine surge occurs during steady-stage at high altitude operation, reduce flight altitude to 35,000 feet or below (if possible)".*
>
> *"NOTE: Thrust lever movement above 35,000 feet should be made very slowly (approx .02 EPR/SEC".*

Manual of Air Traffic Services (MATS) Part 1

MATS Part 1 contains guidance on the two main issues of relevance to this incident. It addresses the manoeuvring, over a densely populated area such as central London, of an aircraft in an unsafe condition and diversion from the flight planned route whilst carrying dangerous goods.

> ***10.10 Handling Aircraft Emergencies***
>
> *10.10.1 When the pilot has declared an emergency and stated the aerodrome to which he wishes to proceed, the controllers shall acknowledge this message. If the controller is instructed to inform the aircraft that it is required or requested to divert to another aerodrome then the reason for this change should be established. The message together with the reason, shall then be passed to the captain and his intentions requested.*
>
> *10.10.2 It is desirable that aircraft in emergency should not be routed over densely populated areas. If this is inconsistent with providing the most appropriate service to the aircraft, for example when any extended routeing could jeopardise the safety of the aircraft, the most expeditious route is the one which should be given. Where possible, when expeditious routing is not required, suggestions of alternative runways or aerodromes together with the rationale that the routing would avoid densely populated areas and be consistent with safety, shall be passed to the pilot and his intentions requested.*
>
> *10.10.3 The decision to comply with advice or instructions to land at an airport, other than his selected diversion, lies with the captain of the aircraft who has ultimate responsibility for the safety of his aircraft.*
>
> *10.10.4 It is recognised that controllers providing en-route services at ACCs (Area Control Centres) may not be aware of the boundaries of major cities, town or villages. However, controllers providing aerodrome approach or approach radar control services should be familiar with the centres of population within their areas of jurisdiction.*
>
> ***11 Dangerous Goods***
>
> *11.1 When the pilot of an aircraft in an emergency states that he is carrying dangerous goods, the message must be relayed without delay to the air traffic services unit at the aerodrome of intended landing. The senior controller at the*

aerodrome must notify the aerodrome authority immediately.

11.2 An aircraft carrying dangerous goods which requires special handling is not to be deviated from its flight-planned route except in an emergency. If the aircraft has to divert, the first choice should be a military airfield (RAF or USAF). Stansted and Prestwick also have expertise in handling and parking aircraft with dangerous goods on board. Heathrow and Gatwick are not suitable for diversion.

ATC guidance for aircraft emergencies

National Air Traffic Services (NATS) have produced a booklet entitled '*Aircraft Emergencies, Considerations for Controllers*'. The document is based upon the original guide produced by the United Kingdom Flight Safety Committee (UKFSC) and the UK Civil Aviation Authority's Safety Regulation Group (SRG). It is aimed at provoking thought about emergencies and increasing the understanding of controllers of the process undertaken by a flight crew handling an emergency. It is also designed to assist controllers during their periodical Training for Unusual Circumstances and Emergencies (TRUCE) exercises.

Regarding flight crew, the booklet emphasises the point that there is a:

"reluctance to acknowledge the extent of the problem – there is sometimes a reluctance to declare an emergency when it is appropriate to do so" and "the pilot should be asked to declare a 'PAN' or 'MAYDAY' if priority is required".

The advice for controllers dealing with an incident comparable to that of N481EV is:

Loss of power from all engines

- *Acknowledge Mayday and inform flight crew of nearest airfield and consider an initial vector.*
- *Consider imposing RTF silence for other aircraft.*
- *Orbiting above an airfield will assist in the planning of a glide approach.*
- *Accurate range and track distances can aid descent planning.*
- *Flight crew workload will be high due to engine relight techniques.*
- *A steeper than normal approach path can be expected.*
- *When giving turns the rate of descent may double.*

Radar Data

Primary and secondary radar data from the radar heads at Debden and London Heathrow (23cm) were available for the incident flight, with radar returns every 6 and 4 seconds respectively. Both radar tracks (Figure 1) begin over the east of London above the Thames estuary and end at London Heathrow.

Flight Recorders

The aircraft's operator supplied the AAIB with a copy of the flight data from the Flight Data Recorder (FDR) that included the incident flight. Data was available for 23 parameters (including time) of which EPR (Engine Pressure Ratio) for each engine was the only recorded engine parameter. Cockpit Voice Recordings during the incident were unavailable as they had been overwritten with more recent information.

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Figure 1

London Heathrow 23 cm and Debden RADAR tracks for N481EV on 24 April 2004

A time-history of the relevant parameters during the incident is shown in Figure 2 and includes comments and aircrew speech (from ATC) for correlation with the radar tracks given in Figure 1. The figure starts halfway through the flight, 40 minutes before touchdown, with the aircraft level at Flight Level (FL) 360, at an airspeed of 290 knots KCAS (Knots Calibrated Air Speed) and a thrust for each of the engines at about 1.45 EPR.

Three minutes later, the thrust on all engines reduced to about 1.4 EPR where they remained for one minute. The thrust on engine No 1 then fell to just under 1.1 EPR over a 10 second period. As the EPR for Engine No 1 reached 1.3, the EPRs for the remaining engines also began to fall, stabilising at about 1.37. The thrust on engine No 1 continued to fall to 0.85 EPR over a 40 second period, and then more gradually to 0.81 EPR[1]. The aircraft's recorded altitude and pitch attitude remained constant throughout these thrust reductions, however; the airspeed slowed by 20 kt. Also, as the thrust on the No 1 engine reduced, the lateral acceleration and bank angles began to increase: the lateral acceleration in a negative sense and the bank angle right wing down, both from nominal values of zero and both consistent with the aircraft side-slipping to the right. (Angle of yaw was not recorded on the FDR.)

Footnote

[1] 0.81 EPR is the lowest value of EPR that the FDR installation can record, even if the actual EPR is less than 0.81.

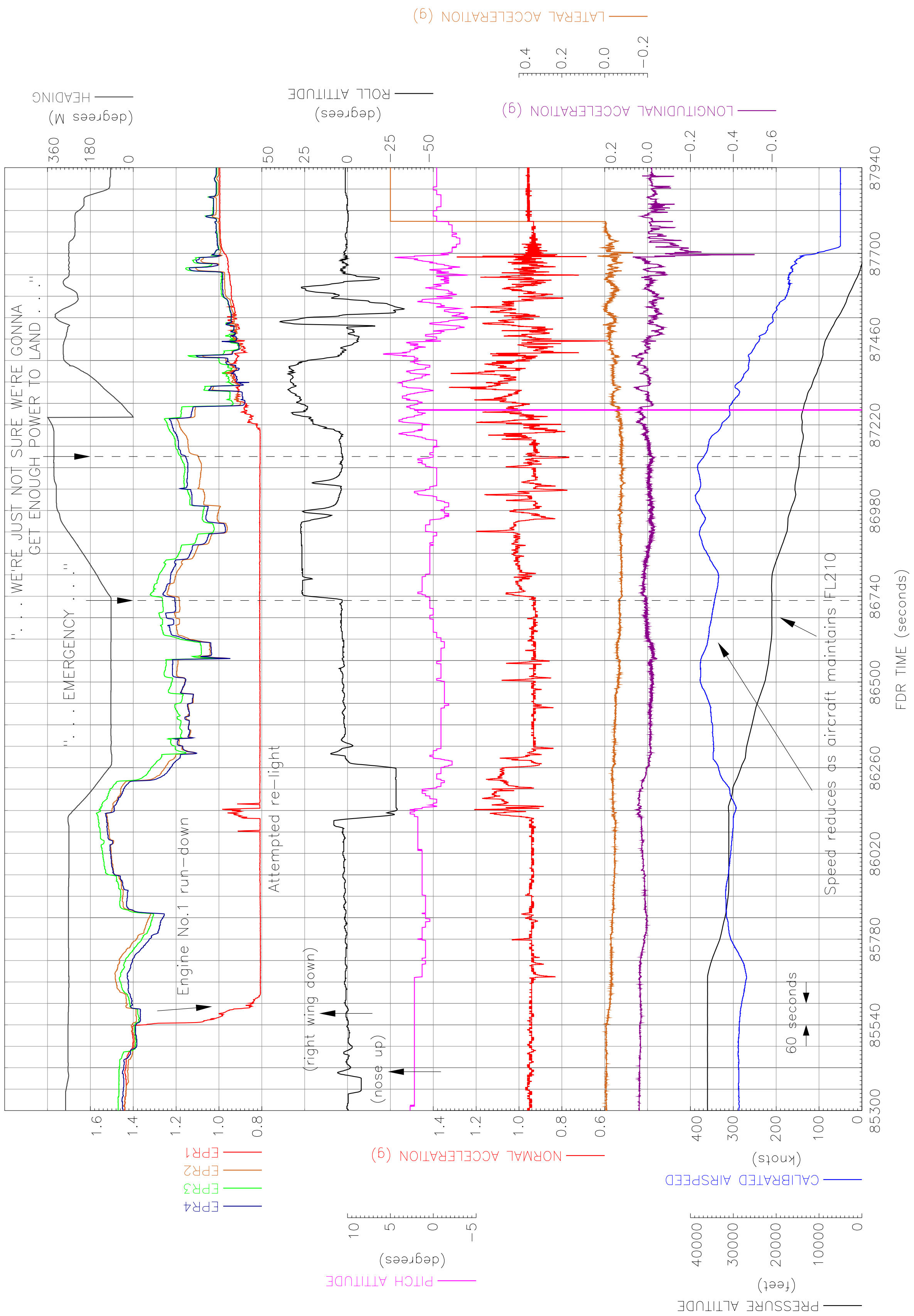


Figure 2

A hime-history of the relevant parameters during the incident

The aircraft then accelerated and descended (with corresponding changes in pitch attitude and altitude), levelling at FL310 for 4 minutes. At the start and end of that period, 3 engines were running at 1.55 EPR (which at that altitude is less than the max continuous of 1.6 EPR). The aircraft then began a descending 180º turn to the left above the Compton VOR, eventually levelling at FL210 just west of Sevenoaks. Small fluctuations in the No 1 engine EPR were evident just before and during the initial stages of the turn, coincident with the stated attempt to re-light the engine. Thereafter the thrust level of the No 1 Engine remained at 0.81 EPR until the aircraft's descent into Heathrow.

The aircraft remained at FL210 for two and a half minutes during which the CAS steadily reduced from 355 kt to 335 kt. Also during this period, the EPR levels on the other three engines were no lower than 1.18 (Engine No 2) and no higher than 1.32 (Engine No 3), each varying (in unison) and by no more than 0.06 (see Figure 3).

Whilst still at FL210 (just south of Maidstone), and coincident with the 0.06 EPR increase of the three engines, the aircraft began a turn to the right before commencing the descent towards Heathrow. The aircraft initially descended at about 2,000 ft/minute before making a 270º right turn (overhead London) on a heading for Heathrow, before continuing to descend at about 2,500 ft/minute until 30 seconds before touchdown. The approach glideslope into Heathrow was calculated at just over 6º, reducing to 2.7º when the aircraft was 1.5 nm from touchdown. The recorded airspeed during the latter stages of the approach was approximately 160 KCAS.

From approximately FL135 (about 8 minutes before touchdown), the indicated thrust levels for the remaining engines reduced below 1.0 to about 0.9 EPR where they remained for the majority of the descent. Also, as the aircraft slowed there was a corresponding increase in the No 1 engine EPR (above 0.8 and eventually reaching 1.0) as the drag produced by the engine reduced towards zero. Thrust on the three operative engines was briefly increased to about 1.15 EPR immediately prior to touchdown. The recorded air speed at touchdown was 145 KCAS.

Performance data

The operator's Operations Manual contained relevant performance data for three-engined cruise flight. The graph of cruise EPR required with one engine inoperative suggested that EPRs of 1.45 would be required to sustain 0.82 Mach (approximately 360 KCAS) at FL210 and 282 tonnes mass. This thrust rating would be above the maximum continuous rating of 1.43 EPR. The Long Range Cruise table, with one engine inoperative with the same conditions, listed a target EPR of 1.31 and a cruise speed of Mach 0.699 (319 KIAS).

There was no information relevant to glide performance, speeds or characteristics.

Simulator evaluation

Having levelled the aircraft at FL210, the commander was unable to maintain 360 KIAS, despite both pilots recalling that the three remaining engine thrust levers were at "position number six". This position is derived from a calibrated arc on the thrust lever quadrant aligned with thrust lever forward and rearward movement. It is used for recording thrust lever position against engine performance, mainly for rigging purposes.

A Boeing 747-200 training simulator was used to assess the thrust developed with the thrust levers at the "number position six" and the ability of the aircraft to

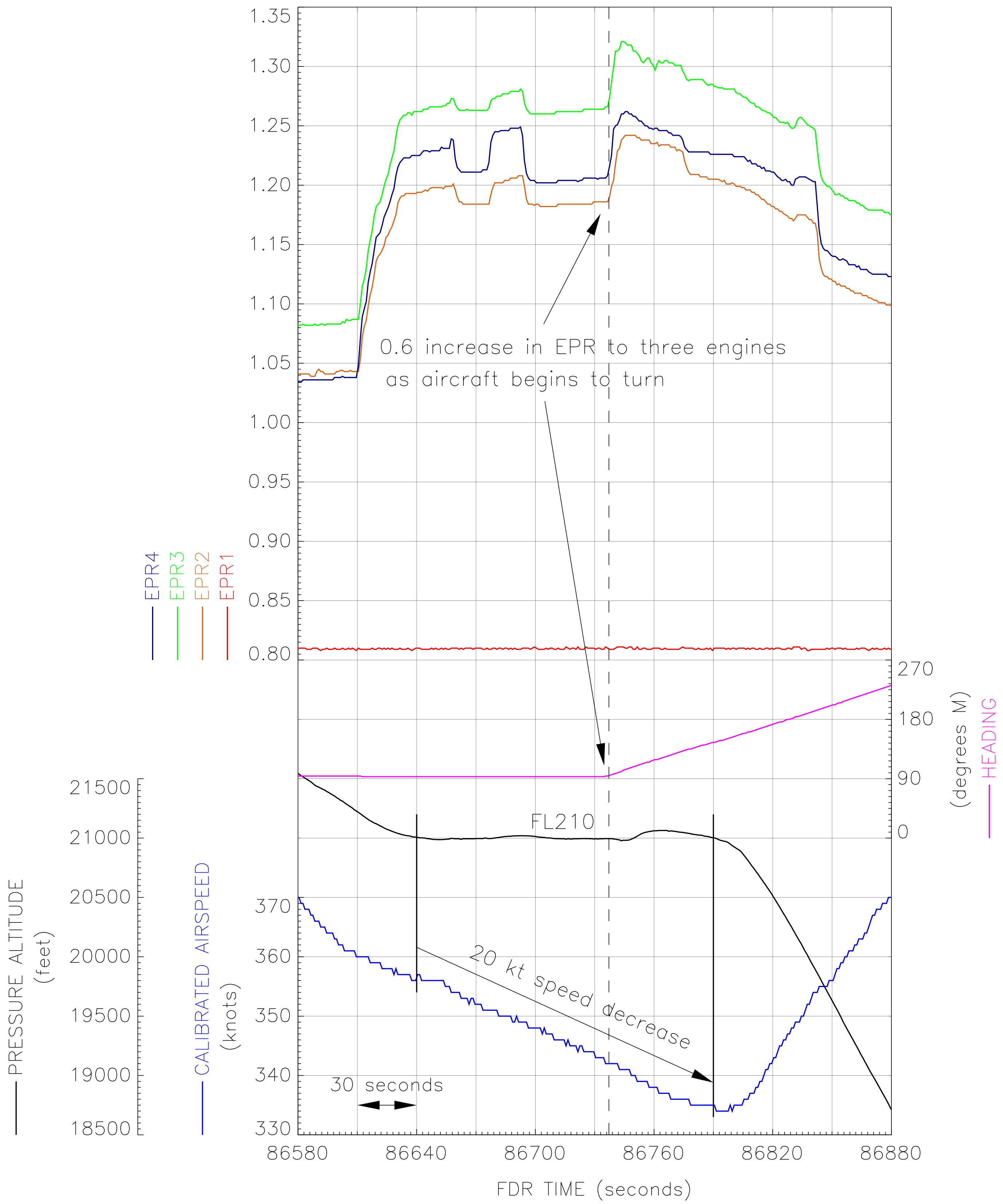


Figure 3

An expanded view time-history of the relevant parameters at FL210 maintain 360 kt using the EPR values recorded by the crew at FL210 and confirmed by the FDR data. The engines represented in the simulator were Pratt and Whitney JT9D-7J series with a max take-off thrust rating of 50,000 lbs. The incident aircraft, N481EV was equipped with Pratt and Whitney JT9D-7F engines producing a maximum take off thrust of 48,000 lbs. The EPR recorded with the thrust lever set at "position number six" was 1.6 EPR. This represented maximum permitted take-off thrust.

The simulator was programmed with an aircraft gross mass of 282 tonnes, a surface temperature of +17°C and a QNH of 1027 which were the conditions prevailing at the time of the incident. A descent was made at 360 KIAS and the simulator levelled at FL210. The EPR recorded by the crew at FL210 were set on the numbers 2, 3 and 4 engines with number 1 engine shut down. The IAS trend was then monitored. The IAS reduced by 8 kt in one minute and 20 kt in three minutes.

FAA Regulations on chart carriage

Federal Aviation Regulations Section 91.503 specifies the flying equipment and operating information that must be carried on board an aircraft comparable to N481EV. This regulation requires the pilot-in-command of an aeroplane to ensure that:

> *'aeronautical charts and data, in current and appropriate form, are accessible for each flight at the pilot station of the airplane.'*

The detail of the regulation further specifies the carriage of:

> *'Pertinent aeronautical charts' and 'For IFR, VFR over-the-top, or night operations, each pertinent navigational en-route, terminal area, and approach and letdown chart'.*

Analysis

The No 1 engine ran down in flight but the reason why could not be determined. Its failure to relight was explained by the faulty No 1 igniter. The most obvious indication that all was not well with the three operative engines was the commander's recollection that he carried out the descent from FL310 to FL210 using the autopilot in the vertical speed mode during which, he became aware that the thrust levers were positioned in the "number six position", well forward of the normal position for such a descent, yet the EPR indications were at idle. Had the problem simply been one of erroneous EPR indications, the aircraft would probably have exceeded it maximum permitted speed but the FDR data shows that the highest speed achieved in the descent was about 380 KCAS at FL240 which did not exceed the Mach 0.92 speed limit.

The lack of any recorded engine parameters on the DFDR, apart from EPR, made it impossible to verify the crew's impression that the thrust levers had to be placed further forward than they expected to achieve the target EPR. It was also not possible to analyse the nature of the rundown of No 1 engine or the statement that, when two throttles were advanced to check power delivery, the EGT rose without a change in EPR.

Some consideration was given to the possibility that No 1 engine did not actually flame-out but the instrument problems with that engine led the crew to believe that it had; they then shut it down prior to an attempt at restarting which was unsuccessful due to the inoperative No 1 igniter. This is difficult to believe, since other parameters, such as High Pressure spool speed (N2) and EPR would still have informed them that the engine was running. Also, the side-slip to the right recorded by the FDR at the time of the engine rundown suggests a loss of thrust as opposed to a loss of engine indications.

The commander's expectation that his aircraft would sustain 360 KCAS at FL210 was misplaced as the published performance data and simulator trials confirmed. At that level the aircraft required three engines producing 1.31 EPR to sustain the long range cruise speed of 0.699 Mach (equivalent to 319 KIAS) but none of the operative engines were producing this much thrust. The EPRs on the three engines changed in unison but were significantly different: No 2 was lowest, No 4 was greater by 0.03 and No 3 was 0.05 EPR greater than No 2. The average was about 1.23 whilst the aircraft was straight and level at FL210.

The apparent lack of performance of the remaining three engines is perplexing, since, in the absence of any anomalies with the fuel quantity or quality, it is difficult to conceive of any common factor which could affect three (or four) independent systems. One possibility is, of course, atmospheric conditions such as icing but a weather aftercast suggested that the aircraft was flying in conditions that were not conducive to this phenomenon.

The aircraft manufacturer and the AAIB's simulator tests confirmed that the rate of decay in speed at FL210 approximated to the decay in CAS on the incident aircraft from 356 kt to 334 kt in 2 minutes and 29 seconds. Consequently, the rate of speed decay experienced by the crew was consistent with the EPRs they had recorded in flight which in turn suggests that the displayed EPRs were correct.

The level of thrust on three engines at FL210 was not sufficient to maintain the speed at which the aircraft had been flying. Because thrust lever angle was not recorded, it was not possible to correlate the EPRs with thrust lever angles and the recollection of the crew of "position number six" was the only available evidence. Moreover, had the three operative engines' thrust levers been set to the number six position, and if they had been producing thrust equivalent to that lever position, total thrust would have had to be reduced in order to maintain the IAS within safe operating limits.

Whilst the commander considered the possibility that the engines were in a surge condition, he did not want to shut down another engine in case, as with the number 1 engine, he was unable to re-start it. He decided that his best option was to carry out an emergency landing as soon as possible and not to rely on the availability of full thrust from the three operative engines during the diversion. Consequently, the crew committed to carrying out an emergency landing at an airport within gliding range. The identification of the lack of thrust occurred at FL210 which limited the choice of airports to those within gliding range and with adequate runway length available to meet the landing distance required. Within range were London Heathrow and Gatwick airports with Stansted and Luton airports more distant. The crew were not familiar with the location of the major UK airports but they had seen London Heathrow from FL360 with CAVOK conditions and considered it was their best option for carrying out a successful visual approach with reduced thrust on the three operative engines.

Having declared their intention to land at London Heathrow, the crew were radar vectored by ATC towards a left base for Runway 27R. The main function of the controllers was to facilitate the positioning of the aircraft onto the final approach for the commander's nominated airport. When it was recognised that a left base intercept would not be possible, due to the altitude of the aircraft, a 270º right turn was given. This removed the altitude problem and the aircraft was able to make its final approach.

There was no profile or guidance for the commander to follow in conducting the approach without thrust available. His handling of the situation was solely a judgement exercise based on his experience of the aircraft's inertia and the effects on its performance, particularly in the vertical plane, as changes in the flap and gear configurations were made. With continuous visual contact with the runway in the fine weather conditions, the pilot was able to maintain an appropriate approach angle, ensuring the runway was achieved whilst slowing down and configuring the aircraft for landing. This meant a steep approach of 6.5º which caused ATC some concerns regarding the relationship between the aircraft's distance from touch down and its height.

In the final stages of the approach the commander instinctively advanced the thrust levers and all three operative engines responded although it is not known if the thrust developed was consistent with the thrust lever angle selected. Nevertheless, it is probable that even without these thrust selections, the aircraft would still have touched down on the runway but short of the normal touchdown zone.

Conclusions

No reasons were found which could account for either the apparent run-down of No 1 engine or the crew's subsequent perception that the remaining three engines were not delivering selected thrust. Whilst only the engine EPR was recorded on the FDR, it was clear from the evidence given by the crew and the aircraft performance that following the run down of the left outboard engine, the three remaining engines were not producing the thrust expected. This situation appears to have arisen following the descent from FL310 to FL210 and was symptomatic of a problem common to all three operative engines but this could not be proved. The aircraft diverted to the only airport that the flight crew considered suitable and in the process, flew over some of the most congested parts of London in a gliding configuration from which a safe landing was not reasonably assured.

Safety Recommendations

The service provided by the National Air Traffic Services (NATS) in supporting the crew of N481EV complied with the guidance and procedures in place which were flexible and permitted interpretation. The aircraft had not suffered any damage and the only hazardous material on board was an engine being carried as cargo, although ATC did not know this at the time. Importantly, the stated requirement of the aircraft commander to land at London Heathrow was facilitated.

The commander believed that he was only able to position the aircraft visually and the safe outcome would not have been possible in IMC. There was no guidance available within the Operations Manual on the glide performance of the aircraft or glide approach technique and the commander was fortunate to have an unobscured view of the airport. Had the weather conditions been IMC, forcing the crew to carry out an instrument approach, the aircraft might have landed well short of the runway.

It must be considered where the proper balance of safety rests when considering the plight of persons onboard an aircraft in difficulties in relation to persons on the ground in densely populated and congested areas such as those of central and greater London. The balance between delaying an aircraft's landing by routeing it around a congested area, versus the aircraft's condition deteriorating and possibly leading to an accident outside the congested area, should be considered. Moreover, circumstances under which the condition of the aircraft, through damage or technical failure, may pose an unacceptable danger to persons on the ground requiring non-standard routeing, should be defined.

Although this incident was safely resolved, it raises again the need to review under what circumstances an aircraft in difficulty should be permitted to fly over congested urban areas. Resolution of this issue may require regulatory action. Therefore, it was recommended that:

Safety Recommendation 2005-069

The Civil Aviation Authority (CAA) should review the guidance provided in the Manual of Air Traffic Services (MATS) Part 1 and Civil Aviation Publication (CAP) 475 (The Directory Of CAA Approved Organisations) and consider whether ATC unit Training for Unusual Circumstances and Emergencies (TRUCE) plans adequately prepare controllers to handle aircraft in emergency, and in particular, whether sufficient guidance is provided on the avoidance of built-up areas when vectoring aircraft in emergency. Where considered necessary, this guidance should be amended as soon as practicable.

The investigation team recognised both the professionalism demonstrated by the NATS personnel and the skill of the crew of N481EV, in particular the commander's hand flying of the aircraft, all of which contributed to a safe landing under such difficult circumstances. However, there was no guidance on the gliding performance of the aircraft within the Operations Manual and the commander had to resort to vigorous 'S-Turn' manoeuvres on final approach to manage the aircraft's energy profile. This would not have been practicable in cloudy or poor visibility weather conditions. Therefore it was recommended that:

Safety Recommendation 2005-070

The Federal Aviation Administration of the USA and the European Aviation Safety Agency should require that aircraft Flight Manuals contain guidance relevant to the aircraft's gliding characteristics in the optimum and approach configurations.

The crew of N481EV decided to divert to Heathrow because they had seen the airport. They were not familiar with the range of airport options available to them nor was it obvious to them that their desired destination involved overflying metropolitan London in a configuration that did not assure a safe landing. One reason for their lack of awareness was they were not carrying the requisite charts for likely en-route diversions. This practice appeared to be at variance with the AAIB's interpretation of the requirements specified in FAR 91.503. Therefore, it was recommended that:

Safety Recommendation 2005-071

Evergreen International Airlines should ensure that its flight crews have available onboard their aircraft all the pertinent en-route and approach charts for all the diversion airports applicable to the aircraft type and routes being flown.

The operator responded to this recommendation by stating that a large proportion of its work was in support of the United States military. Consequently, it was more convenient to adopt US Department of Defense charts since these invariably covered their military destinations whilst also covering a good cross-section of civil airports world-wide. London Heathrow is not included in this chart series but Stansted airport is included. Had this not been a severe emergency condition, the flight crew would have diverted to an airport for which they had charts. The operator concluded by stating that it believed the company complied with all regulations.

One of the criteria covered by MATS Part 1 for handling an aircraft that is diverting due to an onboard emergency is whether or not the aircraft is carrying material classified as Dangerous Goods. The International Air Transport Association (IATA) Dangerous Goods Regulations are the globally accepted field source reference for companies shipping hazardous materials by air. These Regulations are based on the International Standards and Recommended Practices developed by the International Civil Aviation Organisation (ICAO) and contained in Annex 18 to the Convention on International Civil Aviation. However the information on what is carried normally resides on board the aircraft and at its airfield of departure. The information is not readily available to Air Traffic Control at the time they might need it and having to ask the crew for the information when they are quite naturally pre-occupied by dealing with an emergency is inappropriate.

A similar problem was identified during the AAIB's investigation into the accident involving a cargo aircraft near Stansted Airport in December 1999 (Aircraft Accident Report 3/2003). Although this recommendation arose from an accident, its intent is equally relevant to the handling of an aircraft emergency. No response has yet been received from the addressee. However, the UK CAA stated that Safety Recommendation 2003-66 was based on the requirements of the 1999-2000 edition of the Technical Instructions. Following discussions between the AAIB and the CAA, proposals to amend the Technical Instructions were accepted by the Dangerous Goods Panel before the Safety Recommendation was published. New requirements included:

a. A copy of the Notification to Captain (NOTOC - detailing dangerous goods on board) or the information on it must be readily available at the airfield of departure and the next scheduled arrival point.
b. If the size of a NOTOC is such that transmission of information to ATC would be impractical, provision is made for the pilot to pass a telephone number to ATC for the use of the Airfield Authorities to obtain a faxed copy.

The possibility of an annotation on the Flight Plan concerning the carriage of dangerous goods was considered by the Dangerous Goods panel but discounted as impractical for several reasons.

INCIDENT

Aircraft Type and Registration:	Boeing 757-3CQ, G-JMAA
No & Type of Engines:	2 Rolls-Royce RB211-535E4-B-37 turbofan engines
Category:	1.1
Year of Manufacture:	2001
Date & Time (UTC):	23 November 2004 at 1928 hrs
Location:	Manchester International Airport, Manchester
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 9 Passengers - 281
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	8,358 hours (of which 6,833 were on type) Last 90 days - 210 hours Last 28 days - 57 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft rolled unexpectedly during the flare phase of an automatic landing at Manchester International Airport. The commander disconnected the autopilots and landed safely. The aircraft rolled in response to temporary interference of the ILS localiser signal caused by a departing Embraer 145 aircraft; this aircraft took off immediately prior to the Boeing 757's landing. Low Visibility Procedures (LVPs), which are intended to protect aircraft carrying out automatic landings, had been cancelled a short time before the incident but this information was not communicated to the Boeing 757 crew. Two safety recommendations were made.

History of the flight

The aircraft flew from Antalya in Turkey to Manchester. Some low cloud and drizzle were forecast for the scheduled arrival time at Manchester.

During the early part of the arrival, the crew received Manchester ATIS[1] information Quebec, which included information that the meteorological visibility was 200 m and that LVPs were in operation. Because of the reported weather conditions, the crew briefed and prepared for a

Footnote

[1] The Automatic Terminal Information Service is a continuous broadcast, used at many airports to provide pilots with a means of obtaining pertinent weather and operational information prior to arrival and departure.

Category 3A automatic landing using the ILS, with the commander as Pilot Flying.

The flight crew made initial radio contact with the Approach controller and were instructed to take up the hold at DAYNE and informed that the current ATIS information was Quebec. The crew confirmed that they had received this information.

At 1905 hrs, the crew requested Runway Visual Range[2] (RVR) information, and were informed that the touchdown RVR was in excess of 1,500 m, and at the mid-point it was 900 m. Soon afterwards, a pilot of another aircraft asked whether LVPs were still in force and was informed that this was so. During the period that the Boeing 757 was on the Approach frequency, no further mention was made of LVPs.

The Boeing 757 flight crew were instructed to leave the hold, continue the approach, and contact the Director. Whilst the aircraft was on the Director frequency, no reference was made to LVPs by any aircraft or the controller.

At 1923 hrs, the Boeing 757 flight crew contacted the Air (Aerodrome) controller and were instructed to continue the approach. Another aircraft was on short final approach to land, and the Air controller had assessed that the interval between the arriving aircraft was sufficient to permit two aircraft (an MD-80 and an Embraer 145) to depart after the aircraft on short final had vacated the runway but before the Boeing 757's landing.

Footnote

[2] Runway Visual Range is the visibility (in metres) measured adjacent to the runway and is intended to give a clearer indication to pilots of the visibility during landing than meteorological visibility. It is measured at three points along the runway: touchdown, mid-point, and stop-end.

Examination of the RTF recordings showed that the Embraer 145 was slow to respond to instructions from the Air controller, and did not take off promptly, despite twice being instructed to do so.

As the Embraer 145 lifted off, and with the Boeing 757 approaching the runway threshold, the controller cleared the Boeing 757 to land. The final approach continued normally until at about 30 ft height when the aircraft rolled unexpectedly. The commander recognised that the aircraft was not performing the automatic landing correctly, disconnected the autopilots, and completed a manual landing.

The pilots' recollections

The commander reported that during the approach, he became aware that the weather was improving and that the RVR was in excess of 1,500 m. However, he stated that the company policy when an automatic landing had been planned was to carry on and complete the automatic landing, provided there was no specific reason to revert to a manual landing. He reported that he was surprised that the Embraer aircraft was instructed to line up on the runway when it was, because the available time for it to depart would be very short, and that he prepared for a possible go-around. He reported that, as the autopilots flared the aircraft, the aircraft banked to the right. He disconnected the autopilots, banked to the left, and landed the aircraft manually.

The co-pilot reported that he saw the approach and runway lights at approximately 4 nm from touchdown, and judged that the conditions were *"clearly not LVP weather"*. He did not express this surprise to the commander.

Recorded flight data

The aircraft was equipped with a Cockpit Voice Recorder (CVR) and a Flight Data Recorder (FDR). The airport had Surface Movement Radar (SMR) and Approach Radar. By the time that the AAIB was notified of the event, the airport's SMR and the aircraft's CVR had over-written their recordings[3]. The CVR was not removed from the aircraft but the FDR was removed and successfully replayed. The airport's Approach Radar was recorded, and replay was of some value to the investigation in indicating the relative positions of aircraft.

The FDR data showed clearly that the localiser signal was steady until the aircraft's height above ground had reduced below 50 ft. Two seconds after the transition through 50 ft, at approximately 30 ft, the aircraft began the flare and almost immediately started rolling right. Approximately two seconds later the aircraft's heading started drifting right. Just prior to touchdown corrective action was taken, with an initial large rudder input and left roll input. The largest recorded heading deviation was slightly less than 2° although this parameter was sampled only once per second so the FDR may not have captured the maximum deviation. The data indicated that the aircraft was subjected to erroneous localiser deviation signals that led the autopilots to start deviating from the appropriate flight path.

Manchester Airport ATIS dissemination procedures

When ATIS information changed, a new broadcast was made. Each recorded broadcast was identified by a code letter, and pilots were required to report the code letter of the ATIS broadcast that they had received, on their first contact with ATC at the airport. When a pilot had received a particular ATIS broadcast, and pertinent information in it changed, ATC procedures required controllers to provide the new information to pilots on their radio frequency by either a 'broadcast' to all aircraft on the frequency, or by addressing the new information to individual aircraft.

The Manchester Airport Manual of Air Traffic Services (MATS) Part 2, which contains instructions specific to operations at the airport, states:

> *The primary tool for advising pilots that LVPs are in operation is the ATIS. However, there are occasions when, because of the time lag between ATIS broadcasts or the length of time since a pilot listened to the ATIS, there is a need for information to be passed by R/T.*
>
> *Controllers are therefore required to notify pilots by R/T, individually if necessary, of operating conditions other then those contained in the reported ATIS broadcast received.*

Throughout the period from 1833 hrs until 1921 hrs, the ATIS included information that LVPs were in force.

Manchester Airport ATC

ATC staff involved in the incident were interviewed, and documents and recordings were examined.

At about 1830 hours, the Air controller took the decision to instigate LVPs, on account of deteriorating visibility. This information was communicated to the Approach and Director controllers, but neither placed an LVP 'reminder' strip into their displays[4] although procedures approved by the CAA required them to do so.

Footnote

[3] The airport SMR recordings were only retained for 24 hours, the CVR recorded the last thirty minutes of flight.

Footnote

[4] Controllers use Flight Progress Strips upon which pertinent data relating to each aircraft under control are recorded. These strips are kept on display boards, and other strips are also displayed from time to time to indicate the status of navigational facilities, airspace, and the like.

Investigations revealed that when the Air controller took the decision to cease LVPs, this information was communicated by telephone to her colleagues in the Approach and Director positions. However, neither controller passed this information on to the Boeing 757 flight crew. It was noted that a widespread controller 'handover' was in progress at the time and that the controllers were moving between the operational positions.

Analysis

The flight crew prepared to carry out an automatic landing at Manchester because of the reported poor visibility. They established radio contact with the Approach controller and acknowledged receipt of ATIS information 'Quebec', which included the fact that LVPs were in force.

The flight progressed normally until the final approach, when both pilots gained visual contact with the runway earlier than expected. The co-pilot identified that the weather was well above the LVP trigger criteria, but given that conversation on the flight deck is kept to the minimum possible during critical phases of flight, such as during an approach, it is not remarkable that he did not mention this to the commander.

The recorded flight data showed a clear, though slight, deviation in the flight path just prior to touchdown.

Communications within the ATC unit were central to the incident. About one hour before the incident the decision was taken to introduce LVPs on account of the rapidly deteriorating weather conditions. However, when LVPs were introduced, neither the Approach nor the Director controllers placed LVP reminder strips into their displays.

Soon after the decision to cease LVP operations was taken, a controller handover occurred and it is apparent that this played a part in the continuing confusion regarding the communication of LVP status to aircraft.

This incident identified several anomalies in the system by which LVP information was communicated to pilots. ATIS is used not only to communicate LVP status, but also other safety-critical information such as runway in use, meteorological conditions, and Essential Aerodrome Information[5]. The provider of ATC services at the Airport has taken action in light of this event.

Safety Recommendations

Safety Recommendation 2005-098

The Civil Aviation Authority should review the means by which critical information from airports, such as whether Low Visibility Procedures are in force, is communicated to pilots, and its receipt and ongoing accuracy are confirmed, and should take action to eliminate as far as is practicable any weaknesses identified during this review.

The absence of Surface Movement Radar data deprived the investigation of information about the disposition of the two aircraft, and the precise sequence of events, particularly with regard to the Embraer 145's movement relative to the Boeing 757. Therefore, the following Safety Recommendation was made:

Safety Recommendation 2005-099

The Civil Aviation Authority should require providers of air traffic services at aerodromes which have Surface

Footnote

[5] Essential Aerodrome Information is information concerning the state of the manoeuvring area and its associated facilities which may constitute a hazard.

Movement Radar equipment to ensure that arrangements are in place for effective retention of information for a suitable period of time following any incident or accident.

Safety action taken

The Boeing 757 operator has amended the company Operations Manual to include additional guidance to pilots concerning LVP operations and automatic landings.

National Air Traffic Services (NATS), the provider of ATC services at Manchester, issued a NOTAC on 26 November, 2004, reminding controllers of the importance of adhering to correct procedures for dissemination of LVP status information to pilots, especially when there is a change in the status.

NATS investigators carried out a wide-ranging internal investigation into the incident, and identified causal and human factors within it. Their report noted that:

'While it is not uncommon to work using LVP procedures, the process of going into and coming out of LVPs is not a frequent or well-practised activity. As such, a lack of recency in this task was a contributory factor',

and that confusion arose during the period of handover. Seven internal recommendations were made, and in response to these, NATS has made the following changes to the ATC operation at Manchester:

- Controller handover times are to be staggered where possible
- An 'LVP Action List' (in the style of a checklist) has been introduced on a trial basis
- Further training has been planned, in particular to take place prior to the annual 'fog season'

INCIDENT

Aircraft Type and Registration:	Boeing 777-200ER, AP-BGL
No & Type of Engines:	2 GE 90 turbofan engines
Category:	1.1
Year of Manufacture:	2004
Date & Time (UTC):	1 March 2005 at 0910 hrs
Location:	Manchester Airport, Manchester
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 12 Passengers - 332
Injuries:	Crew - 0 Passengers - 31 (Minor)
Nature of Damage:	Slight damage to fuselage skin adjacent to door 3R, heat damage to the No 10 tyre and hydraulic hoses on the left main landing gear
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	13,000 hours (of which 600 were on type) Last 90 days - 176 hours Last 28 days - 36 hours
Information Source:	AAIB Field Investigation

Synopsis

Whilst the aircraft was taxiing, following an otherwise uneventful landing at Manchester, flames were seen around the wheels of the left main landing gear. As the airport Rescue and Fire Fighting Service (RFFS) attempted to extinguish the flames, copious quantities of what the RFFS Watch Commander assessed as smoke were produced and, fearing that the fire was getting out of control, he advised the aircraft commander to evacuate the aircraft. Minor injuries were sustained by some passengers and several fire service personnel during the evacuation. The investigation determined that the cause of the fire, established as being in the No 10 main landing gear wheel, most likely resulted from the maintenance practice used when cleaning the wheel heat shields. It was likely that these had been immersed in a flammable solvent, which allowed the ceramic fibre insulation material contained within to become contaminated. The fire occurred on the second landing after the wheel had been fitted to the aircraft, when the brake pack temperature was likely to have been higher than on the previous landing.

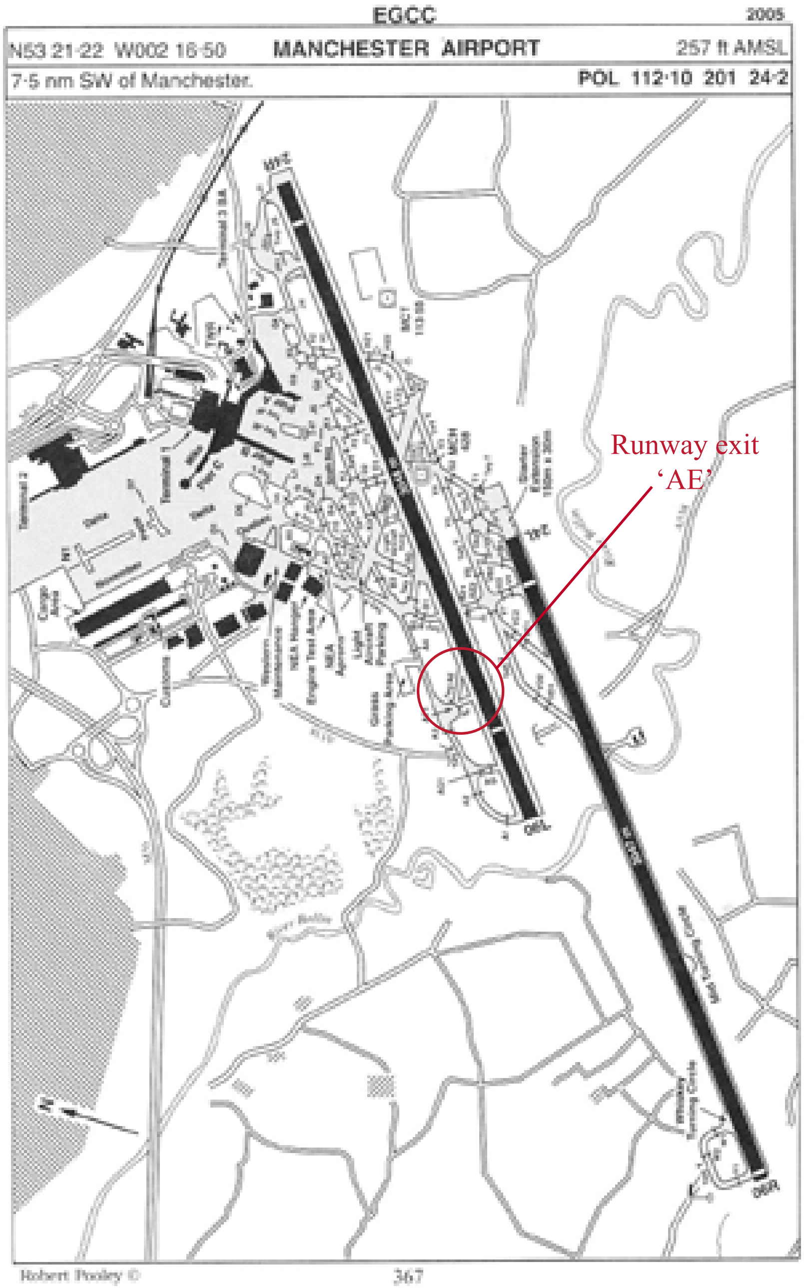
History of the flight

The aircraft left Lahore, Pakistan, at 0047 hrs UTC for a flight to Manchester International Airport, where it was scheduled to stop for re-fuelling, catering, and cleaning, before proceeding to Toronto. Prior to this flight the aircraft had flown from Karachi at a relatively low weight where, amongst other maintenance activity, the No 10 wheel assembly had been replaced.

Approaching Manchester, the co-pilot obtained Automatic Terminal Information Service (ATIS) information 'Whiskey', which indicated that there was a light westerly wind at seven knots, the lowest cloud was FEW at 400 ft, with other layers above, the temperature was 3ºC, the QNH was 1002 hPa and the runway was wet.

The commander flew an autopilot coupled approach to an automatic landing on Runway 24R, with Flap 30, a V_{ref} of 137 kt, an approach speed of 142 kt, and with Autobrake 2 selected. The touchdown was smooth and normal, following which the commander disconnected the autopilot, lowered the nosewheel onto the runway and selected reverse thrust on both engines. Assessing that the aircraft was decelerating normally and that it would reach taxi speed before the 'AE' Runway exit, see Figure 1, he reduced the amount of reverse thrust applied and disconnected the Autobrake. As the aircraft approached the exit, manual braking was applied and reverse thrust was de-selected.

The aircraft vacated the runway and, as communication with the Air Traffic Control (ATC) Ground Movement Control (GMC) controller had not been established, the commander brought the aircraft to a standstill on entry to Taxiway A. Then, having obtained clearance to taxi, the commander released the brakes, increased thrust slightly to about 23% N1 (engine fan speed) and the aircraft started moving.



With kind permission of Robert Pooley

Figure 1

A short time later, as the aircraft was still taxiing, an aircraft on an adjacent taxiway transmitted on the GMC frequency "AND GROUND ERR (CALLSIGN) THE PIA IN FRONT HAS FIRE IN HIS LEFT - ON HIS LEFT MAIN UNDERCARRIAGE". The GMC Controller replied "ROGER". Initially, the crew of the Boeing 777 did not realise that this transmission about fire related to their aircraft. There was a brief exchange of communications on the GMC frequency with other aircraft, and then the GMC controller transmitted "PAKISTAN SEVEN EIGHT NINE ERR JUST GETTING THE FIRE SERVICE OUT TO CHECK YOUR UNDERCARRIAGE CAN YOU HOLD POSITION", to which the co-pilot responded "ERR HOLDING PAKISTAN SEVEN EIGHT NINER". The commander brought the aircraft to a halt and set the Parking Brake. The aircraft was now parked on Taxiway J9, adjacent to the north side Airport Fire Station.

The co-pilot selected the LANDING GEAR pageon one of the Multi-Function Display (MFD) and both pilots observed that the Left Main Landing Gear (MLG) indications were normal, with only the brake temperature display for the Number 1 wheel brake indicating a value, which was 3.0 units[1].

The GMC controller observed the aircraft through binoculars and saw yellow and white flames coming from the left MLG. He activated the Crash Alarm, contacted the RFFS, declared an Aircraft Ground Incident (AGI) and passed the appropriate details.

In the airport fire stations on both sides of the airport the crash alarm, a loud siren, sounded. The communications equipment installed in each station is such that when the RFFS attendant manning the Watch Room in the north side fire station picks up the telephone handset to take details of an incident, the telephone conversation is relayed by loudspeakers throughout both stations. This system had been devised to enable firefighters, whilst going to their appliances, to hear the telephone conversation and be immediately aware of the nature of the emergency, its location, and other pertinent details. Although this equipment worked correctly, the crash alarm also continued to sound, until de-selected by ATC, and the original message was rendered inaudible to firefighters. However, by the time the watch room attendant began to read the information back to ATC, the crash alarm had been de-selected and the firefighters were able to hear the conversation.

Another aircraft then transmitted "AND ERR GROUND ERR (CALLSIGN) THAT'S CONFIRMED IT'S HIS ERR LEFT MAIN GEAR IS ON FIRE", which ATC acknowledged.

Vehicles from the north side fire station arrived within one minute of the activation of the crash alarm. The first vehicle to arrive at the aircraft was a Land Rover Discovery driven by the RFFS Watch Commander. He contacted the GMC controller on his frequency, stating that he was in attendance at the aircraft, that he required the pilots to immediately shut down their No 1 engine and to contact him on the promulgated RFFS frequency of 121.6 MHz[2].

The Watch Commander had stopped his vehicle in front of the aircraft, from where he had an unrestricted view of the front of the left MLG bogie. He saw that a wheel hub appeared fully alight and observed what he described as

Footnote

[1] The maximum indication on the scale is 9.9 units.

Footnote

[2] 121.6 MHz is the frequency promulgated for direct communications between aircraft and Fire Service personnel at most airports within the United Kingdom.

"intense, very bright orange flames" from the rear set of wheels. Firefighters deployed two hose lines, one to the front of the left MLG and one to the rear, and began applying water in a spray pattern on to the wheels and brakes. The ATC Supervisor observed the aircraft from the Visual Control Room (VCR) and saw an intense white fire on the landing gear, which he described as "like a gas mantle" and "like white hot metal". He did not see significant smoke and stated that the fire did not appear similar to hot Boeing 777 brakes that he had seen on previous occasions. As water was applied, significant and increasing amounts of what appeared to be 'smoke' emanated from the landing gear assembly.

The RFFS Watch Commander initially observed the fire and was concerned that, despite the application of water, the volume of 'smoke' appeared to increase as fire fighting took place. Having now established direct contact with the aircraft, he advised the flight crew that "YOUR PORT UNDERCARRIAGE IS ON FIRE SIR, FIREFIGHTING IS TAKING PLACE, I RECOMMEND AN EVACUATION ON YOUR STARBOARD SIDE". The co-pilot acknowledged this message and the commander announced "CABIN CREW AT YOUR STATIONS" on the Public Address (PA) system, before asking the co-pilot to confirm by radio that the RFFS wished the evacuation to commence at once. The Watch Commander replied "AFFIRM SIR, RECOMMEND AN EVACUATION NOW SIR, YOUR UNDERCARRIAGE IS ON FIRE ERR EVACUATE STARBOARD SIDE". The commander then summoned the purser to the flight deck and instructed him to evacuate the passengers from the right side. Both he and the co-pilot then began their evacuation checklist actions.

The evacuation checklist on the Boeing 777 is electronic and is displayed on one of the flight deck MFDs. The checklist items each appear in white text, with the next required action highlighted in a 'text box'. When the action is completed, the text changes colour to green. The fourth action on this checklist required the co-pilot to *'Override, pull and rotate'* the APU Fire Switch. When he did this, the text did not change colour, as expected, but remained white. The co-pilot pointed this out to the commander, then rotated the APU Fire Switch in the opposite direction and checked that the APU BTL DISCH light illuminated, showing that the fire bottle had discharged.

With the evacuation checklist complete, the commander announced "Cabin crew commence evacuation from the right hand side" on the PA and activated the evacuation alarm.

Cabin crew at door R1[3] deployed the escape slide, and this was followed by the slides from doors R2, R3 and R4, in sequence. As the slides deployed, firefighters who were not directly involved in fire fighting ran to take positions at the base of the slides and began assisting passengers. Cabin crew directed the evacuation, depriving some passengers of baggage at the exits, and instructed passengers to remove high-heeled shoes and other sharp objects. Once he had completed his tasks on the flight deck, the co-pilot went into the cabin and assisted with the evacuation of disabled passengers.

Once all passengers had been evacuated, each cabin crew member carried out a check of their assigned area to ensure that no passengers had been overlooked, and then went down the slides themselves. The commander and purser also finally checked that no passengers remained, but one had initially refused to leave and so was taken down the aircraft by the slides by the commander and

Footnote

[3] The aircraft doors are referred to by the side of the aircraft (left or right) and numbered in sequence from nose to tail. Thus, door R1 is the foremost door on the right side of the aircraft.

purser. The passengers and cabin crew were taken by coaches to the Airport terminal buildings, whilst the flight crew remained at the aircraft

When interviewed after the event, the cabin crew indicated that the evacuation command had taken them by surprise. As the landing and subsequent taxiing had appeared normal, and there were no indications within the cabin that anything was amiss, the cabin crew were relaxed. Some mentioned that the fact that the 'farewell' PA announcements which had been made earlier, gave them, and possibly the passengers, the impression that the flight was effectively over.

Visibility from the flight deck

The design of the Boeing 777 aircraft is such that, in common with many large transport aircraft, it is not possible from the flight deck to see the wing inboard of the wingtips. The aircraft was not equipped with external video cameras and so the flight crew are unable to observe the exterior structure of the aircraft and its surroundings.

Airport response

Once an AGI had been declared, airport staff closed the airfield, activated the airport's Emergency Plan and opened the Emergency Response Centre for the reception of passengers. As almost all passengers were transiting through Manchester en route to Toronto, very few relatives were at the airport to meet arriving passengers from the flight and so the Family Reception Centre was not activated.

Passenger coaches arrived at the aircraft very soon after the evacuation commenced and, in fact, before any ambulances attended. A set of mobile steps was also deployed, which enabled prompt access to the aircraft after the evacuation.

Injuries

Medical teams from the nearest hospital treated 24 passengers at the airport for minor injuries, including abrasions to hands, back pain, and superficial injuries to the back of the head. Five passengers were taken to a local hospital by ambulance. One had suffered a fracture to the spine, but discharged herself the same day. Three others suffered minor injuries to their backs and were also discharged later that day, whilst another passenger exhibited signs of shock and was treated overnight. Two further passengers were taken to another local hospital where one was treated for abdominal pain, the other for a high temperature, both being discharged that on the day of the incident. Five firefighters sustained minor injuries as they assisted passengers from the slides.

Communication between the aircraft and the RFFS

The United Kingdom Aeronautical Information Publication (UK AIP) promulgates information on Communication Facilities, including the availability of 121.6 MHz at many airports, for communication between aircraft and RFFS vehicles. As no Air Traffic Service is provided on this frequency, there is no requirement for it to be recorded. This frequency is used at Manchester but is not recorded.

Firefighter training

Manchester Airport RFFS personnel undertook their training both at the airport, where the RFFS have a competence-based training regime, and at the International Fire Training Centre on Teesside.

The advice to firefighters dealing with landing gear incidents is that when the landing gear is hot, but not on fire, it is best left to cool naturally and that the application of water or other firefighting media is not necessary. However, if fire is present, training material indicated that it is appropriate to endeavour to extinguish the fire, and that water is an appropriate extinguishant, particularly because of its effective cooling properties.

In the 'Firefighter Initial' training module *'Tactics and Techniques – Undercarriages'*, the following advice is published under the heading '*Hazards'*:

> *'Toxic Smoke/Carbon Fibres – Due to the materials that may be burning or the type of extinguishing media used there may be vast amounts of toxic smoke given off by a burning undercarriage. If this is the case, breathing apparatus should be worn'.*

The training material did not indicate that steam may 'lift' carbon deposits from landing gears and give the appearance of smoke.

The evacuation

Four different video recordings of the evacuation were available, three from the RFFS and one from an airport security camera. The recordings all began at different times, three of them did not have time-bases and so there was no straightforward means of achieving synchronised playback. However, examination of these recordings showed that there was an increase in ambient light, consistent with a break in the clouds, allowing significantly more sunlight onto the scene during the incident. This shared 'time-stamp' on all four recordings made it possible to synchronise them, albeit only to an accuracy of about ±3 seconds. None of the recordings captured the initial call-out of the fire appliances and it was not possible to synchronise the video information with the evacuation checklist actions in the cockpit.

The following observations were made from these recordings:

> The slides were deployed in the sequence R1, 2, 3 and 4, with 41 seconds elapsed time from the first signs of slide R1 being deployed to slide R4 being fully deployed.
>
> The slides took between six and eight seconds from first signs of deployment to being fully deployed. All of the slides operated by the cabin crew were effectively deployed and used.
>
> It took four minutes and ten seconds from the first signs of slide R1 being deployed to when all of the 332 passengers had been evacuated.
>
> It took three minutes and twenty seconds for the evacuation of passengers down slides R3 and R4. A further two minutes thirty seconds after the last passenger evacuated, a crew member evacuated down slide R3.
>
> A light wind caused the slides to move slightly whilst they were in the process of deployment, but the slides were stable and stationary once in use and passengers were evacuating form the aircraft. The slides from the Boeing 777 are designed for dual lane use. Continuous dual lane use was not achieved, and passengers tended to come down one after another. This, together with the apparent lack of a sense of urgency and the fact that some bags were thrown down the slides ahead of passengers, contributed to the long evacuation time of over four minutes. A rate of one passenger every two seconds appeared to be the best that was achieved.

The average rate down each of the slides was one passenger every two to three seconds. For certification, an evacuation rate of approximately one passenger per second is required to be demonstrated.

The assistance given by members of the RFFS to passengers at the bottom of the slides undoubtedly assisted the speed of clearing passengers away from the immediate vicinity and this probably contributed to reducing the number and severity of the injuries. Many passengers required lifting or some form of physical assistance to clear the slides.

Once out of the aircraft and on their feet at the bottom of the slide, passengers tended to remain in bunches close to the slides towards the rear of the aircraft, and were not rapidly guided away from the immediate vicinity.

Passengers were seen to walk towards the parked busses from the rear exits towards the front of the aircraft, passing downwind of what was believed at the time to be a fire.

Following the successful evacuation of all of the passengers and crew, it took a little over three minutes to load the passengers onto buses for transfer to the terminal

Additional information

Cap 168, Licencing of Aerodromes

The Civil Aviation Authority publication CAP 168, section 8, *Licencing of Aerodromes*, sets out the minimum requirements to be met in the provision of Rescue and Fire Fighting Services at UK licenced aerodromes, which includes the training of RFFS personnel. Section 9 of this document is entitled Emergency Planning, the objective of which is stated as:

'to consider and record how an emergency situation or incident can be managed in order to minimize the effects it may have on life, property and aerodrome operations, and how best the use of appropriate available resources should be applied to achieve that aim.'

CAP 168 is not a wholly prescriptive document and does not, for example, specifically require airport personnel to be designated to assume responsibility for the movement of passengers to a safe area immediately after an evacuation. As in this case, this is often done by RFFS personnel when time permits. However, the immediate responsibility of the RFFS is to save lives and, as also stated in CAP 168,

'this must assume at all times the possibility of, and need for, extinguishing a fire that may occur either immediately following an aircraft accident or incident, or at any time during rescue operations'.

Therefore, it cannot be assumed that RFFS personnel will always be available for this purpose.

Electronic evacuation checklist

Information from Boeing indicated that the software standard of the electronic evacuation checklist installed at the time required that the APU Fire Warning Switch be pulled out and rotated, and the pressure in the APU fire bottle be sensed as low, for the checklist item to change from white to green. This reportedly takes a few seconds. However, a later software standard, now installed on the aircraft, requires that the switch just be pulled when following the evacuation checklist, following which the checklist item will quickly turn to green. The switch is only to be rotated, to discharge the bottle, when following the APU fire checklist.

MLG/wheel description

Each of the two MLGs on the Boeing 777 has six wheels on a three axle truck, each wheel being equipped with a hydraulically actuated multi-disk carbon brake. They are numbered across the aircraft, No 1 wheel being the front left unit on the left MLG, No 12 being the right rear unit on the right MLG. Each main wheel is also fitted with a thermal wheel fuse plug, a thermocouple, a wheel speed transducer and pressure transducer. The brake temperature and tyre pressure is displayed on the landing gear synoptic and brake and steering maintenance pages, see Figures 2 and 3.

An advisory "BRAKE TEMP" message will appear in the Engine Indication and Crew Alerting Syatem (EICAS) engine format page, Figure 3a (next page), when any brake temperature indication reaches or exceeds 5.0 and will stay on until all brake temperatures go below 3.5. Brake temperatures equal to or above 5.0 indicate that the thermal wheel fuse plug may melt. The hottest brake on each gear, if below 5.0 and equal to or above 3.0, will be indicated by a solid white brake symbol. If any brake temperature reaches or exceeds 5.0, then the value and the associated brake symbol will be amber. This amber symbol will extinguish if the brake temperature decreases below 3.5. A 0.0 indication is equivalent to a BTMS peak temperature of 38°C and 9.9 to 1038°C.

The wheel assembly consists of a radial tyre, a split hub, bearings, grease seals, chin ring and heat shields, Figure 4. The chin ring is fitted on the inner hub and uses convection to draw cool air into the brake pack. The heat shield comes in three segments, is mounted on the inside of the hub and is intended to protect the

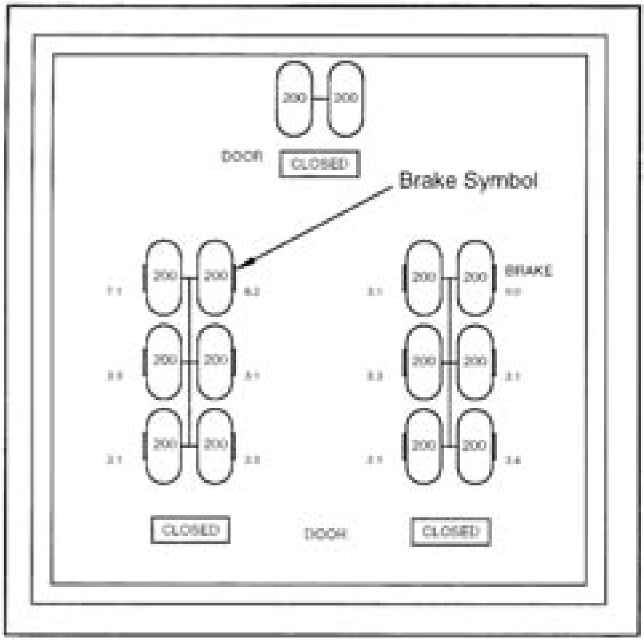


Figure 2

Landing Gear Synoptic Display

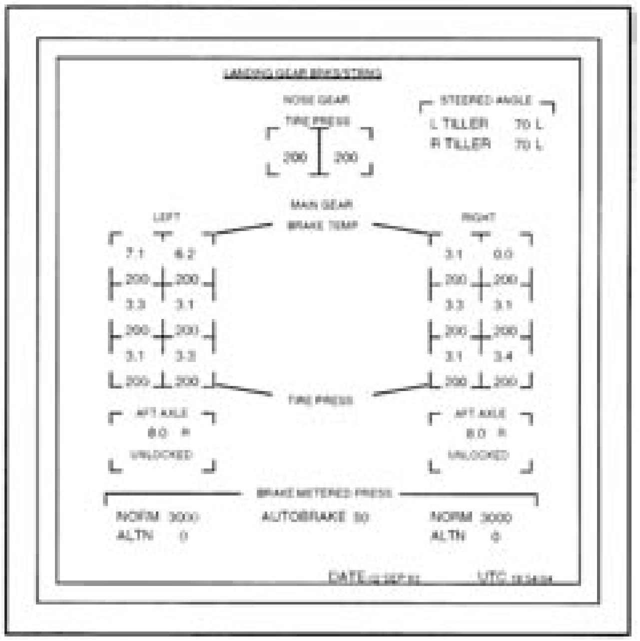


Figure 3

Brake and Steering Maintenance Page

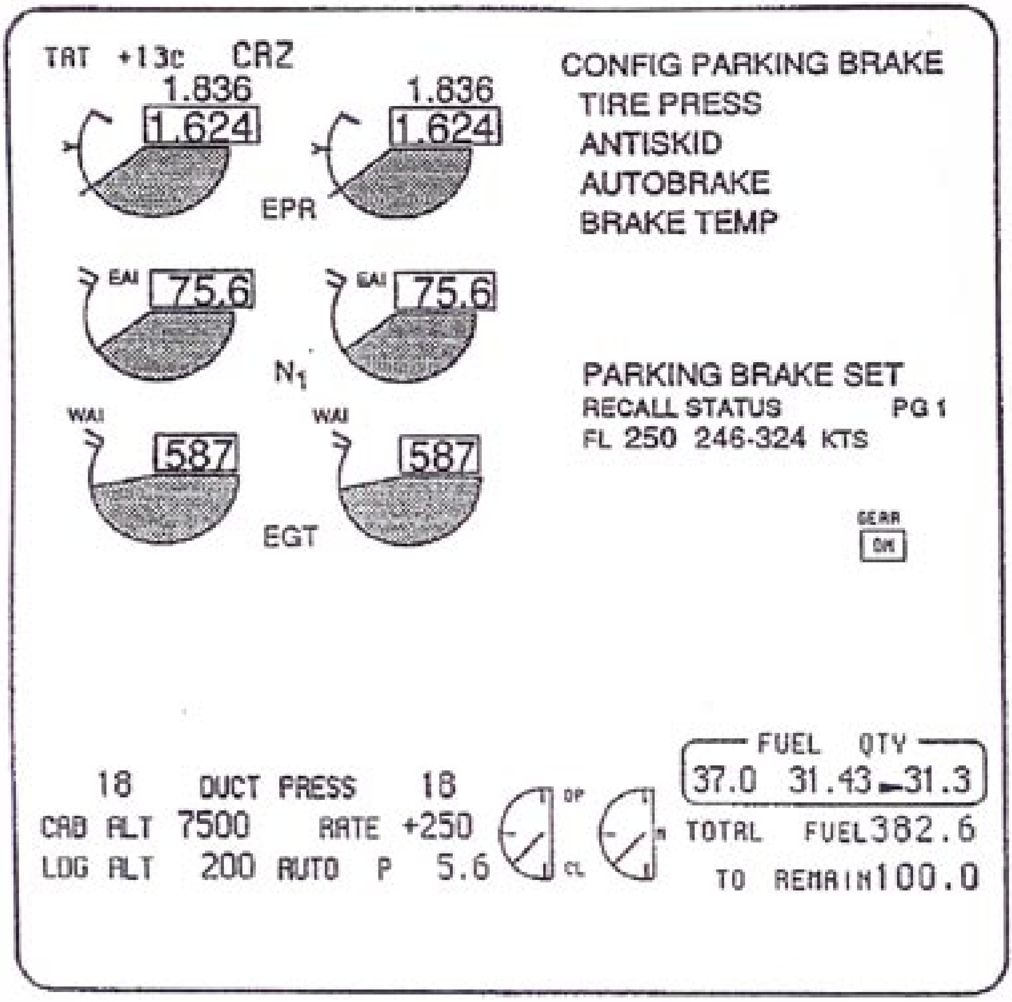


Figure 3a

EICAS Main Format

aluminium hub from the high temperatures generated by the carbon brake pack. The heat shields are constructed from two thin sheets of stainless steel, spot welded around their edges, and which contain an absorbent ceramic insulation material. They have a hole on the outer edge to allow the brake pack drive keys to be secured to the hub, and rubber bumpers fitted along the outside surface to prevent fretting against the wheel hub.

Initial aircraft examination

The only visible heat damage on the left MLG was melting of the anti-abrasion sheaths on the No 10 brake unit hydraulic pressure hose and temperature probe conduit. The damage on each pipe was approximately 16 cm long and was on the side of the pipes facing the wheel. There was also slight damage to the inside of the No 10 tyre, consisting of a small brown area of discoloration at the 12 o'clock position, and two areas were the rubber had just started to turn sticky, indicating that these areas had been exposed to temperatures between 100ºC and 150ºC. Apart from this slight damage, the tyre appeared to be in good condition, Figure 5.

There were no indications of hydraulic or fuel leaks on the left MLG leg, or in the wheel bay. With the bogies covered in a layer of black dust, it was difficult to trace

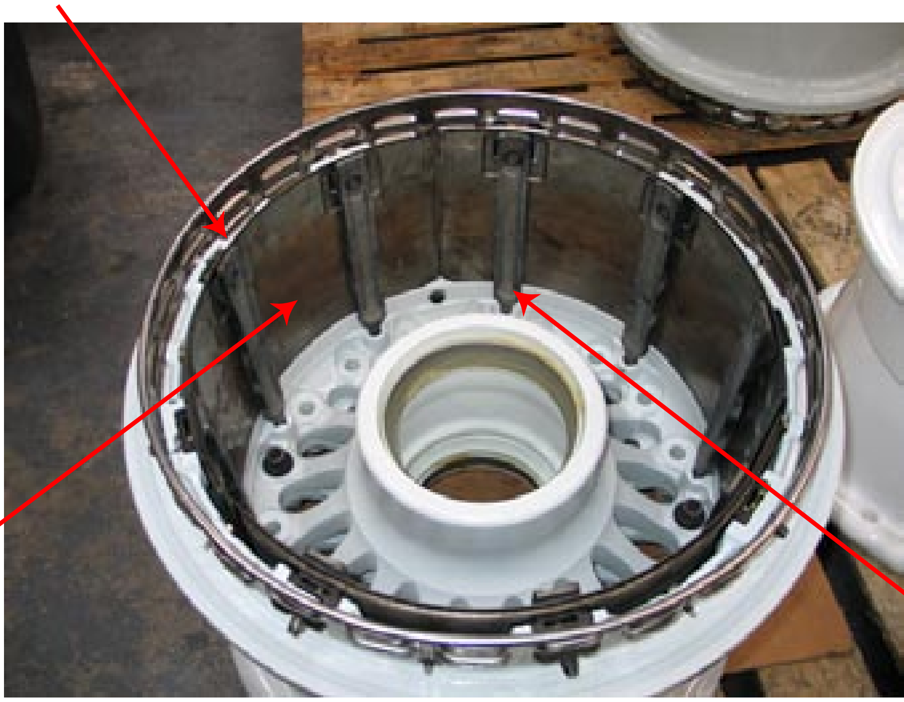


Figure 4

Construction of main wheel

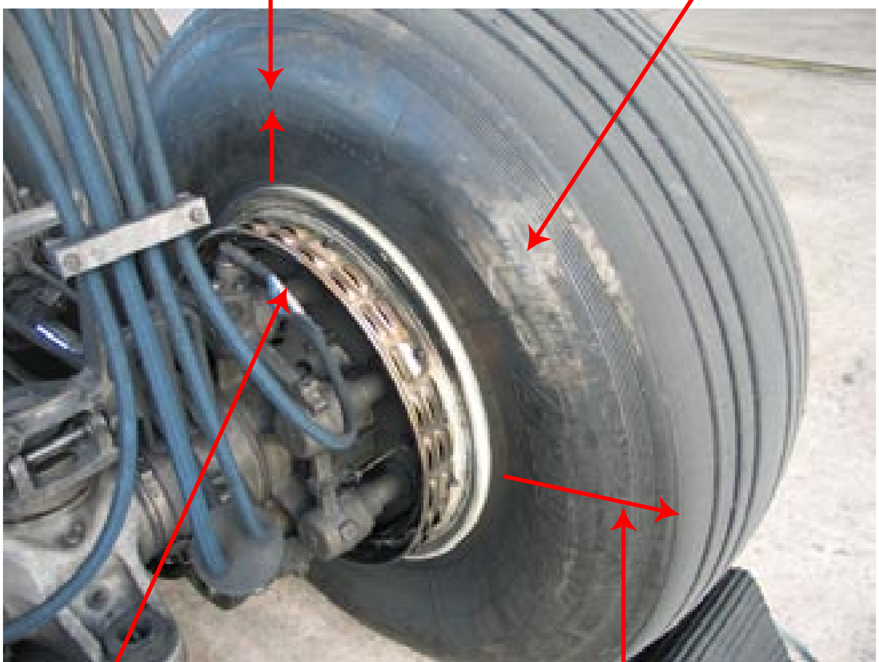


Figure 5

the path of the fire. Nevertheless, there was evidence of light sooting around the top of the No 10 inner wheel rim and on the lower part of the door attached to the MLG leg. The soot pattern indicated that the smoke from the fire passed over the inside of the No 10 wheel at the 11 o'clock position, looking inboard.

A comparison of both MLGs revealed that the left bogie was considerably cleaner than the right.

Detailed examination

General

As there was no reported significant damage to the aircraft it was towed, with the permission, and prior to the arrival, of the AAIB from Taxiway J9 to parking Bay 84, where a more detailed examination took place. Prior to the move, the left MLG was jacked up and it was established by maintenance personnel that the No 10 wheel could be spun with little resistance.

The MLG tyre pressures were noted from the EICAS, as follows: the No 10 tyre was indicating 191 psi, the remainder on the left bogie indicated pressures of between 198 psi and 210 psi. The tyre pressures on the right MLG bogie were between 200 psi and 217 psi. A tyre pressure gauge was used to confirm that all readings were accurate; nominal tyre pressure is 200 psi.

There was no sign of fluid staining on the walls of the left MLG bay, or on the tyres or components of the left MLG itself. Fuel and hydraulic system leak checks were carried out by pressurising the hydraulic systems and fuel lines in the left main landing gear bay, and the hydraulic systems on the left main landing gear. No evidence of leaks was discovered. During these checks, the left brakes were repeatedly applied and the No 10 brake pack was found to operate smoothly with no binding.

In order to establish if wheel bearing grease had played a part in the fire, wheel Nos 6, 9 and 10, which are positioned on the rear of the left bogie, were removed from the aircraft and the grease, bearings and seals inspected. All three wheels had been released from the operator's overhaul facility in December 2004, and fitted to the aircraft on 21 January (No 6), 6 February (No 9) and 28 February (No 10). The grease from all three wheels exhibited a normal light brown colour with no evidence that any grease had migrated beyond the bearing seals. The seals themselves and the wheel bearings all appeared to be in good condition and correctly fitted. The axles associated with these wheels all had a light smearing of grease with no evidence that excess amounts had been applied. When the No 10 wheel brake pack was removed, the grease on the axle was found to be covered in a black coating, believed to be carbon dust from the brakes. An intact layer of light brown grease was discovered under this coating. In summary, no evidence was seen on the three wheels or axles that excess grease had been applied, or that any grease had melted or burnt.

The opportunity was taken to examine two of the operator's spare MLG wheels stored at Manchester, the spare wheels carried on AP-BGL and on another of the operator's aircraft, AP-BGK, which staged through Manchester during this investigation. The wheel bearing grease on all these wheels was light brown in colour, their seals and bearings had been correctly fitted and there was no evidence that excess grease had been applied.

No 10 wheel brake pack

There were no visual signs of damage to the brake pack. The brake wear indicator pin was found extended by 1.59 cm (brake 80% worn with approximately 200 landings remaining). The torque tube was in good condition and there was no evidence of excess grease.

The torque tube heat shield exhibited signs of sooting, but this appeared to have entered the pack through ventilation holes and not to have originated from the wheel bearings. A high and low pressure leak test was carried out on the unit and the brake operated normally at 3,000 psi. Whilst there were signs of wetness around two of the pistons, there was neither any sign of fluid leakage, nor any evidence of hydraulic staining on the brake pressure plate. The overall assessment was that, apart from sooting on the torque tube heat shield, there was nothing unusual about the brake pack.

No 10 wheel hub

The No 10 wheel and brake pack were placed in a warm store room prior to being dispatched to the manufacturers overhaul facility. After several hours, a slight smell, similar to kerosene, was noted coming from the hub. Several days later, a very strong smell of kerosene was evident in the hub when the wheel was removed from the plastic wrapping in which it had been transported.

The chin ring was intact with no signs of overheating, but soot was present around 75% of the circumference of the inner part of the hub. However, there were no soot deposits around the bearing installation. The bearings, which were in good condition, were correctly greased with a 'light brown' coloured grease, and all the grease dams were undamaged and correctly fitted. There was no evidence of the grease having burnt, melted or leaked out of the bearing housing and the wheel's fuseable plug was intact. Paint was removed from the inner hub and a conductivity check was carried out, in order to establish if the wheel had become excessively hot. This indicated that there had been no change to the hardness of the hub material, indicating that the hub temperature had not exceeded 120ºC.

No 10 wheel hub heat shield examination

All three of the heat shields from this wheel were coated in black soot-like deposits, which was considered to have been wear dust from the carbon brakes. One of the heat shields displayed blue and straw coloured interference patterns on its outside surface, a typical signature of heat on the shield material. This emanated from the edge closest to the axle, indicating that the shield section had been subject to abnormal heating, concentrated on the outer edge of the heat shield. Whilst there was slight discolouration on the inner surface, it was less intense and widespread. This was unusual in that the inner surface of the heat shield is normally exposed to the high temperatures from the brake pack, whilst the outer surface is close to the significantly cooler hub. The rubber bumpers showed no evidence of heat damage. The normal weight of a wheel heat shield is 900 g. The measured weights of the three heat shield sections removed from this hub were 1.013 kg, 1.008 kg and 1.009 kg.

Previous incidents

There have been 19 reported occurrences of wheel brake fires on Boeing 777 aircraft since June 1999, of which 10 occurred in the first 20 months of the period. Eight of the fires were attributed to the presence of excessive grease, five to the solvent used in cleaning the wheel components, one to a hydraulic leak, and five where the cause is unknown. Seven of the fires occurred within one or two cycles of a wheel change and one occurred six weeks after a wheel change. The remaining incidents make no mention of when the wheel was last replaced. Wheel No 10 was fitted to AP-BGL one flight prior to the aircraft's flight to Manchester, and this was a relatively short flight from Karachi to Lahore, at a relatively low weight, following maintenance. Upon landing, the braking demands, and the consequent heat generation within the brake packs, was therefore low. The AAIB are aware of other unreported incidents of smoking brakes on Boeing 777 aircraft, some of which were attributed to excessive use of de-icing fluid. The operator took delivery of their first of three Boeing 777 aircraft in January 2004, since when six wheel fires have occurred. Five of these occurred at Manchester Airport. Seven days after the incident to AP-BGL, another of the operator's aircraft was seen to have smoke coming from both the No 3 and No 6 wheels. The smoke from the No 6 wheel was described as "suddenly stopping, as if a tap had been turned off".

The incidents which occurred in 2004 were the subject of AAIB Bulletin 9/2004, which was an omnibus report based on information provided by the operator. The report highlighted that brake fires could be the result of the wheel hub heat shields being contaminated with flammable solvents during maintenance, and the build up of excessive grease.[4] In June 2004, the operator introduced new maintenance procedures to ensure that excessive grease did not accumulate in the wheels and changed the grease from NYCO 22 to Aeroshell 22, which is the grease specifically approved for use on the Boeing 777. At the same time, an internal memorandum was circulated highlighting the potential risk from cleaning heat shields by immersing them in a flammable solvent.

Testing

Grease

Previous fires on the operator's Boeing 777 aircraft have been attributed to using excessive amounts of Nyco 22 grease, a type not specifically approved for use by the manufacturer on Boeing aircraft. However, a comparison of three approved greases with Nyco 22 (see Table 1) indicates that the specifications and upper temperature range are similar; therefore, there is no apparent reason that any excess accumulations of Nyco 22 would be more susceptible to catching fire than the approved greases.

A grease sample taken from both the No 10 wheel and the spare wheel carried on AP-BGK was compared with a sample of Aeroshell 22, using a Fourier Infrared Transform technique. The infrared spectrum of the three samples was essentially identical, with no unique peaks in any of the samples. Therefore, it is highly likely that the grease in the two wheels was Aeroshell 22. As the grease samples taken from the other five wheels were also light brown in colour there was little doubt that they were also Aeroshell 22.

Heat shields

Two of the heat shields from wheel No 10 were sent to an independent laboratory for further analysis. Upon dissection, it was noted that there was considerable charring of the internal ceramic insulating material, particularly at the edges and around the rubber inserts. The material felt damp to the touch and there was a strong smell of a hydrocarbon substance. Two samples of the material weighing 0.9 g and 0.8 g were heated to 50ºC and a weight loss of approximately 31% was recorded after one hour and 43% after 12 hours. Further analysis determined that the material contained a number of volatile organic components, similar to products used

Footnote

[4] Contamination by de-icing fluid, hydraulic fluid and cleaning products can also result in a brake fire. These are well known risks that the manufacturer highlighted in Maintenance Tips issued in 1995 and 2001, and which the operator brought to the attention of its engineers in June 2004.

Grease	Colour	Temp Range	Specification	Approved
Nyco 22	Red	-54ºC - +177ºC	Mil-PRF-81322 DEF Stan 91-52 AIR 4222 XG 293	No
Aeroshell 22	Light Brown	-54ºC to + 177ºC	Mil-G-81322C DEF STAN 91 -52 AIR 4222 G-395 XG-293	Yes
Mobil 28	Dark Red	-54ºC to + 177ºC	Mil-G-81322E DoD-G-24508A G-395	Yes
Mobil Aviation SHC100	Red	-58ºC to + 180ºC		Yes

Table 1

as solvent for paints or de-greasing agents. A 10 cm long sample of the contaminated ceramic material was introduced into a cool Bunsen burner flame. On removal from the burner the material continued to burn with the flame moving slowly along the sample with a yellow, slightly smoky, flame.

Wheel overhaul

The operator's wheel overhaul facility services wheels from their Boeing 747 aircraft, which are fitted with steel brakes, and the A320, fitted with carbon brakes, in addition to those from the Boeing 777. The wheel hubs from the Boeing 747 and A320 aircraft are also fitted with heat shields, but these differ from those on the Boeing 777 in that they do not contain ceramic insulation material. The operator's normal procedure for cleaning the heat shields from the Boeing 747 and A320 is to dip them in a Type II solvent bath. However, the Maintenance Manual for the overhaul of Boeing 777 wheels states:

'Clean the heat shields with a cloth that is dampened with P-D-680 Type II or III solvent or clean it with steam'.

A previous investigation by the Pakistan Safety & Investigation Board identified that the operator had experienced difficulty in obtaining the specified solvent and had, therefore, used an altenative product, which had not been specifically approved by the aircraft manufacturer. It was established by the Board that some of the maintenance personnel were cleaning Boeing 777 heat shields by dipping them in a solvent bath, thereby allowing the ceramic filler to become saturated with the solvent. The operator was unable to establish when the incorrect solvent was introduced or when individuals began the practice of dipping the heat shields into the solvent. It is understood that the alternative solvent used was also Type II, and so would have a similar ignition temperature to the approved solvent. It was, therefore, most likely that the saturation of the ceramic insulation filler by the solvent, rather than the use of an unapproved substance, allowed the heat shields to subsequently catch fire.

Safety equipment

All four escape slides on the right side of the aircraft successfully deployed and sustained no damage from the passenger evacuation. Damage appeared to have occurred to the wing fuselage fairing (panel 198FR) during deployment of the No 3 slide which consisted of a dent 1.2 cm long and a hole approximately 2.5 cm x 1.2 cm in size. The damage had no effect on the subsequent evacuation.

After the No 4 slide had been deflated and removed from the aircraft, engineers discovered that the battery cover of the emergency locator beacon fitted to that slide was broken. It was not possible to establish if the cover was broken when the slide was transported the short distance to the maintenance facility, or when the slide was packed and originally fitted to the aircraft prior to delivery to the operator. The beacon, however, was capable of normal operation.

Discussion

Wheel heat shields

Smoke and the occasional fire associated with aircraft brakes, has often been attributed to contamination of the brake pack by grease. Excess grease can either leak through the bearing seals, or be scraped along the axle by the wheel bearing when the wheel is installed, and be thrown off the rotating wheel onto the brake pack. In the incident to AP-BGL, there was no evidence of any such excess grease or that any grease had burnt or melted. In June 2004, the operator introduced new maintenance procedures to ensure that excessive grease did not accumulate in the wheels and changed the grease from NYCO 22 to Aeroshell 22, which is the grease specifically approved for use on the Boeing 777. Therefore, grease build-up was not considered to have been a cause for the wheel fire in this case.

Also in June 2004, an internal memorandum was circulated by the operator highlighting the potential risk from cleaning heat shields by immersing them in a flammable solvent. The ceramic fibre insulation from two wheel heat shields from AP-BGL's No 10 wheel that were sent for analysis, were damp to the touch, smelt strongly of a hydrocarbon like substance, and reduced in weight when heated. Another sample, when ignited, continued to burn. This strongly indicated that the insulation material had been contaminated with a solvent, most likely when the wheel had been overhauled, as the aircraft had not been de-iced or experienced any hydraulics leaks associated with the left MLG since the No 10 wheel had been fitted.

A review of the incidences of wheel fires on the operator's Boeing 777 aircraft indicated that all the affected wheels had been fitted to the aircraft at Karachi, with the fires all occurring on the 'second' landing at Manchester. It is likely that, in these incidents, solvent escaping from the heated heat shields was ignited and briefly burnt and/or that any excessive grease either on the axle or thrown onto the brake pack during the first landing, could have been ignited when the aircraft landed at Manchester. Either way, the most likely explanation for the majority of the fires occurring at Manchester is that it is here the aircraft normally undertakes its first landing with a full payload following a wheel change at Karachi. Hence the brake packs would likely be hotter than on landing at Lahore, with the result that the heat shields became sufficiently hot for the entrapped solvent to escape as a vapour and ignite, probably, on contact with the hot brakes.

The firemen could see the flames on the inside of the No 10 wheel and, therefore, used water spray to fight the fire. On contacting the hot brake units the water turned to steam which then started to lift the heavy layer of carbon dust which covers all the landing gear components. From video recordings taken at the time, it could be seen that the combination of carbon dust, steam and water spray closely resembled smoke. The apparent increase in 'smoke' emanating from the landing gear led the fire officer to believe that there was an uncontained fire. Consequently, he advised the commander to evacuate the aircraft through the right side doors. However, the damage to the left MLG was relatively minor, indicating that this was a fairly low temperature, short lived fire which appeared to have been contained inside the chin ring of the No 10 wheel.

Since taking delivery of AP-BGL, the operator had undertaken 125 wheel changes with only eight known incidences of brake fires; however, a small fire resulting from the venting solvent vapour, is difficult to see and it is possible that other incidences may have gone unnoticed. Nevertheless, a fire incident rate of around 7% following wheel changes suggests that the cleaning of Boeing 777 heat shields by immersion in solvent, rather than by wiping, was not common practice amongst the maintenance staff employed in the wheel overhaul facility. As a result of this incident, the operator recalled all their spare wheels and dried any suspect heat shields in an oven. It has been suggested that the weighing of heat shields would be sufficient to determine if the ceramic filler had been contaminated. However, laboratory tests showed that the entrapment of even a relatively small amount of solvent is a significant fire risk. The presence of such a small amount of solvent could be masked by the normal variation in the weight of the height shields and thus this method of determining if solvent contamination is present is unlikely to be reliable. To remove the possibility of such fires completely, it would be preferable for the heat shields to be cleaned with a water based detergent. However, if the recommended solvent is used, it is essential that operators follow the manufacturers instructions and take sufficient measures to prevent contamination of the absorbent ceramic filler.

In response to this incident, the operator has retrained their maintenance personnel and now use a steam cleaning process on the Boeing 777 wheel heat shields. The wheel manufacturer has also introduced a warning in the maintenance manual regarding the risks of dipping the heat shields in a flammable solvent.

The evacuation

The evacuation of a large passenger carrying aircraft is, fortunately, a fairly rare event, but always worthy of serious consideration whenever one occurs. This is especially so when, as in this case, injuries, albeit minor, were sustained by both passengers and RFFS personnel. An investigation into such an event becomes more valuable should it have been recorded, as was the case with AP-BGL and, therefore, it was decided to examine the circumstances of the evacuation in detail. This was conducted with the assistance of an acknowledged expert in aircraft evacuation studies[5].

The decision to evacuate

The decision to evacuate a passenger aircraft must rest with the commander and is not a decision that any commander, particularly of a large aircraft, would take lightly as, even in a well executed on-airfield evacuation, injuries may occur.

Footnote

[5] Professor Helen Muir OBE MA (Hons) PhD CPsychol AFBPsS FRAeS, Professor of Aerospace Psychology, Director of the Cranfield Institute for Safety, Risk and Reliability, Head of Department of Human Factors, Director of Passenger Safety Group, Cranfield University, UK.

Due to the restricted view from the flight deck, the commander was unable to see events outside for himself and was reliant upon reports and advice from others. Being aware that another aircraft's crew had reported 'fire' in the landing gear, and with the RFFS Watch Commander recommending an evacuation, the aircraft commander effectively had no alternative but to order the evacuation.

Similarly the Watch Commander, was in a situation which demanded a rapid and effective analysis of the circumstances. Given that he did observe fire, at least initially, rather than evidence of heat alone in the landing gear, it was appropriate that he immediately contemplated the possibility of evacuation. Had he been absolutely satisfied that the apparent fire could be contained and extinguished, then it is probable that he would not have recommended the evacuation to the commander. Given that the firefighting taking place did not appear to reduce the severity of the 'fire', but rather that the volume of 'smoke' increased as firefighting went on, the Watch Commander had doubt about containing the 'fire', unaware that the 'smoke' was in all probability dirty steam coming from the hot brakes. Therefore, his decision to recommend an evacuation was understandable, and it was effectively communicated to the flight crew.

The evacuation process

Flight and cabin crews are generally aware that the most 'risky' periods during a flight are during the take-off and landing. At the conclusion of a long flight, both crew and passengers might be expected to be less mentally prepared for an evacuation than they would be at the start of the flight. In particular, as both the aircraft commander and the cabin crew had made their 'farewell' PA announcements, the cabin crew felt that the flight had to some degree reached its conclusion.

The commander communicated effectively with the purser and cabin crew, first instructing them to take their stations when the first signs of an impending problem presented themselves, and then by issuing the evacuation command by PA. However, the evacuation was not commenced immediately at all doors, but rather, the process of opening the doors and deploying the escape slides seemed to occur with a 'domino effect' towards the rear of the aircraft.

When interviewed, the cabin crew members who operated doors all recalled opening their respective doors on hearing the command to evacuate and the evacuation alarm. The fact that the door at the front of the aircraft was opened first, and that at the rear, last, suggests that the cabin crew also responded to the actions of their colleagues at adjacent doors, given that none of them perceived a threat or reason to evacuate the aircraft.

All of the slides operated by the cabin crew were effectively deployed and used, a situation which does not occur in over 50% of accidents[6], and all of the passengers and crew were successfully evacuated. However, the speed of the evacuation was relatively slow, and was much longer than the evacuation time required to be demonstrated for certification[7]. Studies show that in the event of a major fire involving kerosene there may be less than two minutes before the conditions in the cabin would become non-survivable[8]. The apparent lack of an obvious reason to evacuate the aircraft seemed to instil a sense of normality, not urgency, amongst the cabin crew and passengers in this case and this factor alone probably contributed most to the relatively long

Footnote

[6] NTSB Safety Study NTSB/SS-00/01

[7] Certification requires evacuation of a full load of passengers from 50% of available exits in 90 seconds

[8] AAIB report on accident to G-BGJL 8/88; WAAS report on accident to N388US, CAP479; ICAO Summary 1984-2; NTSB report on accident to N93119; et al

evacuation time. Other contributory factors included the sequential opening of the exits, limited dual lane use of the slides, passengers sitting rather than jumping onto slides, and hand baggage sent down slides.

Safety Recommendations

The fire crew played an important role assisting passengers at the bottom of the slides and the evacuation would have been more difficult for the passengers, and more injuries may have been sustained, if this assistance had not been available. However, the video recordings showed that, once deplaned, most of the passengers congregated close to the slides towards the rear of the aircraft with the potential risk that further injuries could have inadvertently been caused by the activities of the RFFS personnel, fire or fumes, had the fire been sustained. The passengers subsequently walked to the busses located in front of the aircraft on the right side, and in doing so, passed directly downwind of the apparent fire. The RFFS are usually the first to attend the aircraft and would be best able to determine a safe area in which to collect passengers prior, in this case, to the arrival of paramedics and busses. However, the immediate responsibility of the RFFS is to save lives and, as stated in CAP 168:

> *'this must assume at all times the possibility of, and need for, extinguishing a fire that may occur either immediately following an aircraft accident or incident, or at any time during rescue operations.'*

Hence, the RFFS manpower resources deployed to an event may, at some point, all be needed for firefighting duties.

In an evacuation such as this, the cabin crew are required to remain in the aircraft until the evacuation is complete. It would therefore seem appropriate that the immediate responsibility for the welfare of deplaned passengers should reside with specific airport personnel, designated by the Airport Authority. As airports such as Manchester are licenced in accordance with the CAA publication CAP 168, which includes the requirement for an Emergency plan, the following safety recommendation is made:

Safety Recommendation 2005-131

It is recommended that the Civil Aviation Authority review the advice given in CAP 168 in regard to aerodrome procedures for leading passengers, evacuated from an aircraft, to secure areas away from the scene of the incident and ensure that the relevant Aerodrome\ Emergency orders suitably address this topic.

The commander's decision to order the evacuation of the aircraft was based upon the information available to him at the time, and was made because he perceived that there was a real threat to the aircraft from the 'uncontained fire' in the left MLG. It is highly likely that in the commander's considerations, this risk to the aircraft and its occupants would have outweighed the risk that some passengers could be injured in the evacuation itself. Once such a decision is initiated, it is incumbent upon cabin crews to execute an evacuation as expeditiously as possible, irrespective of whether they perceive a risk to the aircraft or not. The relatively long time taken to evacuate the aircraft could have been reduced had all the doors been opened promptly and dual lane use made of the escape slides. The following recommendation is therefore made.

Safety Recommendation 2005-097

It is recommended that Pakistan International Airline Corporation review the training given to their cabin crews with the intention of ensuring that, in the event of an evacuation command being given by the aircraft commander, the evacuation is carried out as expeditiously as possible, irrespective of the lack of any threat to the aircraft perceived by the cabin crew.

Where an ATC service is provided on specific frequencies at such airfields as Manchester, there is a requirement for these frequencies to be recorded by the Airfield Authority, and for them to be held for 30 days, so that any data contained is available for investigative purposes following an accident or incident.

With the incident to AP-BGL, the Cockpit Voice Recorder (CVR) provided a recording of communications between the aircraft, ATC and the RFFS on 121.6 MHz, until the time at which both the aircraft's engines were shut down. Therefore, the investigation was able to confirm the recollections of the flight deck crew and RFFS Watch Commander's dialogue. However, had the CVR not been serviceable, or had the second engine been shut down sooner, no recording would have been available at what could have been a critical time. Clearly, communications on the promulgated RFFS frequency of 121.6 MHz may include critical decisions affecting safety, relating to maters such as evacuation, and a recording of such communications provides valuable information to those investigating such events.

Since 1989, the AAIB have made, on several occasions, safety recommendations relating to the provision and recording of radio frequencies used by the RFFS at major airports. Specifically, following the event at London Gatwick Airport, on 12 April 1988 (AAIB Report No. 2/89) when a BAC 111 landed in error on the active taxiway at night, having mistaken it for the active (emergency) runway, one of the safety recommendations made (4.9) was as follows:

'The radio frequencies used by the Airport Fire Service should be recorded at all major airports.'

In response to this recommendation, the CAA stated:

'The frequencies used for Air Traffic Control/ Airport Fire Service [AFS] communications are already required to be recorded. This recommendation is directed specifically at the frequency used to provide a direct, AFS to aircraft, communication link (121.6).

Provision of this direct link is not a mandatory requirement, nevertheless the Authority recommends that all major airports make such provision. We now propose to consult with the airport operators with a view to recommending that whenever this direct communication link is provided, it should be recorded.

Monitoring this communications link will of course also be covered by the aircraft CVR, but we appreciate that as in the case of this accident, the CVR record may not always be available.'

As the provision and recording of a radio frequency for use by the RFFS and flight crews during emergencies remains a CAA recommendation, the following safety recommendations are made.

Safety Recommendation 2005-092

The Civil Aviation Authority should require at aerodromes, where the Rescue and Fire Fighting Category is 3 and above, or where an air traffic control service is provided, that a radio frequency to facilitate direct communications between an aircraft and the Airport Rescue and Fire Fighting Service, in the event of an accident or incident to an aircraft on the airfield, is made available and appropriately promulgated.

Safety Recommendation 2005-093

The Civil Aviation Authority should require that any radio communication frequency used to facilitate direct communications between an aircraft and the Airport Rescue and Fire Fighting Service, in the event of an accident or incident on the airfield, should be recorded, in order that it may be reproduced to assist in accident and incident investigation.

Safety Actions

Since this incident, Manchester International Airport is reviewing its Emergency Plan, with regard to placing the local Hospital on standby when an Aircraft Ground Incident is declared. Also, the Manchester International Airport Emergency Planning Operations Sub-group is examining the functioning of the RFFS Crash Alarm system, with the intention of ensuring maximum speed of response and clarity of communication, consistent with current regulations.

ACCIDENT

Aircraft Type and Registration:	British Aerospace HS.748 Series 2A, G-BGMN
No & Type of Engines:	2 Rolls-Royce Dart 534-2 turboprop engines
Category:	1.1
Year of Manufacture:	1979
Date & Time (UTC):	28 January 2005 at 0533 hrs
Location:	East Midlands Airport, Derbyshire
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Minor scratch on wing upper surface, severe damage to over-wing exit hatch
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	3,330 hours (of which 1,600 were on type) Last 90 days - 77 hours Last 28 days - 33 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft's left over-wing emergency escape hatch detached from the aircraft during takeoff from East Midlands Airport. A deferred technical defect in the aircraft's pressurisation system meant that the loss of the hatch, was only discovered after landing at Ronaldsway Airport on the Isle of Man. The investigation established that a protective cover, in the cargo area, intended to prevent inadvertent operation of the over-wing emergency escape hatch handle, was not attached prior to loading and that movement of the cargo probably caused the handle to move to the ′open′ position, allowing the hatch to detach from the aircraft. The investigation also established that a number of deficiencies existed in the operator's training and oversight of contracted loading staff. Four safety recommendations are made.

History of the flight

The commander and co-pilot had operated the aircraft from Ronaldsway Airport to East Midlands Airport the previous evening, arriving at East Midlands at 2032 hrs. The crew had then taken overnight rest in a local hotel as part of a 'split duty' roster pattern before reporting at the aircraft at 0505 hrs for a 0520 hrs departure for the return flight to Ronaldsway. The crew had overseen refuelling prior to retiring to the hotel, but the loading of 5,098 kg of mail had taken place overnight in their absence.

The crew arrived at the aircraft and commenced their pre-flight duties. Among the deferred defects in the technical log was one pertaining to the front access door which, as the result of a defect, was restricted to 'emergency use only'. However, as the aircraft was routinely bulk loaded with mail, this door was the only means of access to the flight deck and the flight crew had no option but to use it. The co-pilot prepared the flight deck while the commander carried out an external inspection which revealed nothing untoward. The only unexpected problem encountered was that the ground power unit electrical supply tripped off, so an engine start on battery power only was planned.

As part of the commander's pre-flight inspection, he checked the only two visible cargo bays which were full to the ceiling with mail bags and loose packages. These were Bay 2, which was the foremost bay and visible from the flight deck / forward access door area, and Bay 5, visible from the rear door which the commander opened during his external inspection.

During the start process the ground crew performed their normal checks which included the security of doors and hatches. The aircraft taxied for Runway 27 at a 'brisk' pace, but with no unusual bumps or noises. Takeoff appeared normal, but during the climb the crew noted that the aircraft was not pressurising. The crew negotiated a revised cruising level with ATC and the commander instructed the co-pilot to open the pressurisation dump valve. The crew did not refer to the checklist for this procedure as un-pressurised flight was not an uncommon occurrence on company HS748 freight aircraft. The crew was not concerned by the failure to pressurise, as an ongoing poor performance of the pressurisation system had been entered in the technical log as a deferred defect. The technical log entry consisted of a statement on the poor performance of the system, together with a Minimum Equipment List (MEL) reference and the words 'unpressurised flight'. The MEL reference concerned dispatch with one or more cabin superchargers unserviceable, and stipulated that dispatch was permitted provided that the flight was conducted un-pressurised. Thus, by implication, the fault with the system had been attributed to the cabin supercharger (only one was fitted), though the technical log did not explicitly state this nor that flight should be conducted un-pressurised. Although the aircraft commander had noted the technical log entry, it was not clear to him whether it was cautioning the crew about poor system performance or was stating a requirement for un-pressurised flight. The crew had, therefore, not consulted the MEL prior to departure from Ronaldsway, and in the absence of an explicit statement in the technical log to the contrary, had planned for normal, pressurised flight. The flight from Ronaldsway had been flown pressurised, and the expected poor system performance was noted.

Prior to descent, on the incident flight, the crew noted two other unrelated failures: one concerned the TCAS system and the other concerned an engine anti ice system, which they attempted to troubleshoot without success. The approach and landing at Ronaldsway were normal. After the aircraft had come to a stop on the parking ramp, the ground crew drew the commander's attention to the fact that the left over-wing emergency escape hatch was missing. The commander thought that the hatch had most likely been missing since takeoff and alerted ATC with a request that East Midlands Airport be notified. The commander left the aircraft through the front access door to inspect the structure but no damage was visible. However, mail bags were protruding from the hatch aperture and appeared to have jammed themselves in place. When the mail had been unloaded he entered the cabin and noted that two covers, which were designed to protect the over-wing escape hatch operating handles, were not in place over their respective hatches but were loose on the cabin floor.

The missing hatch was subsequently found adjacent to the runway at East Midlands Airport. There was no reconciliation made of the cargo load to determine if any had fallen from the aircraft in flight. Police forces along the aircraft's track were alerted to the possibility, but no items that might have been from the aircraft were recovered, and none were later reported missing or overdue.

A loading supervisor at Ronaldsway Airport later reported that, when the aircraft was being loaded for the previous sector, the hatch covers were not positioned over the emergency exits, but were left standing on the floor against the cabin side walls. This was the position they had been found in when loading commenced. He recalled that the commander, during his external inspection, had boarded the aircraft through the rear access door to discuss loading with him. At this stage cargo had been loaded into the foremost section only, which was a non standard loading pattern, made necessary by the requirement not to use the front door. The commander later reported that he did not enter the rear fuselage during his external inspection, as the rear door was obstructed by loading equipment and personnel. Neither the supervisor nor the commander made any reference to the covers being off. Loaders interviewed at East Midlands Airport were divided as to whether the covers were or were not fitted at the time of loading at that location.

Aircraft layout

The incident aircraft had been operating for a number of years as a freighter, having been converted from its original passenger layout to enable it to operate in a Class 'E' freighter configuration. This configuration allowed for the cabin section to be fully loaded with bulk freight with no provision remaining for crew members to pass through the fuselage once loading was complete. The conversion included equipping the cabin interior with a liner which covered the parallel section of the cabin above the floor line, and was held in place by longitudinal wooden battens. The cabin liner covered all the windows except those within the two over-wing emergency escape hatches, located in Bay 3. Apertures in the liner were positioned to enable each of these hatches to be accessed, opened and removed from inside or outside the aircraft in the normal way. This access was necessary in order to permit the hatches to be removed during scheduled inspections of the structural aperture in the pressurised fuselage, in accordance with the Maintenance Manual. The conversion also involved adding a series of net attachment points on the floor, cabin sides and roof at intervals along the cabin length. These nets divided the load volume into short sections and restrained the load in each of those sections against longitudinal movement. Cargo would normally be loaded into Bays 2 to 5, which ran from immediately aft of the forward access door to immediately in front of the rear access door. If necessary, freight could be loaded in Bay 1, which was adjacent to the forward door, or Bay 6 which was in the aircraft tail, though freight in Bay 6 would require restraint in the form of nets and lashings.

The over-wing hatches were not normally accessible from within a loaded aircraft and performed no emergency exit role in the freight operation. Rectangular covers, of similar material to the liner, were normally affixed over the hatches during these operations. On the incident aircraft, these covers were approximately two inches higher and two inches wider than the apertures in the liner and were secured over the latter by means of Velcro strips at their edges and corresponding Velcro pads on the inner faces of the liners alongside and above the apertures. Other aircraft in the operator's HS.748 fleet utilised differing systems to retain the hatch cover in place.

Each of the two over-wing emergency escape hatches on the HS.748 is of a design which is secured at its upper and lower edges. The hatch opens outwards and incorporates two abutment spigots protruding from its lower edge member which engage in corresponding recesses in the lower edge of the structural aperture. A pair of over-centring latches, protruding from the upper edge member of the hatch, engage in corresponding recesses in the upper edge of the aperture. During hatch installation, movement of either internal or external handle towards the closed position rotates the two catches in such a way that the upper edge of the hatch is drawn inboard, compressing the edge seal until the latches over-centre allowing a slight relaxation of seal pressure. Conversely, movement of either operating handle on a closed hatch in a 'hatch open' direction initially draws the upper edge of the hatch slightly inboard, against cabin pressure loading (if any), also compressing the edge seal, before allowing the upper edge to move outboard, permitting release of the hatch from the aperture.

The inner handle is stowed parallel with the cabin axis and pivots inboard against light spring pressure before rotating downwards during hatch opening operation. A shaped paxolin block, positioned just below the inner handle, ensures that inboard handle movement occurs before significant rotation of the handle shaft takes place.

In view of the absence of a need to supply air to passengers, the pressurisation and air conditioning system on aircraft of this fleet had been subjected to a weight saving modification which involved removal of one of the two cabin blowers together with certain other components and redundant parts of the distribution system.

Examination of the hatch

The left over-wing hatch was subsequently found close to the point where the aircraft would be expected to have rotated during the take-off run. Extensive impact damage was evident on both lower corners. The remainder of the hatch, including the transparency, the abutment spigots and the locking mechanism appeared undamaged.

Examination of the hatch latching mechanism indicated that it operated correctly and little force was needed to move the internal handle inboard, away from its recessed position. Thereafter, a greater, but not excessive, force was needed to rotate the handle downwards to the open position. It is understood that handle forces are largely the result of the presence of springs and mechanical friction in the door mechanism and are not greatly increased when the hatch is installed in the fuselage aperture. The aperture in which the hatch had been mounted was reported to have been free from damage on inspection at Ronaldsway.

Aircraft pressurisation defect

The aircraft had been operating with a deferred defect in the pressurisation system. Although the technical log indicated that the cause of the loss of pressurisation was diagnosed and rectified shortly after this incident, in practice the low pressure differential persisted until a maintenance input some weeks later. It was then found that the cable operating the cabin pressure dump valve was frayed and jamming within its conduit. This had prevented the dump valve from seating although the operating handle was in its normal flight position.

Recorded data

The aircraft was equipped with a 30 minute, magnetic tape Cockpit Voice Recorder (CVR) and a 25 hour, solid state Flight Data Recorder (FDR).

Review of the flight data was significantly delayed because the data frame layout document for decoding the FDR was not available and had to be generated after the investigation was initiated. The data frame layout is required in order to be compliant with the requirements of Article 53 of the UK Air Navigation Order and/or JAR-OPS 1.160. The investigation process highlighted significant deficiencies with the operator's CVR and FDR systems, which the operator has committed to resolving. As an initial action, the operator has generated a data frame layout document to support the FDR installation.

The FDR recorded: altitude, airspeed, pitch, roll, flap angle, normal acceleration, VHF keying, GPWS and TCAS warnings, manual event marker, trip and date and time powered. The quality of the recorded parameters was not good. The normal acceleration parameter was very noisy and the pitch and roll parameters were not providing useful data due to a problem traced by the operator to the hidden failure of the dedicated output of the gyro. The airspeed, altitude and VHF key discrete data suffered from intermittent, simultaneous, spikes.

The recorded data covered the entire flight but its limited data set did not provide any useful information regarding the loss of the hatch. The quality of the CVR audio recordings was intermittent on two of the channels due to a defective summing amplifier and a missing screw/lock device in a connector. Due to the limited recording period of the CVR, only the second half of the flight audio was captured. Whilst this did not cover the point at which the hatch was lost, it did substantiate the fact that the aircraft was suffering from a number of technical problems including one related to pressurisation.

Other than confirming that the aircraft had pressurisation problems and other unrelated system failures, the recordings offered little to the investigation. Information regarding the quality issues of the recordings has been passed to the CAA and to the operator, which has since taken corrective action to address the issues.

Aircraft loading

The operator was contracted to the Royal Mail for the carriage of small parcels, packages and mail, and each aircraft was contracted to carry up to a certain weight. The operator's loading operation at East Midlands Airport utilised Royal Mail's loading facility and staff. No technical personnel of the aircraft operator nor of any contract maintenance company having responsibility for this fleet were stationed at East Midlands. A handling company was contracted to observe engine starts and carry out pushback operations, but its personnel did not attend the aircraft during the loading process.

Instructions for loading the aircraft were contained in the operator's traffic manual. When loading with mail and small parcels, the freight compartment of the HS.748 could normally be filled before the weight limit was reached and, provided that the freight was evenly distributed, the centre of gravity limitations would not be exceeded. In view of this fact, the operator used a 'standard load plan' (SLP), which simplified loading and aircraft trim procedures, and this was used on the incident flight. Using the SLP, it was normal practice to load each freight hold section, between pairs of cargo nets and up to the cabin ceiling, before fully securing the relevant net(s). Enquiries by AAIB with the CAA after the incident established that the operator did not hold approval to operate to a SLP. This had already been identified by the CAA and raised as a finding during an audit of the operator, two weeks prior to the incident flight. The operator was subsequently required by the CAA to issue revised loading instructions which were not based on a SLP.

Loading at East Midlands prior to the incident flight followed the normal procedure. Although the front door was labelled as inoperative, loading staff had seen flight crews using it and did likewise. Bays 3 and 4, the sections between the two over-wing exits, were loaded first using access from both the front and rear of the cabin. Nets in front of and behind the section were then fully attached to top, sides and floor before Bays 2 and 5, the outer sections, were loaded. Thus, with the aircraft loaded and prepared for flight, it was not possible to inspect Bays 3 or 4 visually.

The operator had commenced operations at East Midlands some years before but was not able to produce records for any training given to staff there. An inspection of the Royal Mail loading facility at East Midlands Airport established that none of the operator's manuals or other written instructions regarding loading were present, nor had they been at the time of the incident. There was no record at East Midlands of any Royal Mail loading staff having undergone training by the aircraft operator, and no record of any audit having been carried out by, or on behalf of, the aircraft operator.

The operator had no formal requirements for initial or recurrent training for loading personnel at its outstations. When a new base was established, a suitably experienced person would conduct training for supervisory staff, which would include the procedures detailed in the traffic manual. However, the content of such training was left to the person conducting the training. Training of ramp personnel would then be left to the supervisory staff at the station.

Operator's Safety Management System (SMS)

In accordance with the requirements of JAR-OPS, the operator had in place a SMS, established in 2001, which was in the form of an integrated safety management and quality system. This system provided for audits of contractors in accordance with JAR OPS and the CAA's recommendations (see '*regulatory oversight'* below), with the first audits taking place in January 2002. The audit schedule allowed for a maximum of three outstations to be audited each year. At the time of the incident, six of the outstations or bases had been audited and those with a greater number of movements had been audited twice in the period. The operator flew to a total of 23 bases and outstations, where loading operations were performed, though at some of these destinations frequency was as low as one movement per week. At the time of the incident there had not been an audit carried out on the operation at East Midlands, nor was an audit scheduled in the coming year. Because of the large number of bases concerned and the limited number of audits per year, only a relatively small percentage of bases had been audited at the time of the incident. A safety recommendation is made in this regard.

Regulatory oversight

As part of it's safety oversight audit programme, the CAA carried out annual audits in areas such as flight operations, ramp operations, management and quality systems. The operator had been subject to audits at its outstations and these had raised a number of findings which included deficiencies regarding the provision of written instructions to loading staff. At the time of writing several such findings remained open, having not been satisfactorily addressed by the operator, and a safety recommendation is made in this regard.

In recent years the Civil Aviation Authority's Safety Regulation Group (SRG) has sought to reduce the number of safety related incidents connected with aircraft loading, and has issued a number of Flight Operations Department Communications (FODCOMs) on the subject. In FODCOM 12/2000, operators were reminded of the responsibility placed on them under JAR-OPS to ensure that:

> *"....all personnel assigned to, or directly involved in, ground and flight operations are properly instructed, have demonstrated their abilities in their particular duties and are aware of their responsibilities and the relationship of such duties to the operation as a whole." (JAR-OPS1/3.205)*

The SRG's communication went on to cover the common arrangement whereby loading duties are contracted to third parties, and reminded operators that:

> *"An operator contracting other organisations to provide certain services retains responsibility for the maintenance of proper standards. In such circumstances a nominated post holder must be given the task of ensuring that any contractor employed meets the required standards." (Appendix 2 to JAR-OPS 1/3.175)*

The FODCOM went on to state in summary that:

> *" ...operators should ensure that flight crew, cabin crew and loading staff, or ground handling agents, are appropriately trained, qualified and periodically examined for competency to carry out their duties."*

In FODCOM 6/2002 the SRG noted that there were 44 loading incidents reported to the CAA in 2001. Whilst the main area of concern was differences between actual and reported loading configurations, the SRG made four recommendations, one of which was specific to trim and centre of gravity issues and not covered here. It was recommended that operators take note of previous related FODCOMs and re-familiarise themselves with the relevant requirements of JAR-OPS and the Air Navigation Order. The final recommendation is reproduced here in full:

> *"Operators should review the instructions they provide to all who can have responsibility for loading their aircraft, and the training that is required to ensure that these instructions are properly understood and implemented. This should ensure that the risk of incidents or accidents arising from loading errors is kept to a minimum."*

Finally, in response to a specific serious incident, the SRG issued the following recommendation to operators in FODCOM 2/2003:

> *"Operators engaged in cargo services should review their Quality Systems and revise them as necessary to ensure that their audits include companies contracted to provide loading services. The schedules should contain items relating to the training and responsibilities of contractors' staff."*

Safety action already taken

Following the incident, the operator introduced a fleet modification to fit larger inner covers to the liner apertures at the over-wing hatches. These were secured at top and bottom by the timber battens which held the liner in place and on forward and aft edges by adhesive 'speed-tape' strips. They thus became permanent parts of the liner only readily removable when the battens were unscrewed. This, in turn, would be expected to occur only during maintenance intervals, when the battens and speed tape strips were removed to enable the inner covers and thereafter the hatches to be removed for structural inspection of the apertures. At all other times, the hatches and inner handles would be covered and fully protected by the inner covers. As an interim measure, the operator issued an instruction to all handling agents regarding security of the protective covers. However, this instruction was not addressed to Royal Mail specifically, and does not appear to have been forwarded to them by the aircraft handling agent at East Midlands.

Analysis

Assuming that the emergency hatch was correctly closed at the beginning of the loading operation and taking account of the absence of damage both to the structural aperture and lack of pre-incident damage to the hatch, the only way in which the latter could have opened was by the inner handle moving inboard and rotating downwards, (ie as in the normal sequence of hatch opening from within).

Both hatch covers were detached and loose in the cabin when the aircraft left Ronaldsway. They may have become detached due to worn Velcro pads, though there is also the possibility that they could have been deliberately removed to allow more light into the cabin during night loading operations if the aircraft was not electrically powered. Although the aircraft did experience problems with the ground power supply at East Midlands, it was powering the aircraft, and hence the lighting system, during loading. Had this not been the case loading staff there would have ceased operations, in accordance with local procedures.

No-one at East Midlands reported fitting the covers, so although loading personnel there were divided about the state of the covers, they were almost certainly not in position covering the hatches when loading commenced. The left hatch handle would therefore have been exposed to contact with items of freight loaded in the cabin. The curved shape of the cabin side above the aperture, coupled with any settlement of freight items during loading, would have permitted articles of certain shapes and dimensions to have moved downwards and outboard in such a way as to have gradually positioned themselves between the handle and the hatch structure. Under such circumstances, the handle would readily move away from the stowed position, pivoting inboard, as settlement of load items continued. Thereafter, such settlement would have been capable of rotating the now protruding handle downwards. If sufficient rotation took place, the over-centring action of the latches would occur, permitting the hatch to open outwards. Presence of any positive cabin pressure differential would increase the force required to over-centre the catches and initiate release of the hatch above that required without pressurisation being present. It is presumed that no differential pressure was present at this point.

The location from which the hatch was recovered indicates that all or most of the take-off ground run had occurred when the hatch detached. Since considerable rotation of the handle is required to over-centre the catches, it would appear that inboard movement and hence un-stowing of the handle most probably occurred during loading, possibly accompanied by some degree of initial handle rotation. The nature of the loading operation results in the hatch area becoming obscured by freight as soon as that section of the aircraft is loaded above the window line.

The technical log entry and the low cabin pressure differential experienced by the flight crew on the previous leg were likely to have created an expectation of similar problems during the incident flight. It thus came as no surprise to the crew that no cabin pressure differential was achieved on the flight to the Isle Of Man and accounts for the fact that they did not consider the possibility that a faulty hatch or door may have been responsible for the lack of pressurisation.

Clearly the importance of the protective covers over the hatches was not appreciated by the loading staff at East Midlands. It was notable that, although the loading operation at Ronaldsway had been the subject of an audit inspection by the operator, the loading supervisor there was also unaware of the significance of the hatch covers and did not therefore notify the commander or take steps to ensure they were re-fitted. The actions of staff at both stations suggested deficiencies in the training of staff with regard to the aircraft type, and a safety recommendation is made in respect of this.

The aircraft was correctly loaded and documented in accordance with the operator's SLP (albeit an unapproved procedure), though the loading operation appeared to rely on the experience of the loading staff and perhaps training given by other operators rather than specific guidance from the operator itself. Although the lack of written loading instructions did not result in an unsafe load configuration, this is considered to be a serious deficiency and one which has contributed to fatal accidents to cargo aircraft in the past. The lack of instructions or training regarding the technical aspects of the aircraft, including the importance of the hatch covers, contributed directly to the loss of the hatch. A safety recommendation is made with regard to the adequacy of written instructions and training at the stations used by the operator's aircraft.

Some anomalies with the acceptance and recording of aircraft defects were noted. The technical log instructions to the crew regarding the exact state of the pressurisation system were somewhat ambiguous and this was borne out by the fact that the crew operated the first sector with the aircraft pressurised, albeit slightly. The aircraft's front door was recorded and labelled as being usable in an emergency only, though this was the only means of access and egress when the aircraft was loaded. This was not a practical proposition given the nature of the operation, as the crew would have to enter the aircraft before loading commenced and would only be able to leave after unloading was complete. The door should have been rectified, or the operation adjusted to accommodate the restrictions that the inoperative door imposed, but neither of these was done.

Safety Recommendations

Notwithstanding that the operator's use of a standard load plan had not been approved by the CAA, the aircraft was loaded in accordance with the operator's procedures and, with regard to the load distribution, was in a safe condition for flight. However, the investigation revealed shortcomings in the operator's training, safety management system, and provision of written instructions. The investigation also established that several findings from the CAA's own safety oversight programme audits remain outstanding, particularly with regard to the provision of written instructions at several of the operator's bases. The following safety recommendations are therefore made:

Safety Recommendation 2005-140

The Civil Aviation Authority should ensure that Emerald Airways reviews its procedures for initial training and periodical examination of contracted loading staff at outstations, including the provision of written instructions and aircraft technical training, to ensure that Emerald Airways fully meets the responsibilities placed on it by JAR-OPS 1.205.

Safety Recommendation 2005-141

Emerald Airways should review its safety management system with a view to accelerating the current audit schedule for outstations, and conduct a risk assessment of them all to establish those most 'at risk', prioritising audit inspections accordingly.

Safety Recommendation 2005-142

Emerald Airways should take immediate action to ensure that applicable, detailed and current written instructions are readily available to loading staff at all bases and outstations.

Safety Recommendation 2005-143

The Civil Aviation Authority should pursue the findings of its own audits of Emerald Airways' loading procedures, particularly in respect of the provision of written instructions, with a view to enforce compliance as soon as practicable.

ACCIDENT

Aircraft Type and Registration:	Cessna 208B Caravan, G-BZAH
No & Type of Engines:	1 Pratt & Whitney Canada PT6A-114A turboprop
Category:	1.2
Year of Manufacture:	2000
Date & Time (UTC):	4 November 2004 at 1600 hrs
Location:	Netheravon Airfield, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - One Passengers - One
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to lower forward fuselage structure and nose landing gear spring fairing
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	10,600 hours (of which 627 were on type) Last 90 days - 91 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was returned to dispersal after its pilot heard two loud bangs from the area of the nose landing gear whilst taxiing to depart. The rear support of the nose landing gear spring had come away from its fuselage mounting point because one attachment bolt had failed due to bending fatigue and the other three had pulled from their self locking anchor nuts. Long-term fretting between the bolts and the rear support casting was evident and elongation of the bolt holes in the fuselage structure had occurred in a forwards direction, indicating that the nose gear spring had moved forward, possibly whilst the aircraft was being towed over a surface irregularity. Four safety recommendations were made which addressed nose gear maintenance inspections and the control of towing loads.

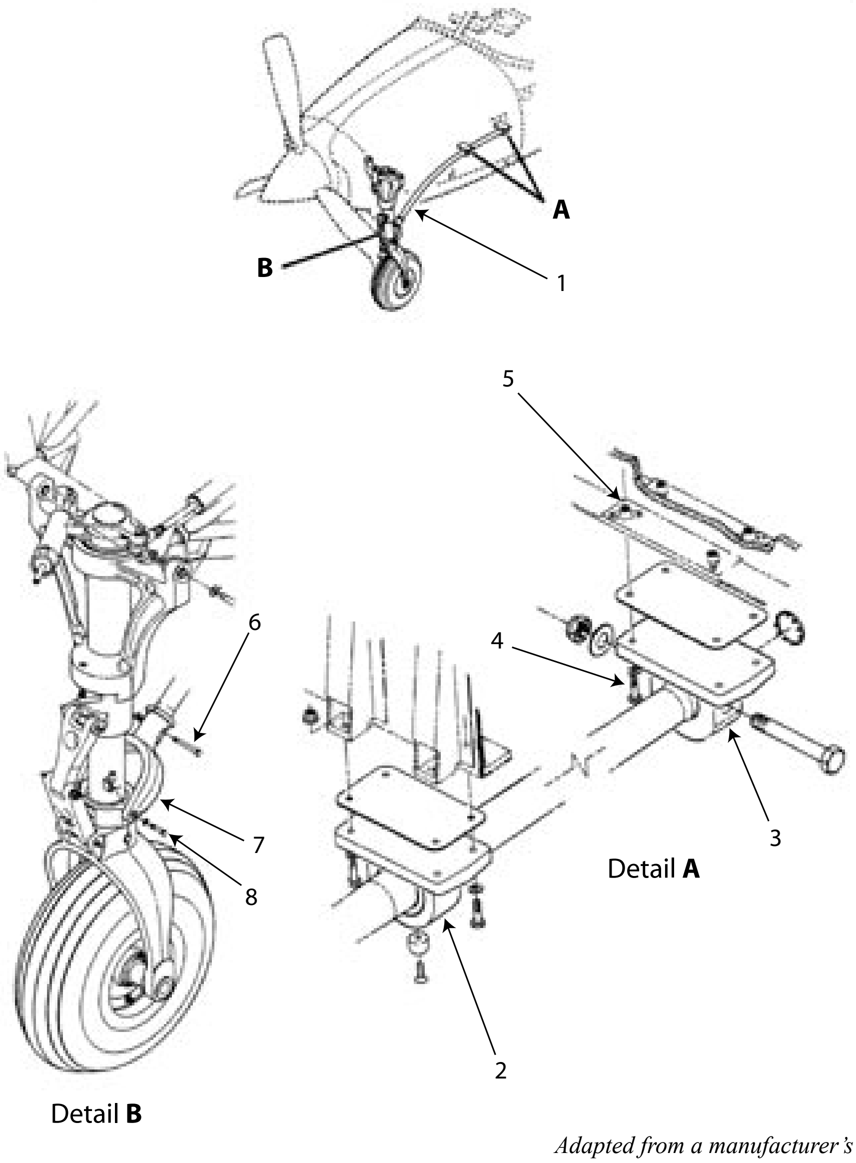
History of the accident

The aircraft was being taxied from the dispersal to the holding point in preparation for departure for a local flight when the pilot heard two loud bangs from the area of the nose wheel. The pilot contacted ATC on the radio and requested them to look for damage or anything abnormal. ATC reported that a 'panel' appeared to be loose so the pilot returned the aircraft to dispersal and shut down the engine.

Examination by the operator's aircraft engineer found that the rear support of the nose landing gear (NLG) spring had come away from its rear fuselage mounting point and had dislodged the composite fairing that was fitted immediately below the spring and its supports.

Engineering Examination

The NLG spring (Figure 1, item 1) is attached to the fuselage by a forward support (Figure 1, item 2) and a rear support (Figure 1, item 3). Each of these spring supports are secured to the fuselage structure by four attachment bolts that are tightened to 50 foot-pounds torque. The four rear support attachment bolts (Figure 1, item 4) are assembled into self-locking anchor nuts (Figure 1, item 5) mounted within the fuselage structure. One of these four attachment bolts had failed leaving the threaded portion located within the anchor nut. The unthreaded shank section of the bolt was never recovered. The other three attachment bolts were found lying loose within the composite fairing fitted below the forward and rear spring supports.

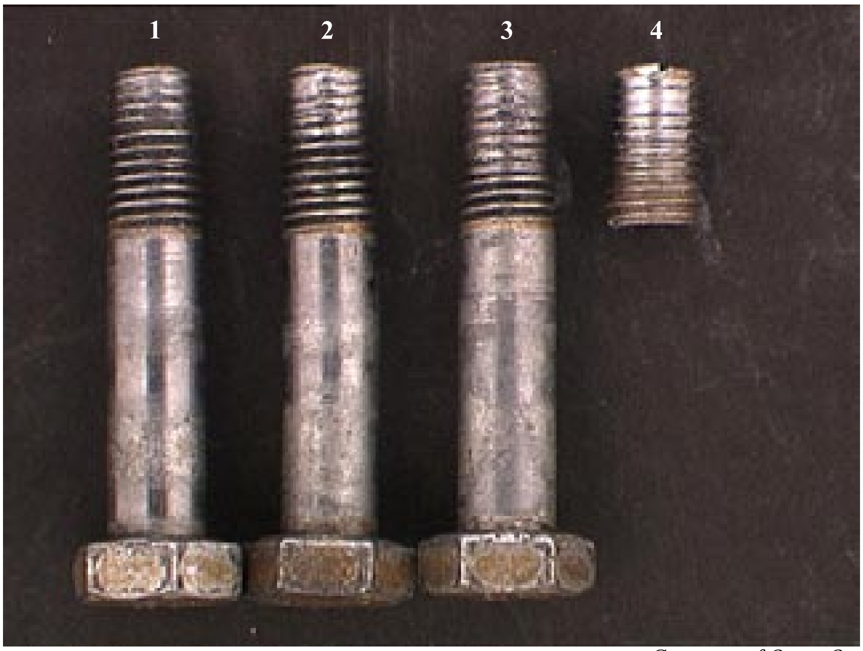


Adapted from a manufacturer's drawing

Figure 1

Diagram of the nose landing gear

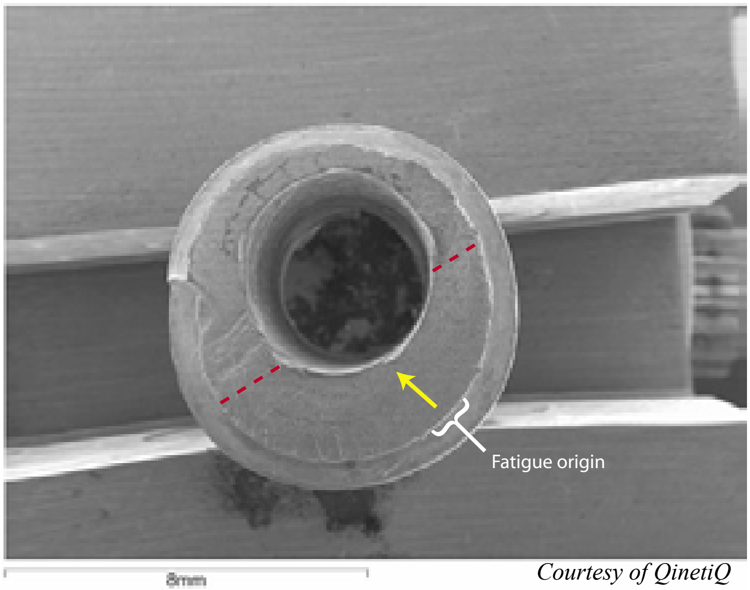
The three attachment bolts and the remaining section of the fourth bolt, together with the sections of fuselage structure with the mounted self-locking anchor nuts, were submitted for metallurgical examination. This examination showed that bolt No 4 bolt failed due to bending fatigue and the remaining three were pulled from the anchor nuts causing the bolt threads to strip (Figures 2 & 3). The fatigue crack in bolt No 4 had initiated at multiple origins in the thread root and propagated across approximately half the bolt's diameter prior to a final overload failure. The multiple origins of the fatigue were at one side of the bolt indicating that it was due to bending fatigue. As the orientation of the bolt in the structure was not known, it is not possible to determine the direction of the loading that was responsible for the fatigue in relation to the fore/aft axis of the aircraft. In addition to the fatigue crack observed in bolt No 4, fatigue cracks were also observed in the thread roots of bolt No 1.



Courtesy of QinetiQ

Figure 2 (left)

The four rear support retaining bolts (Figure 1, item 4) (Note: The numbering of bolts has no relationship to the positions that they were fitted in the rear support; this was not known)



Courtesy of QinetiQ

Figure 3 (right)

Fracture surface of etaining bolt No 4 (fatigue limit highlighted by the red dashed line and direction of growth indicated by yellow arrow)

All four retaining bolts had differing amounts of thread stripping. Four threads were stripped from bolt No 1, five from bolt No 2, eight from bolt No 3 and four from bolt No 4. After re-assembling the rear spring support to the fuselage structure, it was apparent that engagement by the attachment bolts with the anchor nuts should reach at least the eighth thread of the bolt and that four threads would protrude beyond the nut. This showed that at the time of thread stripping, only bolt No 3 was fully engaged in its anchor nut. Either four or five threads were stripped from bolts Nos 1, 2 and 4, indicating that these bolts were not fully engaged in their anchor nuts.

Attachment bolts Nos 1, 2 and 3 showed very good evidence of long-term fretting on the unthreaded shanks and slight bending in the area where the threaded sections abutted the unthreaded sections. All four bolt holes in the rear spring support casting showed very good evidence of long-term fretting between the casting and the shank section of the attachment bolts. It was not possible to determine the period over which this fretting had occurred.

Measurements and material hardness checks were carried out on all four of the attachment bolts which showed that they met their specification. The four self-locking anchor nuts were examined and found to be both serviceable and of the type specified by the aircraft manufacturer.

The examination of the holes in the fuselage structure where the anchor nuts were mounted showed good evidence of elongation (Figure 4). The majority of this elongation had occurred in a forward direction, indicating that the NLG had moved forward relative to the aircraft's fore/aft axis.

Examination of the lower surface of the NLG rear spring support casting (Figure 1, item 3) showed paint loss and polishing of the metal (Figure 5). This polishing was in a fore/aft direction. Examination of the inside surface of the composite fairing, which was mounted directly below this support, showed similar rubbing and polishing that had been caused by contact with the lower surface of the support.

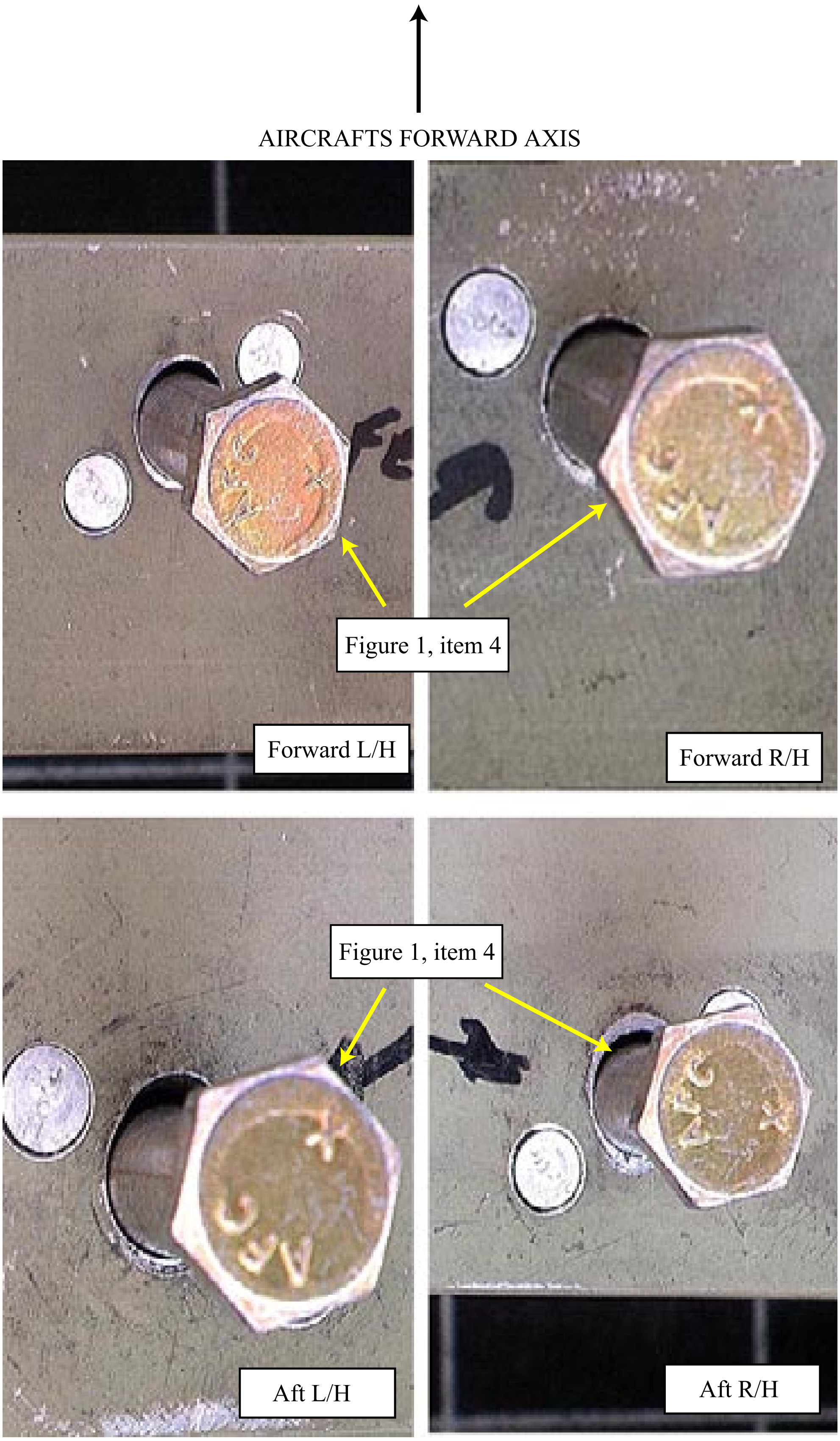
The two bolts (Figure 1, item 6) that attached the forward end of the NLG spring to the fork casting (Figure 1, item 7) where visually examined. They showed good evidence that they had been placed under large shear loads in one direction over a significant period of time. The orientation of these bolts was not known and therefore it was not possible to determine if these shear loads were in the aircraft's fore or aft axis.

The two bolts (Figure 1, item 8) that attached the fork casting to the bottom end of the NLG leg were visually examined. They showed no evidence of excessive or unusual wear markings. It was later established that the operator had replaced these bolts shortly before the accident.

Maintenance history

The aircraft had been regularly maintained by the operator's aircraft engineer in accordance with the manufacturer's schedule. The engineer had been responsible for the aircraft's maintenance from the time it was delivered as new from the manufacturer until the date of the accident. One of the manufacturer's maintenance requirements is to:

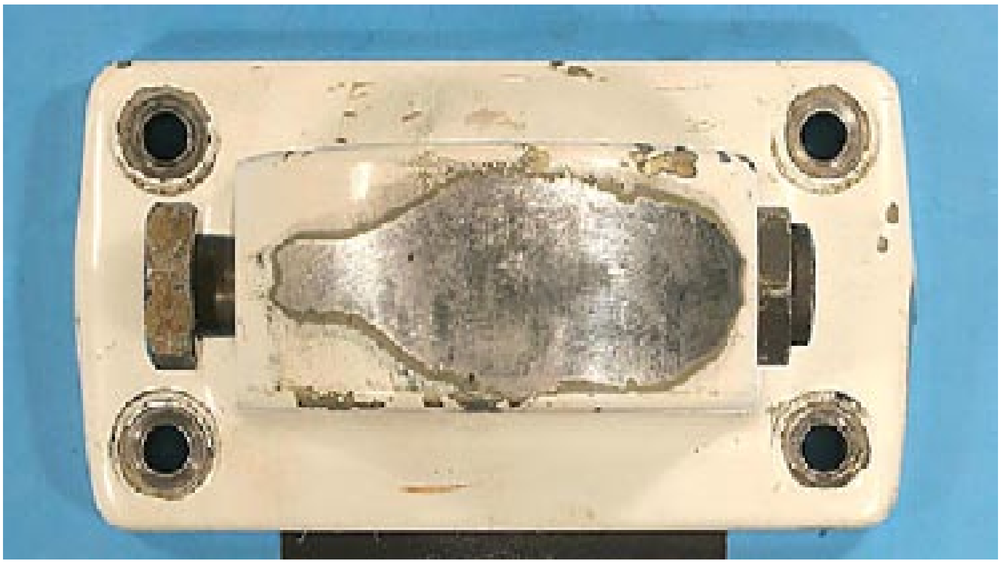
> *'Inspect forward and aft drag link spring supports for condition, loose or worn bushings, loose or missing jack point on forward support and security of attachment of both supports'.*



Courtesy of QinetiQ

Figure 4

Elongation of the rear support retaining bolt holes in the aircraft's structre



Courtesy of QinetiQ

Figure 5

Polishing effect on the bottom of the nose landing gear spring rear support

This inspection was required to be carried out every 200 airframe hours; it had last been performed by the engineer approximately 106 hours (375 flights) prior to the accident.

Early in the service life of the aircraft, the operator had encountered a problem whereby the bush that is fitted between the NLG spring and the forward spring support casting, migrated out of the casting and along the spring. This problem was eventually resolved by 'polishing' the circumference of the spring and bonding the bush into the casting. It was not possible to establish if this rectification involved removal of the rear spring support.

Aircraft operations

The aircraft was primarily used for sport parachuting from a grass airfield. At the time of the accident the aircraft had flown 7,071 flights and 2,527 hours. When not in use it was kept and maintained in a hangar that is situated downhill from the airfield and aircraft dispersal areas, which necessitated the use of a powered aircraft tug to ground handle the aircraft. The aircraft dispersal and refuelling areas are concrete hard standings on the edge of the grass airfield. In a few areas there are significant steps between the grass surface and the concrete.

Ground tug equipment

The aircraft operator used a Hydrau Tug 400 powered tug (Figure 6) to ground handle the aircraft from the dispersals to the hangar and vice versa. The tug functioned by hydraulic fluid under pressure powering two drive wheels and a lift and tilt mechanism and was handled and manoeuvred by an operator who walked with the unit. The tug was connected to the aircraft by manoeuvring it towards the NLG wheel, positioning the wheel onto the tug's platform, raising and tilting the platform towards the tug and attaching a webbed strap around the lower portion of the NLG leg. There was no 'weak link' or safety strap in the attachment between the tug and the aircraft.

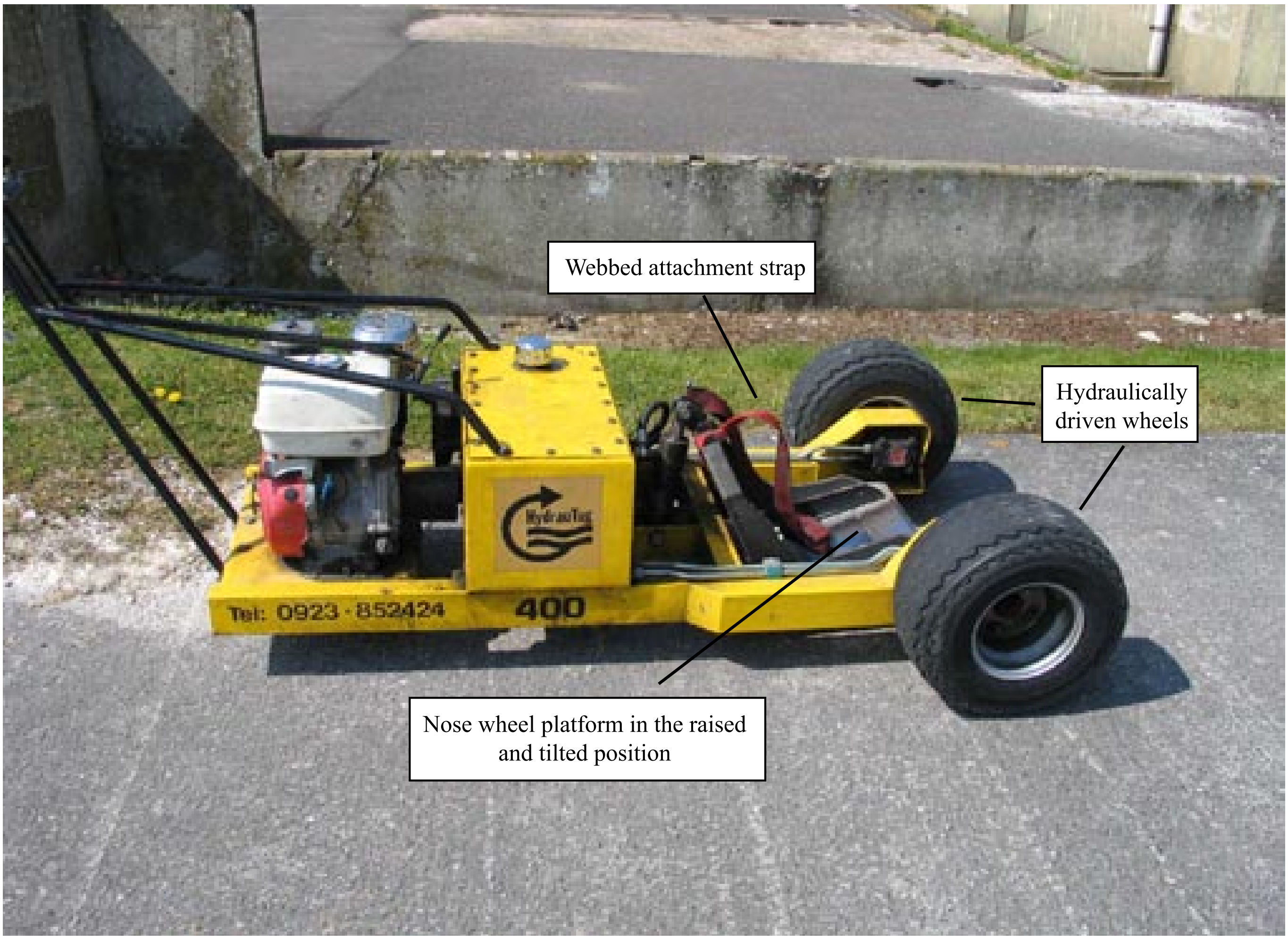


Figure 6

The Hyrau Tug 400

The tug is rated for aircraft weighing up to 25,000 lbs, but in reality could tow aircraft of higher weights on level, hard surfaces.

During a visit to the operator's base by the AAIB investigator it was found to be very easy for an inexperienced tug operator to introduce quite a severe 'snatch' when initiating movement of the tug.

Nose landing gear towing limitations

G-BZAH had an MTWA of 8,750 lb (3,969 kg). There are no towing force limitations stated in the aircraft's Operating Handbook or Maintenance Manuals.

Discussion

Examination of the four bolts that attach the NLG rear spring support to the fuselage has shown that one bolt failed due to fatigue and the remaining three were pulled from their anchor nuts causing the bolt threads to strip. The fatigue crack initiated at multiple origins in the end thread at one side of the bolt indicating that it was due to bending fatigue. In addition to the fatigue crack observed on fractured bolt No 4, fatigue cracks were also observed in the thread roots of bolt No 1. A likely scenario for the initiation of the fatigue cracks observed in two of the bolts (Nos 1 and 4) is that they were caused by movement in the NLG rear spring support due to loose fasteners. This scenario is supported by the evidence of fretting, which indicates 'chattering', between the attachment bolts and the rear spring support casting. The fatigue crack in bolt No 4 was sufficiently large that during a high load event, the bolt fractured, increasing the load on the remaining three bolts. This increased loading on the three bolts caused, over a period of time, the threads to strip and the NLG to fail. The differing number of threads that had been stripped on the attachment bolts indicated that they had not been correctly fitted sometime in the past or that they had loosened in service. No evidence could be found to indicate how these bolts could have loosened in service. It is possible that the loose rear spring support could have been the cause of the forward spring support bushing migrating out of its casting, implying that rear spring support had been loose for some considerable time.

The examination of the elongated holes in the fuselage structure showed that the majority of the elongation occurred in a forward direction, indicating that the NLG spring had moved forward rather than aft as would be expected for the loading experienced during taxing, takeoff and landing.

From the geometry of the NLG it can be seen that towing the aircraft by the nose wheel increases the forward load on the NLG rear spring support. A sudden start, jerk or attempt to start towing with the parking brake on or wheel chocks in place could substantially increase the forward loads on the rear support attachment bolts. Therefore, any of these reasons could be the cause of the forward hole elongation seen in the fuselage structure.

Safety Recommendations

With an MTWA of almost four tonnes, the Cessna 208B is too heavy to be manoeuvred on a slope by hand but there are no towing limits published in Aircraft Operating and Maintenance manuals. Without adequate information on and the observance of suitable towing limits, it is possible for an aircraft to be damaged during ground operations and for this damage to pass undetected during routine maintenance. Therefore, the following safety recommendations were made:

Safety Recommendation 2005-102

It is recommended that the Federal Aviation Administration of the USA requires the Cessna Aircraft Company to augment the current routine maintenance procedure for the nose landing gear forward and aft drag link spring supports of the Cessna 208 Caravan aircraft models with a requirement to torque check the attachment bolts.

Safety Recommendation 2005-103

It is recommended that the Federal Aviation Administration of the USA requires the Cessna Aircraft Company to advise maintainers of Cessna 208 Caravan aircraft to replace the nose landing gear rear spring support attachment bolts if these bolts are found to be loose when torque checked during routine inspection.

Safety Recommendation 2005-104

It is recommended that the Federal Aviation Administration of the USA requires the Cessna Aircraft Company to establish the maximum towing loads that can be applied to the nose landing gear wheels of Cessna 208 aircraft and to publish suitable towing load limits in the Aircraft Operating and Maintenance Manuals.

Safety Recommendation 2005-105

It is recommended that the UK Civil Aviation Authority should ensure that all UK aircraft and airport operators utilising powered aircraft towing equipment define and implement towing procedures that ensure the aircraft manufacturer's published towing load limits are not exceeded.

INCIDENT

Aircraft Type and Registration:	Embraer EMB-145EP, G-ERJG
No & Type of Engines:	2 Allison AE 3007/A1/1 turbofan engines
Category:	1.1
Year of Manufacture:	2001
Date & Time (UTC):	20 February 2005 at 0900 hrs
Location:	West of Coulommiers VOR Beacon, France
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 28
Injuries:	Crew - None Passengers - None
Nature of Damage:	Heat damage to electrical component
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	5,000 hours (of which 1,500 were on type) Last 90 days - 100 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the climb, the pilots were unable to keep the autopilot engaged, and later became aware of smoke and fumes in the cockpit. Shortly afterwards the commander's flight displays and the Engine Instrument and Crew Alerting System failed. Smoke was evident briefly in the passenger cabin and the aircraft diverted to Paris Charles de Gaulle Airport. After landing, disembarkation was delayed whilst the crew attempted to follow complex taxi instructions. The source of the smoke was identified as the number 1 IC-600 avionics integrated computer.

The investigation found that the procedure for recovering information to cockpit displays in the event of failure of an IC-600 had been omitted during a previous revision of the Quick Reference Handbook (QRH). One safety recommendation was made concerning restoration of the appropriate procedure in the QRH.

History of the flight

The aircraft was being flown by the co-pilot on a scheduled passenger flight from Manchester to Venice. While climbing through FL100, the autopilot disengaged but was successfully re-engaged by the co-pilot. The autopilot disengaged again as the aircraft climbed through FL200, but could not be re-engaged, restricting the aircraft to flight below airspace in which Reduced Vertical Separation Minima (RVSM) apply. Later, whilst cruising at FL270 west of the Coulommiers VOR Beacon, an unusual smell became apparent in the flight deck. The senior cabin crew member who was asked to check the cabin reported to the commander that the smell was of nail varnish, although both pilots considered that it was similar to electrical burning. Shortly afterwards, smoke was seen beneath the commander's seat. Simultaneously, the commander's Primary Flight Display, Multi-function Display (MFD), Radio Management Unit and the Engine Instrument and Crew Alerting System (EICAS) all failed. The pilots carried out the emergency actions for smoke on the flight deck, donned oxygen masks and smoke goggles, and declared a MAYDAY, requesting a diversion to Paris Charles de Gaulle Airport. Smoke was also evident briefly in the passenger cabin but, according to the commander, the pilots were not made aware of this at the time. Nevertheless, the cabin crew were told to prepare for an immediate diversion and the passengers were informed of this intention.

As the aircraft descended through FL090, the co-pilot deployed the speed brakes in order to reduce indicated airspeed to below 250 kt. The speed brakes were not stowed prior to the subsequent approach and landing on Runway 27L and the commander noticed that they remained deployed after the aircraft was shut down, but no adverse handling or performance characteristics were reported.

After landing, the pilots received lengthy taxiing instructions to a remote stand in an area of Paris Charles de Gaulle Airport with which they were not familiar. Consequently, disembarkation did not start until five minutes after touchdown, despite advice from ATC that the aircraft could stop at any time, if disembarkation became necessary.

Engineering investigation

The source of the smoke was identified by the operator's maintenance personnel as the number 1 IC-600 avionics integrated computer, which collates data from a variety of aircraft systems and presents them on the number 1 cockpit displays.

Subsequent investigation by the manufacturer of the IC-600, found that a transistor on the A5 Autopilot Circuit Card Assembly had failed. Failure of this transistor caused the Yaw Damper Clutch line to short to ground. This caused excessive current to flow in the Yaw Damper Clutch line circuit, which resulted in overheating and some charring of the circuit card and other components located in the area of the failed transistor. The computer manufacturer concluded that this was an isolated incident. The aircraft manufacturer supports this view, stating that the IC-600 has been a very reliable component on the ERJ family of aircraft, with a mean time between failures of over 100,000 flight hours.

Reversionary procedures

The presentation of information on an electronic flight instrument can be lost either by interruption of the information source or by failure of the display itself. The former is identified by a red "X" on the affected display, the latter by a blank screen. Neither of the pilots recalled seeing anything displayed on the affected screens, but the investigation found that failure of an IC-600 would cause a loss of information to all of the screens normally associated with it and the display of a red "X" on each. The red "X" symbol is generated by the display unit itself in the absence of any other information, and thus is independent of the normal function of the symbol generator (SG) associated with each IC-600.

In normal operation, the number 1 IC-600 presents information on the commander's (left hand) cockpit displays and EICAS, and the number 2 IC-600 presents information on the right hand cockpit displays. In the case of a single display failure, the information that would normally be presented on that display can be shown instead on one of the other screens on that side, and the procedure to be followed is described in the quick reference handbook (QRH). If an IC-600 should fail, however, information from the opposite IC-600 can be presented on both sets of cockpit displays by pressing the "SG" pushbutton on the reversionary panel of the affected side. This simple procedure was absent from the QRH.

The commander reported that no reversionary procedure was attempted because of the high workload involved in diverting to Paris Charles de Gaulle. He conceded, however, that had such an attempt been made, the crew would not have been able to identify the appropriate procedure by reference to the QRH alone. The co-pilot added that he made a reversionary selection in order to present EICAS information on his MFD, but this action would not have altered the presentation of information on screens affected by failure of the number 1 IC-600.

Recorded information

The cockpit voice recorder was replayed successfully. The two solid-state flight recorders recorded information throughout the event, and the flight data recorder (FDR) operated normally until 0837 hrs. After that time parameters associated with the number 1 IC-600 were no longer recorded, whereas others not associated with it were recorded. These included the tri-axis accelerometer, control column and control wheel position transducers, rudder pedal position transducers, brake pressures and the clock. From these parameters it was deduced that the aircraft landed at 0853 hrs.

All of the missing parameters were routed through the failed IC-600 integrated computer. The architecture of the data capture system was such that failure of the number 1 IC-600 prevented data from reaching the FDR, with no possibility of reversion to alternative data sources.

Speed brake deployment

It is likely that the speed brakes were deployed (or selected) throughout the approach and landing. However, they are designed to stow automatically, regardless of the cockpit selection, when flaps are extended by 22° or more, or when the thrust levers are advanced, both of which conditions would be met during an approach. On the ground, with flaps selected up and thrust levers retarded, the speed brakes would have redeployed, as observed by the commander.

If the speed brakes were not in the selected position (for example, because they had stowed automatically in the circumstances described above) a "SPEED BRAKE LEVER DISAGREE" message should have appeared on the EICAS. However, since the EICAS itself was not displaying any information, this message would not have been presented to the crew in the normal way. The co-pilot did not recall seeing any such warning on the "reverted" EICAS display presented on his MFD. The manufacturer and operator consider that it would not have been possible to carry out a normal approach had the speed brakes remained deployed.

Follow up action

Quick Reference Handbook

The QRH current at the time of the incident did not contain a procedure to be followed in the event of failure of an IC-600. The simplicity of the correct reversionary procedure (pressing one button) suggests that adequate crew knowledge alone should have been sufficient to address this failure. Also, the QRH described a procedure for dealing with an "IC bus failure", the symptoms of which would be essentially the same as failure of the IC-600 computer itself. Completion of this procedure would restore information to the affected displays. Nevertheless, the commander of the incident aircraft and senior pilots on the operator's ERJ fleet expressed surprise that a clearly identifiable procedure was not available. The AAIB supports this view. Although sufficient flight instrumentation remained for the co-pilot to carry out a successful approach and landing, easy access to a straightforward remedy would have reduced crew uncertainty and assisted the commander with monitoring of the flight.

The aircraft manufacturer discovered that the relevant reversionary procedure had previously been included in the published QRH but had then been omitted in a subsequent revision. The aircraft operating manual contains advice on reversionary procedures, and the operator has distributed this advice in a notice to its pilots. The manufacturer has undertaken to reinstate the procedure in the QRH.

FDR data acquisition

All of the parameters missing from the FDR are routed via the number 1 IC-600, the system having been certified on the basis that a single IC-600 is considered a reliable unit. Most aircraft have similar single source architecture, as it is not considered practical or desirable to duplicate the system.

Disembarkation following fire

The company Operations Manual advises

> *'After a rejected take-off or an emergency landing the aircraft should normally be brought to a halt on the runway and the emergency evaluated quickly before taxying clear. Stopping the aircraft expeditiously is of prime importance. If required, an evacuation must be initiated promptly'.*

Elsewhere, it cautions:

> *'fire or smoke warnings… may either be false or indicate an overheat condition rather than a fire. The immediate action - to carry out the appropriate emergency checklist - does not automatically include evacuating the aircraft. The primary objective is passengers' safety, and it may be undesirable to carry out an unnecessary emergency evacuation with the attendant risks to passengers'.*

Weather conditions at the time of the incident were such that a disembarkation on or near the runway would have been an uncomfortable experience for the passengers. Nevertheless, a timely disembarkation or evacuation should be the highest priority following evidence of fire or smoke generation on board an aircraft. Previous accidents have demonstrated that any delay after landing can seriously prejudice the survival of those on board in the event of an actual fire. However, in this incident, the commander decided that evacuation was unnecessary. Discretion to make such a judgement was permissible within the operator's flight crew orders.

On 8 September 2005 it was recommended that:

Safety Recommendation 2005-080

Empresa Brasileira De Aeronautica SA (Embraer) should publish a readily identifiable procedure in the quick reference handbook of all ERJ135/140/145 series aircraft which restores information to flight instruments affected by the failure of either IC-600 avionics integrated computer.

Response to Safety Recommendation 2005-080

On 14 October 2005 Embraer notified the AAIB in writing that:

> *'Embraer is at present in the process of revising the current QRH to incorporate the suggested recommendation. Embraer expects to have this revision available for operators by the end of this calendar year'.*

ACCIDENT

Aircraft Type and Registration:	Beech 76 Duchess, G-BMJT
No & Type of Engines:	2 Lycoming (LO/O)-360-A1G6D piston engines
Category:	1.3
Year of Manufacture:	1981
Date & Time (UTC):	10 April 2005 at 1649 hrs
Location:	Adjacent to Belfast City Airport, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Flying Experience:	Approximately 3,000 hours (of which approximately 2,400 were on type) Last 90 days - Not known Last 28 days - Not known
Information Source:	AAIB Field Investigation

Summary

The aircraft took off from Belfast (City) Airport and the landing gear was retracted. Witnesses heard a sound similar to that of a reduction in engine power and shortly afterwards the aircraft turned to the left. It failed to gain any further height, struck some trees and crashed into a sports field, coming to rest against a substantial steel mesh fence. There was an immediate fire. The pilot escaped from the aircraft unassisted but suffered severe burns.

Maintenance activity prior to the flight to Belfast City

The aircraft was based at Ronaldsway Airport, Isle of Man. At some time prior to 8 April 2005 the pilot had become aware of an increase in the oil temperature of the left engine. He had contacted his maintenance organisation to discuss the defect and during this discussion it appears that the maintenance organisation suggested that the 'vernotherm' (a thermostat valve in the engine oil system) be replaced as an initial rectification action. A replacement valve was dispatched to allow the pilot to make arrangements to have the unit replaced locally.

The pilot arranged for an engineer to replace the valve during the afternoon of 10 April 2005. During the latter part of that morning the pilot contacted another engineer to discuss the problem and was advised that prior to replacing the valve it would be advisable for some simple inspections of the oil system be carried out to identify any obvious defects.

The first engineer met with the pilot at the aircraft to carry out the replacement of the valve. The oil cooler, piping and wiring were inspected for obvious defects; none were identified. The engineer then requested that the pilot run both engines in order to verify the readings observed by the pilot. The engines were run for approximately 20 minutes, slightly above idle rpm, although the actual rpm was not recorded nor were the relative positions of the throttles noted. During this period it was observed that although the left engine oil temperature was within the green band, half way between the 200º mark and the limit of the green band, it was considerably higher than the right, which had not yet reached the 200º mark. During this time the left engine oil pressure was observed to fluctuate for approximately 10 seconds before stabilising at a level comparable with the right engine. The left engine cylinder head temperature (CHT) was also observed to be higher than the right and the left fuel pressure gauge was reading off scale and the right fuel pressure gauge showed no reading.

After replacing the vernotherm a second ground run of the left engine was conducted. The engineer reported that the oil temperature, whilst still slightly higher than the right engine, now indicated below 200º. No fluctuation of oil pressure was observed during the second run; however, the fuel pressure remained off scale. An inspection of the engine was carried out after the run to verify that there were no leaks, and the aircraft was returned to its hangar. The variations in CHT and fuel pressure readings were brought to the attention of the pilot who confirmed that he was already aware of them; he has reported that the instruments were unreliable and difficult to maintain, although he had made efforts to correct these deficiencies.

History of flight

Following the completion of the maintenance activity the pilot arranged to carry out a short flight since he intended to fly the aircraft to France on 11 April 2005. A family friend had planned to travel to Belfast by ferry but he offered to fly her there instead, a flight of 20 to 30 minutes. She accepted the offer and the aircraft departed from the Isle of Man on the afternoon of 10 April 2005, and landed on Runway 22 at Belfast City Airport at 1614 hrs. The passenger subsequently reported that the flight had been uneventful.

The pilot and his passenger left the aircraft, which was parked on the ramp area and were taken to the terminal; the passenger then left the airport. The pilot paid the landing fees and returned in a minibus to his aircraft; also on the bus was the pilot of a Piper Chieftain. There was some general conversation between them before the pilot was dropped off at G-BMJT. The ground handling agent later removed the chocks from G-BMJT and checked that the pilot was able to start the engines unassisted, as he had been called away to another task.

The pilot requested start clearance at 1640 hrs. The Chieftain pilot, who was carrying out a pre-flight inspection of his own aircraft, watched the engines of G-BMJT start and reported that there had not been any apparent problem. At 1642 hrs the pilot requested taxi clearance and was given clearance to the holding position for Runway 22.

At 1645 hrs ATC passed an airways clearance to the pilot and asked if he was ready for departure; there was a gap in the traffic movements which would allow an opportunity for the aircraft to backtrack and depart. The pilot confirmed that he was ready and was given a clearance to enter, backtrack and line up Runway 22. ATC then gave him a local clearance to climb on runway track to an altitude of 1,500 ft before turning left on track.

At 1647 hrs G-BMJT was given take-off clearance and the pilot was advised that there was landing traffic at ten miles. The tower controller watched G-BMJT get airborne and then gave the inbound aircraft clearance to land. After becoming airborne the landing gear of G-BMJT was retracted. The controller's attention was drawn back to G-BMJT by a change in engine note, which he described as the sound of an engine running down. He looked up from his position in the tower and saw the aircraft airborne immediately in front of him. At around this time there was a brief radio transmission, believed to be from G-BMJT, which was blocked by the landing aircraft reading back his clearance. As the controller watched, the aircraft started to turn left, eventually through some 90 degrees, and passed around the side of the tower. He made a radio call to the pilot who he could see sitting up in the cockpit, but there was no response. The aircraft started to descend and he saw the wings level briefly before it crashed into trees and then dropped into a field. An immediate fire started on ground impact and he alerted the emergency and security services.

The aircraft had come to rest against a fence and the pilot was able to escape unassisted although he suffered severe burns in the post impact fire. Bystanders were able to assist him once he was clear of the aircraft and helped him to a safe area.

The tower controller contacted the Airport Fire Service (AFS) on a radiotelephony link and gave authorisation for a full deployment. The fire vehicles exited the airport through a security gate and, although the accident site was very close, had to travel several miles by road to reach it; the first vehicle arrived at the scene six minutes after the accident. The other emergency services were also alerted and arrived at the scene after a similar time.

Pilot information

The pilot obtained his Private Pilot's Licence in 1982. He purchased this aircraft in 1995 and had flown in excess of 2,000 hrs in it. He had completed his annual refresher training and flight tests on the aircraft.

The pilot was interviewed four months after the date of the accident while he was still in hospital. His recollection of the accident and the events leading up to it was understandably vague. He described experiencing an event immediately after lift off in which there was a bright flash after which he felt that he was temporarily blinded. He did however recollect sensing that the aircraft had asymmetric power following this event. His impression was that the aircraft was in flight for a period of time, perhaps reaching a height of 700 ft, but that he became aware that he was going to crash and aimed for a field.

Meteorological information

The synoptic situation around the time of the accident showed a weak warm sector covering Northern Ireland with a westerly airflow. Belfast (City) Airport departure information 'Romeo', valid at 1620 hrs and listened to by the pilot prior to departure, reported: surface wind from 260º at 13 kt, visibility 30 km, a few clouds at 2,500 ft, temperature 13ºC, dewpoint 5ºC and pressure 1025 hPa.

Aircraft information

The aircraft was a Beech Duchesses BE76 twin engine aircraft, constructed on 30 October 1980. It had originally been registered as ZS-KMI. It was transferred to the UK register on 4 December 1985 as G-BMJT, and had operated for a total of 2,582 hours to

21 February 2005 when the log books were last brought up to date. The aircraft was powered by two Lycoming O-360-A1G6D engines with opposite rotating Hartzell HC-M2YR-2CEUF constant-speed, fully-feathering propellers, which had been installed on the aircraft during manufacture. The aircraft had been owned and operated by the pilot since it had been transferred to the UK register.

The total useable fuel was 380 litres (100 USG). The landing gear takes about ten seconds to retract and approximately eight seconds to extend.

Performance

The aircraft is certificated in performance Category E; there is thus no requirement for positive climb performance to necessarily be available following a loss of one engine on takeoff. An engine failure or power loss soon after takeoff is a difficult situation to manage in a relatively small, low performance, twin engine aircraft such as this. The time at which a failure occurs and is recognised is critical, and at a low height the time available for decision making and taking action is short.

The minimum control speed in flight (V_{MCA}) for the aircraft is 65 kt, the stall speed at full power and 0º flap is around 70 kt, the recommended lift off speed is 71 kt with a 50 ft take-off speed of 80 kt, and the best rate of climb single engine speed (V_{YSE}) is 85 kt. The aircraft has a maximum take-off weight of 3,900 lbs (1,769 kg) and the estimated take-off weight for the accident flight was 3,400 lbs (1,545 kg).

At the estimated take-off weight the takeoff ground roll was calculated as 700 ft (215 m) and the take-off distance to 50 ft was 1,400 ft (425 m). The distance from the start of the runway to abeam the ATC tower is 3,800 ft (1,160 m). With an engine failure after takeoff at this weight, and with all the necessary immediate actions taken, a slight positive climb should just have been achievable.

Maintenance History

The airframe, engine and propeller logbooks confirmed that the aircraft had been maintained in accordance with CAP 411 (Light Aircraft Maintenance Schedule) by a single maintenance organisation since its transfer of registry, and that all of the required airframe maintenance had been carried out within the required time scales. The last inspection, an annual inspection, was completed on 3 March 2005 when the aircraft hours recorded were 2,582 hrs.

The engines fitted to the Beechcraft Duchess are subject to a 2,000 hour recommended overhaul life which, with the approval of the CAA, can be extended, provided that the continued satisfactory performance of the engines can be demonstrated. The CAA had approved an extension to the recommended overhaul life of the two engines fitted to this aircraft allowing their continued operation.

Both propellers had been overhauled and zero lifed in March 2001. The right hand propeller was removed again in July 2002 for rectification of an oil leak. By 21 February 2005, when the log books were last updated, the propellers had each accumulated 610 hours since overhaul.

A review of the correspondence between the owner and the maintenance organisation showed the owner to be extremely fastidious regarding the aircraft's maintenance requirements and defect rectification.

Airport information

Runway 22 at Belfast City Airport has a Take-Off Run Available (TORA) of 5,797 ft (1,767 m) and a width of

200 ft (61 m). The airport is located in a part industrial, part residential area with expanses of open water to the north and west. Immediately to the south of the airport is a recreation area with sports fields.

Once the AFS had left the airport there was no fire cover until they returned. The airport was declared closed and a NOTAM was issued. The one aircraft on short final approach already cleared to land was allowed to continue; four other inbound aircraft subsequently diverted to their alternate airfields. The airport reopened at 1839 hrs.

Recorded information

Recordings of the communications between the aircraft and ATC were available for the investigation. There was a single brief transmission from G-BMJT after takeoff which was blocked by a transmission from another aircraft. There were also two subsequent brief carrier wave only transmissions which may have been from G-BMJT. There was not enough information in these transmissions to allow an analysis of the engine/ propeller noise.

Wreckage and impact information

Accident Site

The aircraft had come to rest on an approximate heading of 040°M in the boundary hedge of a football field. The hedge was approximately three metres high and within the hedge was a substantial steel framed fence. Immediately in front of the fence was a railing designed to separate spectators from the field, through which the aircraft had passed before hitting the hedge. The railings were constructed of steel tubing similar to scaffolding poles. The aircraft's passage through these obstacles disrupted the airframe resulting in an intense post crash fire. Due to the location of the crash site, by the time the AFS were able to control the fire a significant portion of the aircraft had been destroyed. The fire destroyed the left wing, the outboard section of the right wing and the majority of the aircraft fuselage with the exception of the empennage.

Examination of the accident site showed that the aircraft had flown through a line of trees on the opposite side of the field, approximately 75 m from its resting point, in a wings level attitude at a height of approximately 15 m. In passing through the tree line the aircraft had removed a significant number of branches from the trees which were carried into the football field, a large number of these were found to be broken into approximately 35 cm lengths. Due to their relatively uniform size it is probable that these branches were broken by the action of a normally rotating propeller. Ground marks showed that the aircraft first made contact with the ground approximately 55 m from the tree line in a slightly nose down attitude and banked slightly to the right, the initial point of contact being the right wing tip followed by the right engine and propeller. These marks also indicate that the right propeller was turning at impact. The aircraft finally came to rest in the hedge approximately 20 m from the first point of impact. The left aileron was lying approximately 20 m from the tree line, together with portions of the left wing tip. Scoring made by the flap hinges indicated that the aircraft was on a heading of approximately 124ºM when the airframe made contact with the ground. Further ground marks indicate that the right engine and its propeller made a significant impact with the ground six metres from the initial impact mark; it is probable that the right propeller separated from the engine at this point. The scoring produced by the flap hinges indicate that after this impact the aircraft began to turn to the right. When the aircraft hit the spectator rail the aircraft rotated rapidly to the right swinging the left wing through the railing and hedge.

The left wing had been substantially destroyed by fire; the remaining structure consisted primarily of the spar and undercarriage. The position of the left engine and propeller relative to the remaining wing structure indicated that these were attached to the wing when the aircraft came to rest. The left propeller was found in the feathered position, with the spinner cap detached and wedged under the lower engine cowling. The left propeller appeared to have little rotational damage and this, together with the witness marks found on the blades, indicate that the left propeller had little or no rotation as the aircraft passed through the tree line and hit the ground.

The right wing had been destroyed outboard of the engine nacelle, with only the wing spar and control cables present. A three foot section of the right wing tip was found propped against the remains of the rear fuselage. It was not possible to confirm if this had been placed in this position by some person or as a result of the crash. The right aileron was detached from the right wing. It was sooted, but did not show signs of being subjected to the post crash fire indicating that it was not attached to the wing when the aircraft came to rest. The proximity of the aileron to the main wreckage and the sooting indicate that the aileron had separated from the wing after the aircraft had hit the ground. The inner wing, engine nacelle and engine were complete; however the right propeller had separated from the engine and was lying one metre forward of the engine, in the feathered position. The ground marks and damage to the right propeller blades indicate that the propeller was rotating normally as the aircraft passed through the tree line and when the aircraft hit the ground.

The aircraft's nose and cockpit sections had been subject to intense heat which had led to the destruction of the structure. The undercarriage appeared to be in the retracted position. The flaps had been heavily damaged which prevented confirmation of their position during the crash. Due to the fire damage no estimation of the position of the cockpit controls could be made on site. The instrument panel had been destroyed and the remains of the aircraft instrumentation had been subjected to significant heat damage. The integrity of the aircraft control cables was verified as far as was possible prior to recovering the aircraft to the AAIB.

Detailed examination of the wreckage

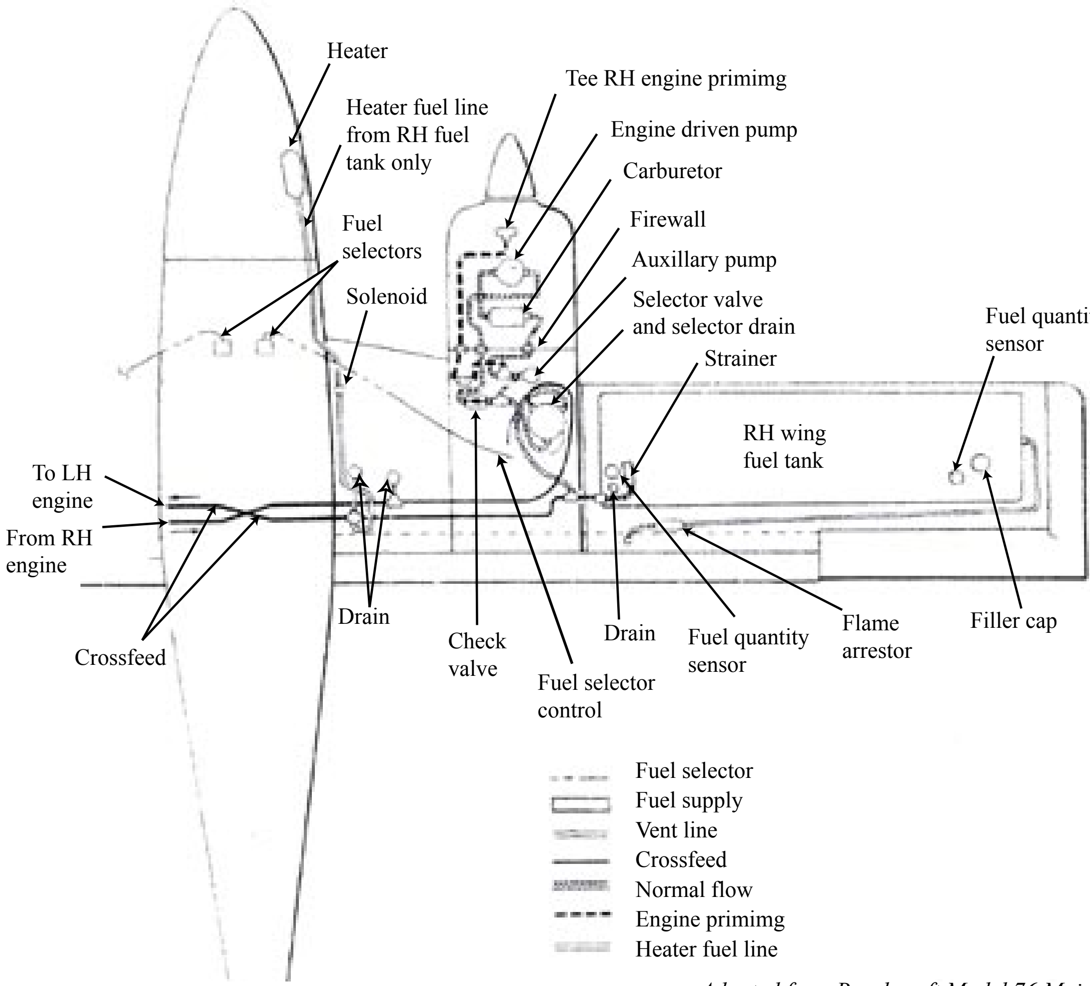
Based on the initial witness statements the investigation primarily focused on the engines, propellers, fuel system and associated controls. The intensity of the post crash fire had destroyed a significant portion of cockpit including most of the instrumentation; control levers and supporting structure. Detailed examination of the remaining aircraft instrumentation failed to identify any readings which may have been attributable to the aircraft's attitude, airspeed or engine condition immediately prior to impact.

Controls

The continuity of the aircraft flight and engine control cables was verified. The flap actuator was recovered, measurement of the exposed thread confirmed that the flaps were fully retracted at the time of impact. During the examination of the wreckage, two pairs of control levers were found attached to the remains of their hinge points and cables. These were identified as being the left and right engine carburettor heat and cowl flap controls. Both pairs showed a relative displacement between the left and right engine controls. The orientation of this displacement indicated that the cowl flap of the left engine was selected towards the CLOSED position relative to the right engine and that the left engine carburettor heat was selected towards the ON position relative to the right engine. The remaining engine control cables, throttle, mixture and propeller, were located, but due to the destruction of the associated levers and hinges no estimation of their position immediately prior to impact could be made. Measurement of the distance between the remaining cable rod ends and their locating clamps showed that these control cables had the same relative displacement, indicating that both the left and right engine had been selected to similar settings prior to impact.

Fuel System

The aircraft was fitted with a 51.5 gallon fuel tank in each wing. Each engine is equipped with a fuel selector valve which is located aft of the engine firewall in the engine nacelles. This selector has three positions which are selectable from the cockpit, ON, CROSSFEED and OFF (see Figure 1). In the ON position the selector allows the engine to consume fuel from the fuel tank in the same wing, in the CROSSFEED position the fuel flow from the same wing is closed and fuel flows from the opposite wing tank via cross feed pipes. In the OFF position, both the cross feed and the normal fuel supplies are closed. During take off both fuel selector valves would normally be selected to the ON position. If the aircraft experienced an engine failure after take off then the Emergency Check List requires that the fuel selector for the inoperative engine is selected to the OFF position.



Adapted from Beechcraft Model 76 Maintenance Manual

Figure 1

Fuel System Schematic

Examination of the remains of the fuel selector levers located on the cockpit floor showed that both levers were in the CROSSFEED position. There was a significant witness mark in the left fuel lever track at the CROSSFEED position which was likely to have been made by the fuel lever during the impact sequence; the left fuel lever was jammed in this position. The right fuel lever remained free to move and had not left any identifiable witness marks in its track and therefore its selected position at impact could not be confirmed.

Due to fire damage the aircraft fuel system could not be fully reconstructed; however, both the left and right fuel selectors were recovered and examined. The right engine selector remained within the engine nacelle together with its associated pipe work. When removed the valve was found to be in the ON position with the remains of the melted fuel filter bowl preventing any further movement of the valve plate. The left engine fuel selector was attached to the remains of the left wing by the selector cable, its locating structure having been destroyed in the fire. The valve was found to be in the CROSSFEED position; the remains of the fuel filter bowl prevented any movement of the valve plate.

Right Engine

Due to the post crash fire both the carburettor and dual magneto on each engine had been substantially destroyed and no tests to verify any pre-existing defect with these units could be carried out. The forward end of the crankshaft had broken during the impact sequence allowing the right propeller and starter gear to separate from the engine. The engine cylinder heads were removed and no abnormalities were observed in the cylinder bores, pistons, connecting rods or crankshaft. The crankshaft could not be rotated by hand due to fire damage to the forward crankshaft oil seal and the accessory gear train which had not been removed.

The engine oil cooler and the remaining pipes were examined; the cooler matrix was intact and no blockages or obstructions were found within it. No pre-crash defects could be identified in the remains of the oil feed and return pipes.

Left engine

As with the right engine, the post crash fire had severely damaged the engine's dual magneto and carburettor which prevented meaningful examination or testing. It was possible to confirm that the common drive shaft of the dual magneto was intact, making a failure of both magnetos themselves unlikely. The carburettor venturi was unobstructed and the throttle valve was in place, and had probably been functional at impact. Fuel supply to the carburettor is from two supply pipes, one for the engine driven mechanical pump and one for the electric pump, and both of these supply pipes were connected, although the pipes themselves were burned. The float chamber into which they fed was holed and burned, precluding any meaningful examination. The engine driven fuel pump was also burned, however the mechanical drive to the diaphragm was intact.

A significant quantity of oil was drained from the engine prior to disassembly; this oil showed little sign of thermal distress. The oil filter was disassembled and although the paper element had charred in the fire, there was no evidence of metallic debris or other particles within the element. The engine oil pump could not be turned by hand, further disassembly of the pump showed that one of the gear elements was partially seized in its bearing. The input drive spline and gear elements showed no evidence that the pump had failed in operation. It was concluded that the condition of the pump was as a result of the impact sequence and subsequent fire. Removal of the valve gear covers showed all of the valves, rockers and push rods to be in place and undamaged. Examination of the cylinder heads and pistons revealed no abnormalities, all piston rings were in place and complete. After removal of the pistons the connecting rods and crankshaft were visually examined, no significant defects were observed and the crankshaft was found to be free to rotate with no perceivable binding or roughness.

The engine oil cooler and the remaining pipes were examined; however the cooler matrix was found to have been breached as a result of the post crash fire. No pre-crash defects could be identified in the remains of the oil feed and return pipes

Propellers

The Hartzell HC-M2YR-2CEUF propeller fitted to the Beechcraft Duchess is a constant speed unit which uses a spring, supplemented by an air charge to move the propeller piston towards the propeller hub; this moves the propeller blades towards the feathered position in the absence of an opposing force. In normal operation the propeller governor provides a metered supply of pressurised oil through the engine crankshaft to the opposite side of the propeller piston to control the pitch of the propeller against the action of the spring and the air charge. The governor provides variable oil pressure to the propeller to maintain the pilot selected engine rpm by increasing or decreasing the propeller pitch as the airspeed of the aircraft changes. In the event of loss of oil pressure to the propeller during normal operation, either due to the pilot manually selecting FEATHER with the propeller control lever, or due to mechanical failure, the propeller blades will be driven to the feathered position by the action of the spring and air charge, ensuring that the propeller produces the minimum aerodynamic drag in the event of an engine failure. If the propeller were to feather during normal shutdown procedures, significant difficulties would arise during the subsequent engine start. In order to prevent this, the propeller is fitted with a pair of pitch locks which are held in the 'closed' position by a circumferential spring. At engine speeds greater than 800 rpm centripetal forces move the locks to the open position allowing the propeller to operate through its full range of movement and, in the event of a loss of propeller oil pressure, allowing the propeller to feather. At engine speeds below 800 rpm, as in ground operation, the propeller governor will position the propeller blades to the fine pitch position and the locks close. They then prevent a sleeve on the piston shaft from passing the lock and thus prevent the blades moving towards the feathered position when the oil pressure decreases on engine shutdown.

The right propeller

Examination of the right propeller showed it to be complete. The damage to the blades was indicative of some rotation at the point of initial impact. On removal of the spinner cap, the propeller air valve was found in place and the air charge still present. Examination of the propeller cylinder revealed one witness mark. The most likely cause of this witness mark was identified as the corresponding propeller counter weight. It is likely that during the impact with the ground, the blades were displaced, forcing the counterweight to contact the cylinder. The position of the witness mark clearly shows that at the time of impact the right propeller was in a fine pitch position. Given that the propeller was found at the crash site in the fully feathered position, and separated from the engine, at some time during the crash sequence the propeller was subject to sufficient force to drive the blades to the feathered position possibly despite the pitch locks being closed.

On disassembly of the feathering spring and piston, one of the pitch locks, together with both of its locating bolts was found in the base of the piston. The lock appeared to be undamaged; the two bolts had clearly been pulled from their locating holes. The threads of these bolts were heavily contaminated with the remains of the thread material from the locating holes. The piston sleeve which engages with the pitch locks was inspected, however no damage associated with the sleeve being forced through the locking mechanism could be identified.

No other abnormalities were observed during the disassembly of the remaining right hand propeller components.

The left propeller governor and propeller

On removal from the engine accessory housing the propeller governor input shaft could not be turned by hand. When disassembled, the internal components of the governor were found to have suffered from heat damage as a result of the post crash fire. They did not, however, exhibit indications associated with any existing pre crash defect. The input drive shaft and pump gears were complete with no damage to the gear elements or the drive spline. The gear elements were jammed by the remains of a plastic plug from the unfeathering port which appears to have melted as a result of the post crash fire. The unfeathering function of the governor was not used on this aircraft and the external union for this facility was securely wire locked in place. The oil inlet and outlet ports and internal cavities were free from obstructions.

The left propeller was complete with the exception of the spinner cap which was found under the left engine at the crash site, and the air valve located under the cap. The fasteners securing the spinner cap to the spinner remained in situ together with small sections of the spinner cap material confirming that the cap had become detached from the spinner during the crash sequence. Approximately four of the last threads in the locating hole for the air valve had been stripped. It is therefore likely that the propeller air valve was pulled from the propeller as a result of the impact sequence.

Examination of the propeller after removal of the spinner revealed no witness marks or damage. Prior to disassembly of the propeller, a pressurised air supply was connected to the oil inlet to function the propeller through its pitch range. When the air pressure was increased, the propeller blades moved smoothly through approximately half of their full range of movement before stopping, further application of pressure failed to move the blades towards the fine pitch stop. The air pressure was removed and the blades returned smoothly to the fully feathered position.

The propeller was then dismantled. The propeller cylinder was found to contain an appropriate quantity of apparently suitable oil, which was clean and bright in colour. The cylinder should be part filled with hydraulic oil to MIL-H-5606 specification. During removal of the feathering spring, the remains of one of the propeller pitch locks was found in the base of the propeller piston together with one of its retaining bolts. The remaining bolt had been partially pulled from its housing and had been distorted. The pitch lock was found in two pieces, having failed across an area of minimum wall thickness adjacent to one of the machined slots used to allow the lock to move under the influence of centrifugal forces in normal operation. (See Figure 2.)

Figure 2

The pitch lock was identified as being part number A-1590. This is an uncoated weight with an open design of slot. It is no longer available, having been replaced on an attrition basis with coated weights, part numbers B-317 and B-318 as appropriate for the propeller. These parts have a different slot design.

The presence of the broken pieces of pitch lock in the base of the cylinder, depending on its orientation, could have provided a mechanical restriction to the forward movement of the propeller piston preventing the propeller from moving to the fully fine position when the function test was carried out. This was the only plausible explanation for the observed restriction when the propeller was first tested.

Subsequent metallurgical examination of the fractured surface of the pitch lock showed it to be cracked by a fatigue mechanism which had then been finally fractured in overload. There was a distinct change in direction of the fracture at the final overload, which was over about 60% of the cross sectional area, indicative of a different loading mechanism. The fatigued portion of the surface was contaminated with corrosion deposits, including traces of sodium, chlorine and cadmium. The orientation of the fracture surface suggested that an element of torsion had occurred.

Metallurgical examination of the bolts which secured the pitch lock showed them to have corrosion deposits due to oxidation of the base material. They also showed evidence of impact underneath the heads, caused by the pitch lock weights. The impact features showed that both parts of the broken pitch lock weight were in position when the impact on the bolts occurred. There was fretting or wear damage to the cadmium plated steel disc on which these parts were assembled, and this was thought to be the source of the cadmium found on the fracture surface.

Examination of the piston sleeve, which normally engages with the pitch lock weights when the engine is shut down, showed 'shouldering' of the pitch lock contact face together with two pairs of parallel scores 180 degrees apart. These score marks were the consequence of at least one heavy engagement with the pitch locks. Comparison of the scoring with the pitch locks shows that this was likely to have been the result of the sleeve being forced through the pitch locks prior to them becoming fully open. The symmetry of the score marks also suggests that the lock weight was unbroken at this time. In normal operations the pitch locks close when the engine speed approaches idle; at these speeds the propeller governor has already driven the propeller to the fine position, placing the piston sleeve beyond the locks prior to their closure. When the engine is shut down, the reducing oil pressure allows the feathering spring to move the piston sleeve until it makes contact with the closed locks. In this situation contact is made between the end of the piston sleeve and the side face of the pitch locks and no opportunity for scoring or shouldering of the sleeve should exist.

The propeller log book confirmed that it had been overhauled in March 2001 by a CAA approved organisation. A review of the complete work pack for the propeller revealed that the pitch locks had been inspected for cracks using a Magnetic Particle Inspection technique and were found to be free of defects. A visual inspection only is required. After inspection the locks were reinstalled in the propeller. No other defects with the propeller components were identified during the overhaul process.

Most propeller overhaul shops seem to have very few problems with these pitch locks; however, there was some anecdotal evidence that the earlier design, as fitted to this aircraft, could jam and this would occasionally result in repairs in the field. In such cases the propeller would go into feather on shutdown, and sometimes, when the propeller was investigated, one of the pitch locks was found broken and sometimes also one of the retaining bolts would have pulled out of the assembly by stripping the internal aluminium thread. Marks were often found under the heads of the bolts. Fitting the later design of pitch lock was an effective cure.

Witnesses

There were a number of witnesses in the vicinity of the aircraft who either heard or saw parts of the accident flight. They variously described a normal take off, with a drift to the left followed by a distinct turn to the left with bank angles from 10º to 20º. Some people saw puffs of black smoke coming from one or both engines and one witness described a thin stream of white smoke or vapour from the left engine. Estimates of the maximum height attained varied from 80 to 200 ft. The propellers were generally described as turning although some persons observed them turning at different speeds from each other. One witness, a pilot with extensive twin engine experience, particularly noted that after lift off the right propeller appeared to be turning more slowly than the left which struck him as odd because the aircraft then began to roll to the left. Witnesses who could hear the aircraft heard the sound of an engine running down, and one witness further along the flight path described an engine as faltering, briefly recovering and then going quiet. Two witnesses who observed the final part of the flight reported that the left propeller was not turning and the described the aircraft as 'gliding'.

Analysis

The pilot's recollections were limited and separate events have probably overlapped. No evidence of aircraft flight control failure was identified during the examination of the aircraft. Due to damage caused by the post crash fire no investigation could be carried out which could verify the correct functioning of either engine ignition systems or carburettors. The position of the engine and propeller controls relative to each other suggests that both the left and right engines had been selected to similar settings prior to impact. No mechanical abnormalities associated with a significant loss power were identified in either the left or right engine during the strip and investigation. There was evidence from the accident site examination that the left propeller was not turning under power at the time of impact with the trees whereas other evidence indicates that the right propeller was turning. Without more definite evidence the behaviour of the aircraft may help to provide an indication of the nature of the problem.

The pilot was very familiar with the aircraft so it is likely that he would have noticed anything unusual prior to departure. It is not known precisely from where along the runway his take-off run started, so an estimation of whether the aircraft achieved its expected performance during takeoff was not possible. Several witnesses heard a change in engine note soon after takeoff, earlier than would be expected for a normal reduction to climb power. The aircraft was then seen to turn to the left from a low level, despite the fact that the pilot had acknowledged a clearance to climb ahead to 1,500 ft. A loss of power from the left engine, which was not corrected for with an early application of right rudder, would result in a yaw and roll to the left; this seems to be the most plausible explanation for this manoeuvre.

With a loss of power at an early stage after takeoff there are several options which may be open to the pilot, one of which is to close both throttles and to accept a landing ahead. This option is only available for as long as directional control is maintained; also, if the landing gear has already been retracted it may result in a wheels up landing. Another option is to control the aircraft, establish a climb, fly a circuit and return to land. This requires prompt action by the pilot to ensure that sufficient airspeed is maintained, which will allow directional control to be achieved, and that the propeller is feathered and any additional drag is reduced. If these conditions cannot be met it is unlikely that the aircraft will be able to climb.

When interviewed four months after the accident the pilot could not recollect whether he had carried out any actions to secure the engine. The relative position of the cowl flap and carburettor heat controls for the engines indicates that the left engine cowl flap was in a closed position and that carburettor heat was selected towards the ON position. The position of the left engine fuel lever, its associated witness mark and the fuel selector valve position showed that the left engine was drawing fuel from the right fuel tank at the time of impact. The variation in the position of these controls when compared to the right engine might indicate that the pilot may have been attempting to troubleshoot a problem associated with the left engine.

On this occasion if there was a loss of power before sufficient speed or height was attained then continued flight may not have been possible, closing the throttles and landing ahead may have been the only option. However the aircraft deviated from the runway track soon after the problem developed thereby effectively removing this option; furthermore the landing gear had already been retracted. The pilot's next possible option was to keep the aircraft flying or, if he could not, to attempt a forced landing off the airfield. The witnesses reported that the aircraft did not achieve a climb and there is some evidence that during the turn power from the right engine may also have reduced; this may have been for a technical reason or as a result of action by the pilot, either intentional or inadvertent.

After turning past the control tower there was an open area of ground ahead of the aircraft and it is possible that the pilot, unable to achieve a climb, decided to attempt a forced landing. This accords with his recollection that he realised that he was going to crash and aimed for a field. However, before the open ground there was a line of tall trees, which the aircraft failed to clear. The damage to the tree tops indicates that the wings were approximately level at the time the aircraft went through them; however, after hitting the trees there was no longer a possibility of a controlled landing.

The aircraft crashed into a grass field, right wing slightly low and travelled forwards through some iron railings into a strong steel mesh fence. The collision with these structures was the reason that the aircraft was so badly disrupted. The post impact fire was severe and although the pilot was able to escape he suffered serious burns. The AFS arrived at the scene as quickly as was possible but could not have been in time to help the pilot out of the aircraft had he required assistance.

The ground marks indicate that the right propeller was rotating on impact, and that the right engine and propeller hit the ground early in the crash sequence with sufficient force to break the right engine crankshaft and release the right propeller. Witness marks on the right propeller indicate that the blades were in a fine pitch setting at the time of impact. At some point in the crash sequence the propeller blades were driven towards the feathered position, overloading two of the pitch lock bolts and allowing one of the lock sections to be released and the propeller to move into the fully feathered position.

Based on the witness marks and control positions, it is likely that the left propeller was not selected to FEATHER by the pilot prior to impact. At some point in the crash sequence the propeller blades were driven towards the feathered position.

The shouldering and scoring present on the left propeller piston sleeve indicates that the pitch lock mechanism within the left propeller did not experience the same impact conditions as that of the right propeller. The existence of fatigue and the repetitive nature of the shouldering indicate that a problem existed before takeoff on the accident flight, although it is clear from the impact marks on the bolts that the final fracture of the lock was a result of ground impact.

It is possible that because of the corrosion found on the bolts, or for some other reason, the pitch locks had not opened and closed freely, resulting in contact with the sleeve and loads in the lock which may have generated the fatigue. During the ground impact the sleeve made heavy contact with the cracked but intact lock, causing the final overload failure. From the nature of the fatigue fracture of the pitch lock weight it appears this part had been subjected to an unusual, repetitive, and moderately high stress loading. This would be consistent with the lock not sliding properly due to contamination with the corrosion deposits found on the retaining bolts. The reason for the corrosion was not identified, however light corrosion of these bolts is reportedly sometimes found when propellers are overhauled. It is possible that the hydraulic oil absorbed moisture - the MIL-H-5606 oil specified is known to do this, and it is also possible that traces of salt (brine) were introduced when the propeller was charged with air or nitrogen. This would explain the traces of sodium and chlorine found on the fracture face.

Because the design of the lock, part A-1590 appears to be more susceptible to jamming than its later replacements, and because its design is more susceptible to cracking, the following safety recommendation is made:

Safety Recommendation 2005-138

It is recommended that the FAA, in collaboration with Hartzell, ensure that all Hartzell propellers in service that are fitted with part A-1590 pitch locks should have these replaced by part B-317 or B-318 pitch locks, as appropriate, at the next overhaul.

Conclusion

The engine indications observed before the accident flight have not been explained. However, the pilot has reported that the instruments were unreliable and difficult to maintain, although he had made efforts to correct these deficiencies. It is therefore possible that the anomalies reported by the engineer who fitted the replacement vernotherm were 'normal' erroneous indications and that the pilot had been concerned about an increase in the left engine's oil temperature, which was at least improved by the fitting of the replacement part.

It is possible to conclude that there was a defect within the left propeller, prior to the takeoff on the accident flight. However the evidence is conclusive that this had no effect upon the flight. No other defect with the aircraft was found. It must be noted that some possible defects would be very difficult to identify after the post crash fire, and in particular the carburation and ignition systems could not be verified. It is therefore not possible, on the basis of the available technical evidence, to account for a power loss.

The pilot's recollections were also insufficient to provide an explanation for the accident. The loss of directional control was most likely to have been caused by a loss of power and although the pilot was able to regain some control, he could not apparently get the aircraft to achieve a climb. It is possible that the nature of the failure made continued flight impossible and occurring as it did, at the most critical time during takeoff, the pilot was then in a very difficult situation.

ACCIDENT

Aircraft Type and Registration:	Cessna 150M, G-BOVS
No & Type of Engines:	1 Continental O-200-A piston engine
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	6 August 2005 at 1125 hrs
Location:	Near Rumney, north east of Cardiff, S Glamorgan, Wales
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nosewheel, engine cowling.and left wing: insurance total loss
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	473 hours (of which 69 were on type) Last 90 days - 214 hours Last 28 days - 81 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

At the conclusion of a trial lesson, the instructor was returning to Cardiff Airport at 1,400 ft on the published Cardiff Docks arrival when the engine started to vibrate. The vibration was slight to begin with but became rapidly worse and, after checking carburettor heat and magnetos, the pilot transmitted a PAN call to Cardiff Radar, turning the aircraft away from the bay area towards fields to the north-east of Cardiff as he expected to make a precautionary landing.

The vibration became severe, accompanied by a loud mechanical banging sound and the airspeed was decreasing, so the pilot reduced engine rpm and sought the nearest suitable field, transmitting a MAYDAY call before concentrating on the landing. The aircraft was landed in a grass field and touchdown was made at minimum airspeed with 40º flap selected. The grass was wet and, despite application of the wheel brakes, the aircraft over-ran the field boundary, passing through brambles and a wire fence. The left wing struck a fence post, turning the aircraft through 90º before it came to rest on a minor road with the nose landing gear collapsed. The instructor and student vacated the aircraft normally and without injury.

Subsequent engineering examination of the aircraft found that the No 2 engine cylinder had a large circumferential crack around the base of the fins (see Figure 1). The

AAIB has not performed a metallurgical examination of this failure but, from discussions with the maintenance organisation, it was almost certainly due to metal fatigue originating in corrosion pitting on the outer surface of the cylinder at the base of the fins. This is a known problem with parts which have a long calendar history and/or very low utilisation. Interrogation of the CAA's Mandatory Occurrence Report database showed that they had been notified of 18 cases of cracking and/or separation of cylinders over the last ten years, occurring to several different makes and models of engine but all sharing similar construction and layout. The date of original manufacture of the subject cylinder is not known, but it was recorded as being fitted to this engine in August 1996 and had run 1,570 hours since that time. The standard of the cylinder itself suggested that it was of a considerably earlier manufacturing date.

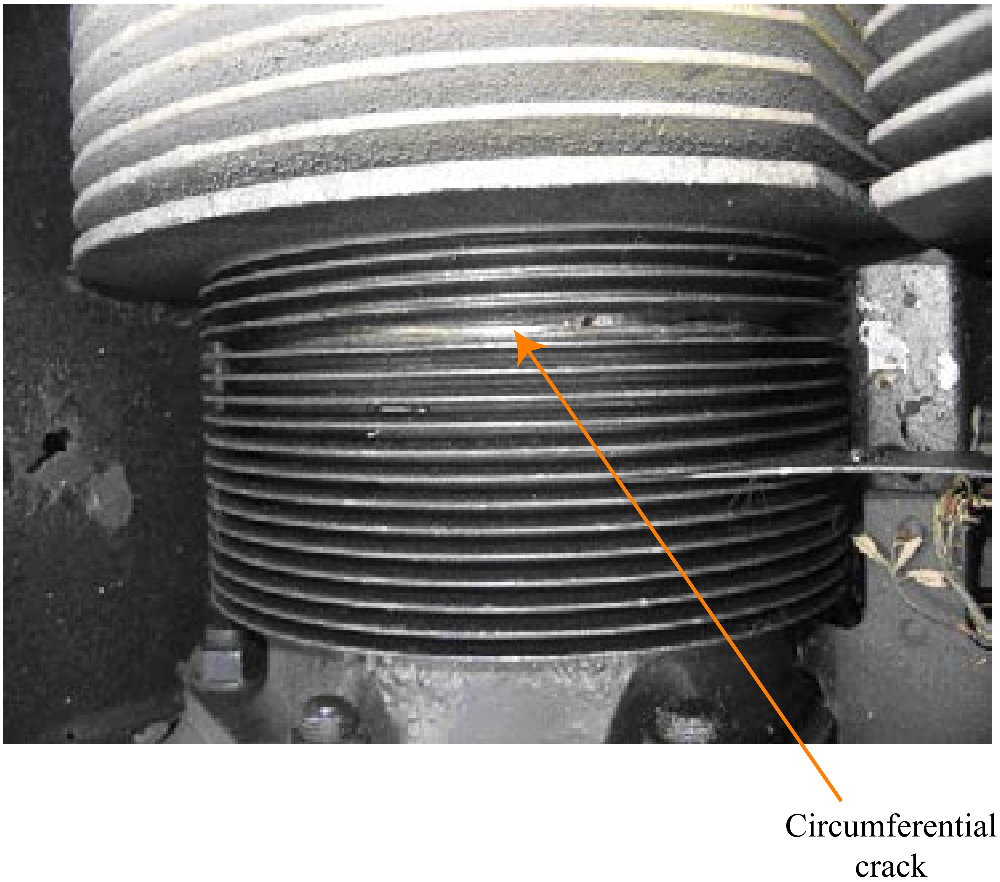


Figure 1

Circumferential failure in cooling fin root

ACCIDENT

Aircraft Type and Registration:	Cessna 182E, G-KWAX
No & Type of Engines:	1 Continental Motors Corp O-470-R piston engine
Category:	1.3
Year of Manufacture:	1962
Date & Time (UTC):	31 October 2005 at 1452 hrs
Location:	Derby Airfield, Derbyshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose leg, propeller, cowling damaged. Engine shock loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	271 hours (of which 43 were on type) Last 90 days - 16 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was returning to the airfield following a short local VFR flight. A normal approach was made to Runway 23 but, during the flare, the pilot became dazzled by the low sun and made a heavy landing which caused the nose landing gear to fail. The aircraft came to rest after sliding a short distance on its lower forward fuselage and both the pilot and passenger evacuated unaided and uninjured.

ACCIDENT

Aircraft Type and Registration:	DG-800B, G-MSIX
No & Type of Engines:	1 Solo Kleinmotoren GmBH 2-625-01 piston engine
Category:	1.3
Year of Manufacture:	1999
Date & Time (UTC):	23 June 2005 at 1530 hrs
Location:	Near to West Trading Estate, south of Gloucester, Gloucestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear collapsed and lower fuselage damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	74 years
Commander's Flying Experience:	2,506 hours (of which 202 were on type) Last 90 days - 36 hours Last 28 days - 22 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsquent enquiries by the AAIB

History of the flight

The pilot reported that he was flying in a gliding competition, on what he described as a "very hot" day. He took off from the launch site under the glider's own engine power and, at the end of the self-launch, noted that the engine coolant temperature (displayed digitally in the cockpit) was high. The soaring conditions became difficult, and the pilot decided to end the task. At about 1,200 ft above ground level, the pilot raised the propeller mast and started the engine, with the intention of flying back to the airfield under power. The engine started without difficulty, and achieved full power, but after climbing about 600 ft, the engine high temperature warning began to flash, indicating that the temperature of the coolant had reached 95ºC. The pilot shut the engine down, and established a circuit around a "good looking" hay field.

The pilot was unable to centre the propeller, and thus could not lower the mast fully. Instead, he lowered the mast about half way. Using 8º of positive flap and an approach speed of 60 kt, he flew the approach to the field. After a fully held off landing with a small amount of airbrake, the glider touched down. Soon after touchdown, there was a "high impact" and the landing gear collapsed. The aircraft ground-looped and came to rest erect, and the pilot vacated the aircraft without difficulty.

After the accident, the pilot noted that there were severe ruts throughout the field, and the landing gear had collapsed where the aircraft ran over one rut. He found that the engine had seized, and concluded that this had been caused by loss of coolant, although the coolant level had been normal when last inspected, two days prior to the accident flight. Inspection of the engine after the accident identified that there was significantly more than normal white staining around the radiator filler, consistent with a coolant loss in flight. A maintenance engineer, familiar with the engine, offered the opinion that the position of the radiator within the mast made positioning the cap onto the filler somewhat awkward, and that it was possible to replace the cap incorrectly, allowing coolant to escape under pressure.

Figure 1

Installation of radiator on mast

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-ADGT
No & Type of Engines:	1 De Havilland Gipsy Major 1F piston engine
Category:	1.3
Year of Manufacture:	1935
Date & Time (UTC):	14 September 2005 at 1120 hrs
Location:	Oxford Airfield, Oxfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Partially collapsed undercarriage and damage to propeller
Commander's Licence:	Air Transport Pilot's License
Commander's Age:	66 years
Commander's Flying Experience:	20,050 hours (of which 500 were on type) Last 90 days - 116 hours Last 28 days - 49 hours
Information Source:	AAIB enquires and Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after taking off the engine suffered a reduction in power, as a result of a sticking exhaust valve, that required the pilot to undertake a forced landing within the airfield perimeter. The aircraft landed heavily, which resulted in the collapse of the left main landing gear and the propeller blades striking the ground.

History of the flight

On the day of the accident the wind was reported as 230º/10 to 15 kt and the pilot, who was a flying instructor, planned to carry out a series of flights, with a student, covering Exercises 1 to 6 and 9 of the JAR-PPL syllabus. Following two uneventful flights of 30 minutes duration each, the pilot then experienced difficulty in starting the hot engine for the third detail of the day. In accordance with the operators normal procedure, the magnetos were switched off and the engine was turned backwards through 12 revolutions in order to purge the cylinders through the exhaust ports. The engine started and power checks were carried out prior to the aircraft taxing to the threshold of Runway 27, where it held for a short period whilst awaiting clearance to take off. The engine performance and aircraft's initial acceleration were normal and once airborne the engine speed was reduced from 2,150 rpm to 2,050 rpm for a 'standard' climb. At a height of about 150 ft, the engine speed decreased by about 450 rpm and it started to run roughly; the engine did not respond to the throttle being moved to the full power position.

With a rough running engine and insufficient power to climb the pilot was left with the option of either landing ahead or turning approximately 90º to the left to land in the airfield helicopter landing area. The first option entailed negotiating a hedge, a dual carriageway and a footpath, whereas the second option required the aircraft to turn sufficiently to the left to miss some houses and aerials sited on the airfield. The pilot selected the second option and successfully remained clear of the obstacles, before touching down heavily on the left wheel with the aircraft banked to the left. The aircraft was then seen to bounce several times before the left Main Landing Gear (MLG) collapsed, causing the propeller to strike the ground. The aircraft ground looped 180º to the left before it came to rest in the helicopter landing area.

Damage to aircraft

The left MLG lower casting and locating bolt had failed during the landing, which allowed the left wing to drop and the propeller blades to strike the ground. The outer portion of both wooden blades broke off approximately four inches in from the blade tips. The repair organisation, who recovered the aircraft, considered that the casting and locating bolt had failed due to a high side load imparted into the left MLG as it made contact with the relatively soft turf.

Engine description

The DH Gipsy Major engine is an air cooled in-line inverted four cylinder carburetted piston engine. The original Gipsy Major 1 series engines were equipped with aluminium bronze[1] alloy cast cylinder heads and had a compression ratio of 5.25:1. Later models were equipped with bronze cylinder heads, with a higher compression ratio of 6:1 and were fitted with 'Stellite' valve seats to resist corrosion resulting from operating on leaded fuels. Later Marks of the Gipsy Major were fitted with aluminium cylinder heads and had a compression ratio of 5.25:1 for operating on unleaded fuels and a compression ration of 6:1 for use on the higher octane leaded fuels.

Engineering investigation

On the first engine ground run, undertaken by the company maintenance organisation following the accident, the engine started normally and the power checks were found to be satisfactory with no excessive magneto drop. However, when the engine was hand swung during the next engine start it was evident that there was no compression in one of the cylinders. It was suspected that a valve had stuck open and, therefore, the cylinder heads were removed and sent to a specialist overhaul facility who established that a heavy build up of carbonised deposits had caused the No 2 and No 3 exhaust valves to stick in the valve guides. It has been suggested that the sticking valves was probably a result of operating engines, fitted with bronze cylinder heads, on Avgas 100LL.

Research

In the past, there were many different grades of aviation fuel in general use ranging from 80/87 octane to 115/145 octane, and it is widely assumed that the Gipsy engine series were initially designed to run on an 80/87 octane fuel. However, whilst 80/87 grade appeared to have been used for much of its service life, the Gipsy Major 1

Footnote

[1] Bronze: Alloys of copper and tin and/or aluminium.

series handbook states that when the engine first entered service it was designed to run on '*good grade automobile fuel'*, or non-leaded grade 73 fuel. With decreasing demand, the different grades were rationalised down to one, 100/130, which was a leaded fuel designated as Avgas 100; however, an additional grade was subsequently introduced for engines that were designed for operating on fuels with a lower lead content. This grade was designated Avgas 100LL, where LL stands for low lead. Avgas 100 is only available in a few locations around the world and, for practical purposes, is now considered to be obsolete.

It is known that since, at least, the early 1950s grade 80/87 and 100LL have had the same calorific value and nominally burn at the same temperature. Both fuels now contain Tetra Ethyl Lead (TEL), which is used to increase the performance of the fuel, particularly when operating in high compression or turbo/supercharged engines. The difference between these fuels is that grade 80/87 has a lead content of 0.14 g Pb/l, which corresponds to a mix of 0.6 ml TEL/Imperial gallon, whereas 100LL has a lead content of 0.56 g Pb/l, or 2.4 ml TEL/Imperial gallon. This lead content is within the maximum limit of 4 ml TEL/Imperial gallon specified in the Gipsy Major engine operating handbook. However, engine oils have a limited capacity to dissolve lead and its by-products and there is a risk that, once the oil is 'lead saturated', solid deposits form which can, for example, obstruct oil-ways. Also, TEL degrades within the combustion process to form lead oxide, and this can remain as a solid at temperatures up to 1,000ºC. In order to prevent the formation of such solid material, ethylene dibromide is added to the fuel which reacts with lead oxide to form lead bromide. This is a gas at 200ºC to 250ºC. However, the chemical process to convert lead oxide to lead bromide requires a reasonably high combustion temperature which, if not achieved, will allow lead oxide to form on spark plugs and valve guides, a condition commonly referred to as 'lead fouling'. This fouling can occur in engines that have been subjected to long, low power descents, or have taxied for some distance and where, consequently, the cylinder temperatures are relatively low.

Originally Gipsy Major engines were fitted with cylinder heads made from an aluminium bronze alloy[1]; however later Marks were fitted with aluminium alloy cylinder heads. One disadvantage of the bronze head is that lead reacts with the copper in the alloy, and may cause considerable corrosion, particularly around the exhaust port. This reaction will occur with 80/87 and 100LL grade fuels, which both contain TEL. Whilst this reaction will ultimately result in a loss of performance, it will not normally cause valves to stick in their guides. Another disadvantage is that, in comparison with the aluminium alloy cylinder heads, bronze heads conduct heat less well; indeed for a number of flight conditions, the Cylinder Head Temperate (CHT) operational limits quoted in the Gipsy Major (1 series) handbook, are 40ºC higher for the bronze head in comparison with the aluminium alloy head. Incorrect setting of the carburettor, leaks in the induction system and deterioration of the engine cooling baffles could all cause the engine to run excessively hot, with the risk of carbonising oil on the valve stems. The maintenance manual for the engine states that the inlet and exhaust valve stem to guide clearance should be between '*0.003 and 0.004¾*' inch; however the experience of an engine overhaul organisation is that exhaust valve guides that have been reamed out to give a minimum of 0.0045 inch clearance between the guide and valve stem are less likely to stick than those with lower clearances. The engine fitted to the accident aircraft had operated for approximately 154 hours since being overhauled, when the valve stem to guide clearance was measured at '*0.004 $^{3}/_{10}$'* inch.

Whilst the cylinder heads on the Gipsy Major engine have a stud to which a cylinder head temperature transducer could be attached, very few aircraft, including G-ADGT, have this modification fitted and therefore a pilot has no way of determining whether the engine is running hot or cold. Instead, an assessment of cylinder compressions during the starting sequence, and subtle changes in engine performance, are generally used to give some warning of an emerging problem.

Discussion

At 150 ft, with a rough running engine and insufficient power to climb, the pilot's options were somewhat limited and the decision to attempt a landing in the helicopter landing area with an 8/13 kt cross wind was probably the best option available. It is likely that it was the combination of the drift from the crosswind and a touchdown made on the left wheel that resulted in the left MLG lower casting and locating bolt failing when the wheel touched the ground.

The Gipsy Major engine was not designed to be run on modern fuels and, in comparison to modern aircraft engines, requires more careful handling. Consequently, if an engine is not maintained or handled appropriately, then the cylinder heads could either reach temperatures sufficient to cause the oil on the exhaust valve stems to carbonise, or run at temperatures low enough to precipitate 'lead fouling', thereby increasing the risk, in both cases, of a reduction in the clearance between the valve stem and guide with the possibility of the valves sticking. Operation of the engine with the cylinder head temperatures in an appropriate range, correct setting of the carburettor, regular oil changes, ensuring that the induction system and cooling baffles remain in a good condition and opening the exhaust valve guides out to give a minimum of 0.0045 inch valve stem-to-guide clearance, are all measures that may help to reduce the occurrence of sticking exhaust valves.

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-TIGA
No & Type of Engines:	1 De Havilland Gipsy Major I piston engine
Category:	1.3
Year of Manufacture:	1955
Date & Time (UTC):	17 August 2005 at 1610 hrs
Location:	Nottingham Airport, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Undercarriage strut and underside of starboard wing damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	72 years
Commander's Flying Experience:	5,224 hours (of which 1,650 were on type) Last 90 days - 8 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was practising visual circuits at Nottingham Airport. Runway 21 was in use, and the pilot was using the central grass portion of the airfield, which was bounded by two runways and a taxiway, for takeoff and landing. This area was specially prepared for use by aircraft such as the Tiger Moth, and the pilot had already completed one 'touch and go' landing on it during the accident flight. On the second approach, the aircraft landed normally but, as power was applied, the aircraft drifted to the right to the extent that it struck a runway marker board on the edge of the grass area. The aircraft structure limited forward visibility, consequently the pilot was initially looking to the left. As the tail was raised during the 'touch and go' he transferred his vision to the right, and it was only at this stage that he became aware of the proximity of the marker board shortly before it struck the lower right mainplane. The pilot immediately closed the throttle and landed on a grass area straight ahead, before taxiing back to the aircraft hangar and shutting down. The weather was good at the time, with a southerly surface wind which the pilot considered caused the aircraft to drift to the right.

ACCIDENT

Aircraft Type and Registration:	Grob G115, G-BOPT
No & Type of Engines:	1 Lycoming O-235-H2C piston engine
Category:	1.3
Year of Manufacture:	1988
Date & Time (UTC):	19 June 2005 at 11:10 hrs
Location:	Barton Airfield, Manchester
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Significant damage to landing gear and propeller
Commander's Licence:	Student pilot
Commander's Age:	35 years
Commander's Flying Experience:	59 hours (of which 53 were on type) Last 90 days - 15 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst flying solo circuits the student pilot encountered a rough running engine. He attempted to clear the problem without success and found himself high on the approach with no alternative area in which to land. The aircraft touched down at the end of the runway, coming to rest in rough ground with damage to the landing gear and propeller. The pilot was uninjured. No cause for the engine problem has been found although conditions were conducive to carburettor icing.

History of the flight

The student pilot had completed three circuits with his instructor at his home airfield before continuing on a solo circuit exercise, the instructor watching from the air traffic control tower. Runway 20 was in use, a grass runway 528 m long. The weather at the time was reasonable with a southerly wind of about 6 kt, visibility of 8 km in haze and no significant cloud. The temperature was 26ºC with a dew point of 20ºC.

Having disembarked his instructor the student taxied to the runway threshold. He could not recall whether he completed a pre-takeoff engine check at this point, but stated that the needle of the engine rpm gauge was oscillating more than normal whilst the engine was at low power with the aircraft stationary prior to lining up.

He had completed an engine check earlier during his flight with the instructor and no problems were apparent. In addition, although the gauge was oscillating, the engine noise remained constant and so the student did not believe there was a problem.

The student successfully completed two solo circuits and was downwind on his third circuit when the aircraft's engine began to run roughly. He completed his downwind checks, which included briefly selecting the carburettor heat to hot. The student did not attribute the rough running to carburettor icing and so he returned the carburettor heat control to cold. Indeed he stated that whilst the carburettor heat was selected to hot, the engine continued to run roughly, but when he returned it to cold the engine seemed to run more smoothly.

On turning onto base leg the engine's rough running became worse. The student stated that despite this, the engine temperatures and pressures were indicating normal. He re-selected carburettor heat to hot before reducing the throttle to idle in order to commence his base leg descent. At this point the rough running became considerably worse and the student tried selecting different power settings in order to try and rectify the situation. This was to no avail and, anticipating an engine failure, the student set the throttle to idle and raised the aircraft's nose to preserve altitude. He left the flaps up until he could be certain of making the airfield.

The student turned onto finals and again tried selecting power, but the rough running continued. Once confident of being able to complete a glide approach to the runway, the student reported on finals to ATC and glanced down at his airspeed indicator, which was indicating a speed well above his required approach speed. In response, the student instinctively pitched the aircraft up in an attempt to slow down, however he then realised he had become too high on the approach and was likely to overshoot the runway. He considered, however, that he had no option other than to continue, due to the problem with the engine. He selected full flap and at 300 ft height he instinctively set the carb heat to cold. Aware of his excess height on crossing the threshold, the student looked for somewhere else to land, but in the absence of anywhere better decided to continue his attempt to land on the runway. The instructor had been watching the approach from the Tower and realising the student was too high, uttered the phrase "go round", as if willing him to do so. The controller overheard the instructor's comment and told the student pilot to go around. The student tried to apply power but once again the engine response was poor and so he returned the throttle to idle.

The aircraft finally landed at the far end of the runway, bounced and landed again beyond the end of the runway on some rough ground. The pilot braked hard and the aircraft came to rest on sloping ground just short of the airfield perimeter. The student was unhurt and had no difficulty vacating the aircraft. The airfield emergency services were on the scene in just over two minutes.

Analysis

At the time of writing this report no fault has been found with the engine. The temperature and dew point recorded would have put the aircraft at risk from carburettor icing (Figure 1). The student had been flying circuits and had been using carburettor heat for only a limited period during each circuit. Thus there had potentially been sufficient time for ice to form when the carburettor heat was set to cold and insufficient time for it to clear when the carburettor heat was set to hot.

The flying school's chief instructor commented that whilst he accepts conditions were conducive to carburettor icing, another aircraft of the same type belonging to the club was airborne at the same time and reported no such icing problems. The student's description of the rough running becoming worse on the selection of carb heat to hot may, however, be an indication of the presence of induction system ice. This rough running condition only clears when the carb heat is set to hot for sufficient time to melt any ice present. Consequently, a false assumption may be made that carburettor heat is making matters worse and so the control is returned to cold when it should be kept at hot. However it is accepted that the rough running could have been induced by some other unidentified cause.

Irrespective of the reason for the rough running, the pilot became distracted in trying to resolve the problem. This, together with his determination to be high enough to glide to the airfield should the engine fail completely, led to the aircraft becoming high and fast on the approach. This matter was made worse by the late selection of flap and by various attempts to apply power when the aircraft was already too high or too fast.

The choice of alternative landing sites was limited by the presence of a dual carriageway beyond the end of the runway and by various buildings and tall hedges on either side. Unable to clear the problem in order to go around and without the option of another suitable landing site, the pilot was committed to landing on the airfield. He was fortunate that despite touching down at the far end of the runway, the aircraft stopped short of the road.

Whilst it is completely understandable that the student might wish to clear what appeared to him to be the principal problem, the rough running engine, this accident highlights the top priority of flying the aircraft with trouble shooting taking second place.

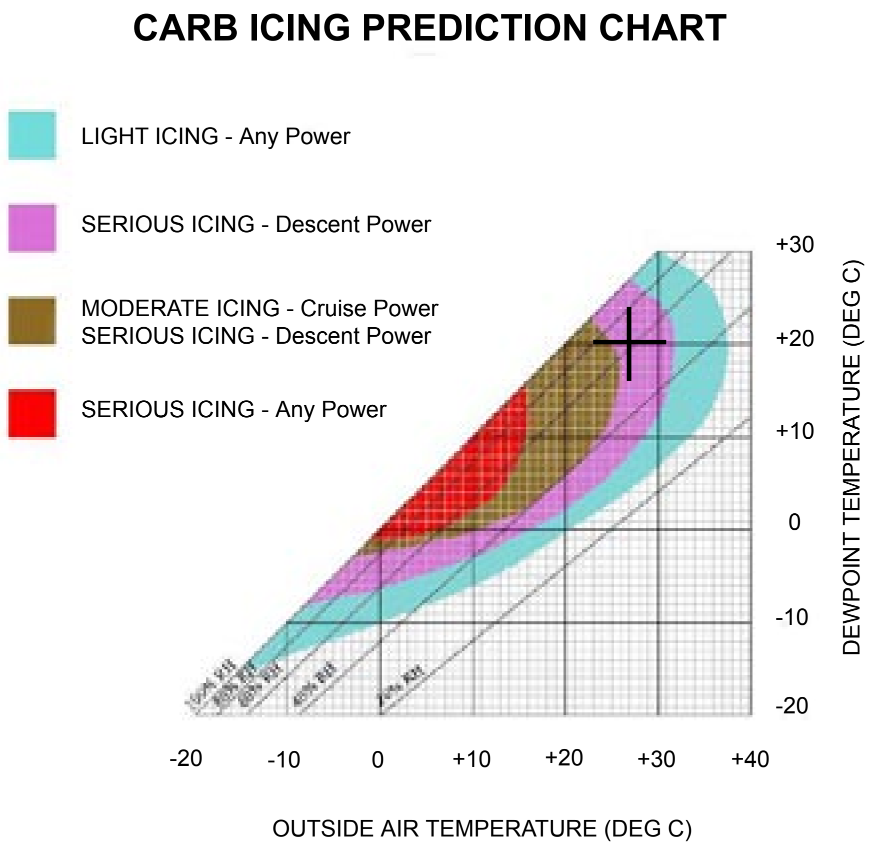


Figure 1

ACCIDENT

Aircraft Type and Registration:	Hoffmann H 36 Dimona, G-KOKL
No & Type of Engines:	1 Limbach L 2000-EB1C piston engine
Category:	1.3
Year of Manufacture:	1989
Date & Time (UTC):	29 October 2005 at 1255 hrs
Location:	Rufforth Airfield, North Yorkshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Left main landing gear collapsed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	251 hours (of which 4 were on type) Last 90 days - 48 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The Dimona is a two-seat motor glider constructed from glassfibre. It has a 52 ft wingspan and the landing gear is of the tailwheel type. The main landing gear legs are attached to the fuselage forward of the wing.

An instructor pilot was carrying out a training flight with another qualified club pilot to address crosswind takeoff techniques. The first takeoff was on Runway 24 with a surface wind of 160º/10 kt which created the required crosswind component. The student performed a satisfactory takeoff from Runway 24 which met the requirements. For the remainder of the flight, the instructor decided to carry out some further circuits using Runway 18 which was more into wind.

On the first approach to Runway 18 the student began to undershoot the runway whilst using the airbrakes. He closed the airbrakes and corrected the approach angle to that of a normal approach. As the aircraft neared the ground, the student re-opened the airbrakes fully and rapidly which caused what the instructor described as "a firm but not heavy landing". The student performed a touch and go followed by two further circuits.

On the final full stop landing, the student carried out a smooth and gentle touch down. As the aircraft slowed and the wheel brakes were applied positively, the aircraft "listed to port". The aircraft was stopped immediately. Having stopped the engine, the pilots vacated through the normal exit. The left main landing gear had collapsed rearwards.

Analysis

Apart from the initial firm touch down, the landings performed during the rest of the training session were normal. The instructor considered that given the smooth final landing, there must have been some previous damage to the left main landing gear and that it may have been inflicted during the takeoff that preceded the instructional flight when a swing developed during the ground roll. This damage had been exacerbated by the firm landing and heavy braking during the training, leading to its collapse under positive braking on the final landing.

The gliding centre concurred with this assessment but stated that the collapse may have been caused by cumulative stress on the landing gear over a longer period of time, perhaps due to repetitive over-enthusiastic application of the wheelbrakes.

ACCIDENT

Aircraft Type and Registration:	Luton LA4A Minor, G-ATKH
No & Type of Engines:	1 Lycoming O-145-A2 piston engine
Category:	1.3
Year of Manufacture:	1967
Date & Time (UTC):	24 September 2005 at 1630 hrs
Location:	Laddingford Airfield, Paddock Wood, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Broken wheel axle and subsequent damage to landing gear, propeller and cowling
Commander's Licence:	Private Pilot's Licence with IMC rating
Commander's Age:	60 years
Commander's Flying Experience:	1,589 hours (of which none were on type) Last 90 days - 36 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and a metallurgical examination of the wheel axle

Synopsis

The right stub axle failed in overload during a heavy landing made by a pilot who was making his first flight on type.

History of Flight

The pilot, who had over 900 hours experience on tailwheel aircraft, was making his first flight on the Luton Minor. On the day of the accident, he had made four short local flights in his Europa aircraft before being briefed by the owner of the Luton Minor. After flying uneventfully for some 20 minutes, he made an approach to Runway 11 at Laddingford. In a frank statement to the AAIB, the pilot reported that aircraft stalled about 10 ft above the runway and that in the resultant hard and short landing, the right wheel stub axle failed and the right wheel detached. The aircraft came to rest on the lower part of the engine cowling, with the propeller broken and both the right landing gear and its associated fuselage structure damaged.

The pilot was uninjured and he reported that the full RAF type harness fitted was very effective. Importantly, the pilot assessed the cause of the accident as insufficient recent experience of a high drag airframe with little inertia coupled with too much recent experience of the Europa aircraft with low drag airframe and very powerful all flying tailplane.

Aircraft examination

The right wheel stub axle had failed across its diameter just inboard of the inner face of the brake drum attachment plate. The stub axle was removed from the wheel and brake assembly and submitted to the AAIB for detailed examination. A photograph showing the stub axle is shown in Figure 1 (right).

Previous Stub Axle Failures

In February, 1994 a Luton Minor stub axle failed during a landing at RAF Halton. The subsequent AAIB investigation, including a detailed metallurgical examination (AAIB Bulletin No 5/94), found that that the stub axle had failed across the axle diameter just inboard of the inner face of the brake drum attachment plate, ie, in a similar location to the failure on G-ATKH. It was concluded that:

> *'the failure of the axle had resulted from the stress induced in the last landing, but that the static strength of the assembly, as manufactured, had been adversely affected by very poor quality welding'.*

The PFA noted that two failures had occurred in a similar region on Luton Minor stub axles and, as a result, issued a mandatory inspection; MOD/051/001 Inspection of Axle Welds for Cracks & Corrosion dated 2 March 2001. In this inspection it is noted that:

> *'The undercarriage design is considered adequate if well constructed, however if corrosion is present then cracks may soon appear leading to structural failure'.*

Figure 1

Examination of the Stub Axle

The right stub axle of G-ATKH was the subject of a dedicated metallurgical examination using visual and low magnification techniques. The view in Figure 2 (below) was taken from a view along the axle centre line in an outboard direction, with the landing load being in a direction vertically upwards as depicted.

Figure 2

The examination concluded that:

- Poor welding had resulted in tube wall thinning and some weld burn through
- A region of gas porosity existed; however, this was present on the upper part of the weld in a region subject to compressive loads in the landing gear and would not therefore have adversely affected the strength of the joint, as this would have been the last to separate
- Some corrosion pitting had occurred but, considering the direction of the load that had caused the separation, the resultant reduction in strength was considered minimal
- The separation had resulted from overload bending conditions
- There was no evidence of separation by a progressive mechanism such as fatigue or stress corrosion.

ACCIDENT

Aircraft Type and Registration:	Maule MXT-7-180, G-BZDT
No & Type of Engines:	1 Lycoming O-360-C1F piston engine
Category:	1.3
Year of Manufacture:	2000
Date & Time (UTC):	25 October 2005 at 1700 hrs
Location:	Portadown, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	480 hours (of which 290 were on type) Last 90 days - 60 hours Last 28 days - 45 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was being flown to a private grass strip near Portadown where it was occasionally kept. Due to recent rainfall and a strong south-westerly wind the pilot decided to inspect the landing strip by means of a low overflight, prior to landing. He configured the aircraft with two stages of flap, reduced speed and descended to approximately 100 ft agl over the threshold of the strip's south-easterly runway. On flying down the runway he observed surface water patches and, noting a 15 kt crosswind, decided to divert to Belfast International Airport where the aircraft was normally based. Just before he initiated the diversion, and whilst still at 100 ft agl, the aircraft encountered severe turbulence with downdraughts and lost height. Full power was applied and a positive pitch attitude was selected in an attempt to climb away. However, an uncommanded roll to the left led to a nose low attitude and the left wing and propeller struck the ground before control could be regained. The aircraft then cart wheeled onto its right wing before coming to rest against some trees. The pilot, who was wearing a lap and diagonal harness, was rendered unconscious for a short period before vacating the aircraft without assistance.

Evidence indicates that the aircraft flew into an area of turbulence when downwind of buildings and trees adjacent to the runway. In attempting to fly out of the downdraughts whilst at a low airspeed a rapid selection of a positive pitch attitude is likely to have caused the aircraft to stall. An associated wing drop would lead to the roll and subsequent nose low attitude described by the pilot. Such a stall would have been irrecoverable from 100 ft agl. The flaps in the wreckage were found to be in the raised position; any reduction in the flap setting during the attempt to climb away would also have increased the likelihood of an aerodynamic stall.

Figure 1

ACCIDENT

Aircraft Type and Registration:	Pierre Robin DR400/180, G-BSLA
No & Type of Engines:	1 Lycoming O-360-A3A piston engine
Category:	1.3
Year of Manufacture:	1990
Date & Time (UTC):	4 November 2005 at 1700 hrs
Location:	Rochester Airport, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller tip damage and engine possibly shock loaded
Commander's Licence:	Private Pilot's Licence (with night rating)
Commander's Age:	53 years
Commander's Flying Experience:	797 hours (of which 350 were on type) Last 90 days - 15 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

History of the flight

The pilot was intending to carry out some circuits after sunset. After carrying out his pre-flight checks he started the engine at 1655 hrs and taxied out to Runway 20R grass (sunset was at 1626 hrs). While approaching the departure end of the runway, the Aerodrome Flight Information Service Officer (AFISO) instructed him to carry out his power checks on the concrete area behind and to the north of the 20R threshold. He was asked to taxi to the left of the traffic cones which marked an area of damaged concrete. The pilot followed the instructions and carried out his power checks on the concrete surface. Then, as he taxied forward to the runway threshold the nose of the aircraft pitched down and the propeller struck the ground. The pilot heard the strike and saw stones fly up but the aircraft continued rolling forward and the propeller continued turning. He taxied the aircraft away from the threshold and shut down the engine. He saw the damage to the propeller blades and informed the AFISO that he would taxi back to the apron.

Examination of the concrete surface

After the incident the airport staff inspected the concrete area and found a depression with propeller strike marks. They placed three traffic cones over the area to warn pilots to stay clear. The pilot inspected the concrete area five days later and measured the depressed area.

He reported that it was approximately 3 m in diameter and was approximately 9 cm deep over most of its area. The area was cracked and had grass growing along the cracks. The propeller strike marks were at the edge of the depressed area.

Aircraft examination

Both propeller blades had damaged tips that had curled forward. The aircraft had not sustained any other visible damage although the engine may have been shock loaded. The pilot measured the propeller clearance at 17 cm, then he compressed the nose gear oleo which reduced the clearance to 10 cm. The pilot said he had heard of other incidents involving propeller strikes with this type of aircraft. He said that the aircraft type was originally designed for a lower powered engine with a smaller diameter propeller. However, the oleo was also found to be softer than normal and the aircraft owners had been having problems with the nose gear oleo for some time. At one point the oleo was too hard, which prevented the nose wheel from being steered. The oleo pressure had last been adjusted by the maintenance organisation on 10 October 2005. The cause of the soft oleo had not yet been investigated at the time of writing.

Discussion and conclusions

The propeller strike was caused by the nose gear dropping into the depressed area of concrete. The concrete surface appeared to be poorly maintained and the depression was unmarked at the time of the incident, which occurred after sunset. The soft oleo was probably a contributory factor to the incident and probably allowed the oleo to bottom out, further reducing the already small propeller tip-to-ground clearance. The airport manager was contacted by the AAIB and he said that he planned to have the depressed area of concrete filled.

Figure 1

Depressed area of concrete marked by three cones (post incident)

ACCIDENT

Aircraft Type and Registration:	Pierre Robin HR200/120B, G-BXDT
No & Type of Engines:	1 Lycoming O-235-L2A piston engine
Category:	1.3
Year of Manufacture:	1997
Date & Time (UTC):	15 November 2005 at 1216 hrs
Location:	Durham Tees Valley Airfield, Co. Durham
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear and propeller
Commander's Licence:	Student
Commander's Age:	44 years
Commander's Flying Experience:	71 hours (of which 70 were on type) Last 90 days - 9 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The student pilot was outbound to Durham Tees Valley Airfield from Leeds to complete his qualifying solo cross country flight. On approach to Runway 23 he noticed his approach speed was slightly high but decided to continue. The aircraft was observed to touch down initially on the nose landing gear before bouncing back into the air. The pilot applied a small amount of power; however the aircraft touched down again and continued to bounce several times along the runway before the pilot could regain control. During this process the propeller struck the ground. The pilot taxied the aircraft off the runway and exited the aircraft normally without injury.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-180 Cherokee, G-AWET
No & Type of Engines:	1 Lycoming O-360-A4A piston engine
Category:	1.3
Year of Manufacture:	1968
Date & Time (UTC):	10 October 2005 at 1030 hrs
Location:	Cromer (Northrepps) Airstrip, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Minor) Passengers - 2 (Serious)
Nature of Damage:	Serious damage - including propeller, engine, wings, landing gear, fuselage and tail
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	725 hours (of which 619 were on type) Last 90 days - 8 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

Having departed from another airfield 30 minutes beforehand, the aircraft joined the downwind leg of the left hand circuit for a landing on Runway 36. The pilot checked the windsock and considered that the light tail wind component would be offset by the runway's 1.8% uphill gradient. He reported that the final approach proceeded as normal but at a very late stage he realised that the aircraft would land too far along the runway. As the aircraft touched down the pilot retracted the flaps and applied full power in order to convert the landing into a 'touch and go'. The aircraft became airborne again but then appeared to sink. The pilot heard a loud bang and the aircraft came to rest in a field beyond the end of the runway. He made the aircraft safe and helped his passengers to exit through the cabin door. Both passengers were seriously injured and the pilot received minor injuries. The aircraft itself was severely damaged but there was no fire. All three emergency services attended the scene.

In a straightforward and candid report the pilot stated that the accident was a result of his misjudgement, together with a possible increase in the tailwind during the latter stages of the final approach to an airfield where he had landed about ten times before. He confirmed that the engine had produced full power during the touch and go but could not recall what speed the aircraft had achieved after it became airborne again, although he was not aware of hearing the stall warning. Nor could he remember how far along the runway the aircraft had touched down. The ground marks and wreckage trail indicated that in the process of the touch and go the aircraft had struck a low bank just beyond the threshold of Runway 18. It had then flown approximately 125 m across a field, struck another low bank which had removed all the landing gear, and, finally came to rest about 50 m into the second field beyond the runway.

Cromer (Northrepps) Airfield is unlicensed and has a single grass runway which is 493 m long. The pilot estimated the surface wind to be 135º/5 kt, which equated to a tail wind of 3.5 kt. The temperature was 13ºC, the QNH pressure setting was 1017 hPa and the grass was damp. For a reported landing weight of 968 kg, the aircraft flight manual gives a landing distance required (LDR) of 504 m. This figure includes all the relevant safety factors for field length, the tail wind and a dry, grass surface. No factor is given for a damp grass surface. Of note, the CAA's General Aviation Safety Sense Leaflet Number 7c, entitled *Aeroplane Performance*, advises that wet grass on a firm subsoil increases the LDR by 35%.

Many light aeroplanes are in performance group E and certificated with unfactored data, based on the performance achieved by the manufacturer using a new aeroplane and engine, or engines, flown by a highly experienced pilot in ideal conditions. It is strongly recommended in the General Aviation Safety Sense Leaflet Number 7c that the safety factors which must be applied to Public Transport flights are also used for private flights, to take account of:

- Lack of practice
- Incorrect speeds/techniques
- Aeroplane and engine wear and tear
- Less than favourable conditions

From the information given in the AFM, the factored LDR for the landing on Runway 36, downwind into the runway upslope, was 27 m greater than would have been required for a landing in the opposite direction, assuming the same wind conditions. Therefore, if the aircraft had made an approach to land on Runway 18 instead, the aircraft's ground speed would have been some seven knots slower during the final approach and the LDR would have been less than the length of the runway.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181 Cherokee Archer, G-LACD
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Category:	1.3
Year of Manufacture:	1998
Date & Time (UTC):	19 October 2005 at 0922 hrs
Location:	Barton Aerodrome, Manchester
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Port wing leading edge and wing tip damage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	431 hours (of which 99 were on type) Last 90 days - 81 hours Last 28 days - 46 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The aircraft was being flown on a training detail during which the student pilot was to practise glide approaches. Runway 09 Left was in use, with a reported surface wind from 170º at 7 kt. The runway had a grass surface and was 518 m in length. There had been recent rain and the instructor reported that the grass was wet. G-LACD was initially behind another aircraft in the circuit, but the pilot of the leading aircraft called that he would extend his downwind leg to enable the crew of G-LACD to fly their glide approach.

Whilst on finals for the glide approach, which was intended to be to a 'full stop' landing, the student pilot deployed full flap but commented to the effect that the aircraft was too high. The instructor suggested that the student used sideslip to increase the descent rate, a technique which the student had practised previously. Although the student did this, the aircraft was still higher than normal when it crossed the runway threshold, and appeared to personnel in the visual control room to be faster than was normal. The student pilot was allowed to continue with the landing and initiated a flare, but the aircraft had still not touched down by the time it was about half way down the runway. At this point, the instructor considered ordering the student pilot to 'go around' but thought that the aircraft may not be able to clear trees and buildings in the climb out path. His thoughts were influenced by the knowledge that this particular aircraft tended to experience a slight lag in engine response when selecting full power from idle, a situation he thought was caused by an over-rich mixture setting. The instructor therefore considered that the best course of action was to allow the student to continue the landing and then to brake hard.

After touchdown, both the instructor and his student commenced hard braking. It was apparent that the aircraft was heading for the hedge at the airfield boundary, so the instructor turned the aircraft to the right. As he did so, the instructor felt that the wheels had locked up. The aircraft struck the boundary hedge with the left wing, causing it to yaw to the left and come to rest with the aircraft nose in the hedge. The aircraft suffered damage to its left wing leading edge and tip, which occurred when it struck the hedge. The aerodrome fire service was immediately alerted and attended the scene. The two occupants were uninjured and able to vacate the aircraft normally.

Aircraft performance

Performance calculations based on the reported configuration, weight and zero headwind component show that the aircraft's actual ground roll on a paved, dry runway, with a 'full stall' touchdown and maximum braking would have been 256 m. A grass runway increases this distance by a factor of some 20%, and wet grass by a factor of 30% or, for short grass, by as much as 60%. Therefore the actual landing roll would have been between about 330 to 410 m, depending upon the grass length.

Discussion

The accident resulted from an un-stabilised approach which appears to have been outside of normal parameters and the lack of timely intervention by the instructor to initiate a go-around. The aircraft was evidently high from a relatively early stage of the approach. The aircraft ahead of G-LACD called that he would extend his down wind leg to enable the crew to fly their glide circuit. Understandably, the instructor would therefore have wished to be fairly expeditious in his approach in order not to further delay the aircraft giving way, and this may have contributed to the aircraft's excess height on finals. It is not clear why the instructor did not order the go-around at an earlier stage. He would have been expected to have a good appreciation of the aircraft's landing performance and the fact that the landing ground roll would be increased significantly by the wet grass. Additionally, there was clearly no headwind component, and possibly even a slight tailwind component. The runway grass would have been kept short, and so it is likely that the aircraft would have required the majority of the available length to stop, even if it had landed on the threshold in a 'full stall' condition.

The decision as to when to take control from a student, or to order an alternative course of action is not an easy one for an instructor. On many occasions, a student will gain the most value from being left to recognise and correct his own errors. However, as this accident shows, an instructor cannot afford to allow safety margins to be compromised for training value. Airmanship and airborne decision making are skills that the student pilot also needs to learn, and being allowed to continue with a poor approach to the extent that safety is compromised will do nothing to develop or enhance them.

ACCIDENT

Aircraft Type and Registration:	Pitts S-1C, G-BOZS
No & Type of Engines:	1 Lycoming O-320-A2B piston engine
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	2 September 2005 at 1440 hrs
Location:	Bellarena Airfield, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Right main gear leg collapsed, propeller damaged and engine shockloaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	1,024 hours (of which 250 were on type) Last 90 days - 21 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Following a local flight the pilot had returned to the airfield for a landing on Runway 31 (grass). The pilot estimated the wind to be approximately 5 to 6 kt from 040º. During the landing, as he initiated the flare, the aircraft ballooned and then descended rapidly resulting in a heavy touchdown. The suspension bungee attachment of the right main gear leg broke causing the right gear leg to collapse and the propeller to strike the ground. The aircraft rolled on its wheels for a further 23 m while veering to the right before coming to rest. The pilot was able to exit the aircraft unassisted.

The Pitts S-1C is an aerobatic bi-plane with a tailwheel landing gear configuration. The aircraft's configuration results in very poor over-the-nose visibility during the flare leading to pilots needing to rely on their view to the side of the aircraft to judge height before touchdown. The pilot stated that he probably misjudged his height during the flare because his perception of height was based on his view of a fence approximately 300 m to his left. Runway 31 sloped downwards and to the right in the direction of landing and the runway surface beneath the aircraft was lower than the base of this fence. The pilot stated that he felt he should have looked both left and right during the flare, better to judge his height above the ground.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BHNA
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	13 October 2005 at 1530 hrs
Location:	Breighton Airfield, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	80 hours (all on type) Last 90 days - 16 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had planned to depart on a local flight from Breighton Airfield. The weather conditions were good, with broken cloud at around 2,500 ft. The surface wind varied in direction between 360º and 040º at 7 to 8 kt. The pilot carried out his pre-departure checks and after checking the windsock lined up on Runway 11, a grass runway 852 m (2,795 ft) in length and 45 m (148 ft) width.

As the aircraft accelerated along the runway the pilot applied into wind aileron and right rudder to counter the crosswind. The aircraft started to lift off and as it did so it yawed to the left then touched down again; it was now heading towards the side of the runway. The pilot closed the throttle but before he could commence braking the aircraft left the side of the runway and went into a ploughed field. The nose pitched down and the aircraft flipped over coming to rest upside down. The pilot and passenger were not injured in the accident and were able to evacuate the aircraft unassisted. The pilot ascribed the accident to the effect of a crosswind gust just as the aircraft lifted off the ground.

ACCIDENT

Aircraft Type and Registration:	Scheibe SF28A, G-BARZ	
No & Type of Engines:	1 Limbach SL 1700-EAI piston engine	
Category:	1.3	
Year of Manufacture:	1973	
Date & Time (UTC):	4 July 2005 at 1010 hrs	
Location:	Taxiway Alpha, Lydd Airport, Kent	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Minor damage to right wing	
Commander's Licence:	Private Pilot's Licence (Motor Gliders)	
Commander's Age:	65 years	
Commander's Flying Experience:	800 hours (of which 450 were on type) Last 90 days - 19 hours Last 28 days - 12 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The aircraft, a 16 metre span low wing motor glider, was taxiing on Taxiway Alpha in preparation for taking off from Runway 21 at Lydd.

Located either side of the taxiway were two posts set in the ground amongst weeds approximately three feet high. The post on the left supported a sign, whilst the sign for the one on the right lay on the ground. As the aircraft passed by, the right wing contacted the post on the right, which punctured the plywood skin of the aircraft's outer wing.

The Fire Officer at Lydd, who was at the airport at the time of the incident, reported that the signs are being replaced and that taxiing procedures are under review.

ACCIDENT

Aircraft Type and Registration:	Socata TB 20 Trinidad GT, N565G
No & Type of Engines:	1 Lycoming IO540 piston engine
Category:	1.3
Year of Manufacture:	2002
Date & Time (UTC):	9 October 2005 at 1112 hrs
Location:	Caernarfon Airport, Gwynedd, Wales
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to tips of propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	1,085 hours (of which 415 were on type) Last 90 days - 46 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The pilot was flying to Caernarfon Airport from Blackpool Airport. Runway 20, which has a LDA of 1,031 m, was in use at Caernarfon and its asphalt surface was dry.

An aftercast obtained from the Meteorological Office stated that the synoptic situation showed a fresh south-westerly flow covering Wales. The visibility was expected to have been 20 km with a few scattered cumulus clouds at 2,500 to 3,000 ft. The mean sea-level surface wind over the area was expected to have been from 200º at 25 to 27 kt, gusting to 35 kt. However, with this surface wind direction, Caernarfon is slightly in the lee of the Lleyn Peninsula. Consequently, the wind could have had a more variable direction and speed at times as a result of funneling through the valleys and around the hills to the south-south-west of the airfield. This could have meant the wind was more southerly at times, perhaps with a larger variation in speed. These wind conditions would have made low-level turbulence likely in the area. Given the wind strength and proximity of high ground, the degree of turbulence would almost certainly have been moderate but it could have been severe at times.

The pilot reports that the surface wind was 190º/25 kt and gusty whilst he was making a normal approach to

Runway 20. He added that he was flying approximately 10 kt faster than the normal approach speed of 80 kt because of the gusty conditions. As he was approaching the normal touchdown point, at approximately 10 ft agl, the aircraft's nose suddenly dropped by about 10º to 15º; at the same time he became aware of a significant drop in the aircraft's indicated airspeed. He immediately applied a "burst of power" and pulled the control column back in an attempt to arrest this change in attitude and the increased rate of descent. These actions had some effect but the aircraft then bounced on its nose wheel before landing on its main landing gear. Initially the pilot did not think the aircraft was damaged. However, after shutting down and vacating the aircraft, he discovered that 5 cm of each propeller tip had been bent as a result of striking the runway. He thought this had happened when the aircraft landed on its nose wheel.

Aircraft damage

An assessment of the damage by the repair agency found that the propeller was damaged beyond economical repair and the engine was examined for shock-loading damage.

Eyewitness report

An eyewitness to the landing of the incident aircraft and other aircraft stated that he had noticed a lot of them "drop dramatically" on the final approach, albeit from a greater height than the accident aircraft. He added that he thought the pilot of N565G could not have done anything else in the circumstances.

ACCIDENT

Aircraft Type and Registration:	Bell 206B Jet Ranger III, G-BXLI
No & Type of Engines:	1 Allison 250-C20J turboshaft engine
Category:	2.3
Year of Manufacture:	1989
Date & Time (UTC):	22 January 2005 at 1242 hrs
Location:	Priors Park Wood, 5 nm south of Taunton, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - 1 (Fatal) Passengers - 3 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	330 hours (of which 220 were on type) Last 90 days - 10 hours Last 28 days - 4 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot had planned to fly with some friends from Staverton Airport, near Gloucester, to a private landing site in the Torbay area but, due to deteriorating weather, landed at Topsham to the south of Exeter Airport. After a period of several hours, the weather had not improved so the pilot decided to return to Staverton. Although on the outbound trip he had routed south via the Bristol Channel and the M5 corridor, an area of low lying terrain, he elected to return to Staverton via Sidmouth, and communicated this to Exeter ATC, advising them that he would be flying at an altitude of 900 ft. As he approached Sidmouth, he then informed Exeter that he was going to go north towards Wellington and Taunton. This route would take the helicopter over the Blackdown Hills, which rise to a height of some 1,000 ft amsl. Witnesses in an area approximately 5 nm south of Taunton generally heard, but did not clearly see, a low flying helicopter and one heard a 'bang'. A subsequent search and rescue effort failed to locate the helicopter, due to very poor weather conditions, and it was found by a dog walker the following morning. All four occupants had received fatal injuries in the accident. No pre-accident defects were found during the wreckage examination.

History of the flight

The pilot had planned to fly two friends and the son of one of those friends in G-BXLI, a Bell 206B helicopter which he part owned, from Staverton Airport, near Gloucester, to a private landing site in the Torbay area of Devon. They then intended to spend the day in the pilot's boat, which he kept at Torquay, before returning to Staverton Airport at about 1800 hrs.

G-BXLI departed from Staverton on the morning of the accident, before the airport had opened[1] and routed south via the Bristol Channel and the M5 corridor at various altitudes. The weather had been good at Staverton, but it began to deteriorate as the helicopter flew towards Torbay. G-BXLI transited through Exeter Airport's overhead at 0923 hrs and, as it continued further south, the pilot decided that the weather was unsuitable for him to carry on to the intended landing site at Torbay. Instead, he elected to land in a playing field at Topsham, a town 3.5 nm to the south-south-west of Exeter Airport. He told Exeter ATC that he was "GOING TO HAVE TO" do so because the cloud was "DOWN TO THE GROUND" to the south of Exeter. ATC advised him that the cloud base at the airfield was scattered at 800 ft above airfield level (aal), broken at 1,500 ft aal and asked the pilot to telephone them after he had landed. G-BXLI landed on the playing field at 0929 hrs and the pilot and his passengers walked into the town in search of a café to await an improvement in the weather.

The pilot made a number of calls on his mobile telephone, to Exeter ATC (as agreed), the local police, the aircraft operating company at Staverton and friends and members of his family, to advise them of the situation. After two and a half hours he decided that, in view of the continuing poor weather to the south, he and his passengers would fly back to Staverton, having established that the weather there remained suitable. Once they had boarded the helicopter and started up, an onlooker noticed the front left seat occupant was wiping the inside of his windscreen. The helicopter took off from the playing field at 1219 hrs and the pilot advised Exeter ATC by radio that he would be routeing via Sidmouth and then on to Gloucester, at an altitude of 900 ft amsl.

At 1226 hrs the pilot informed Exeter ATC that he was "JUST COMING UP TO SIDMOUTH AND I'M GOING TO GO NORTH TOWARDS WELLINGTON AND TAUNTON". GPS data, which was subsequently recovered from the wreckage, revealed that the helicopter approached to within 1.5 nm of Sidmouth before turning north and following the valley of the River Otter towards the Blackdown Hills, and on a line towards Taunton beyond. The co-owner of G-BXLI stated later that it was common for the pilot to route via Dunkeswell when returning to Staverton from Torbay. On this occasion the route took the helicopter 4 nm to the east of Dunkeswell.

At 1240 hrs, the Exeter ATC Approach Controller, who had spent the previous few minutes conducting a Surveillance Radar Approach (SRA) for an inbound scheduled commercial aircraft, tried to contact G-BXLI on the radio but received no reply. At 1245 hrs the controller routinely handed over his duties to a colleague. He informed him of G-BXLI's routeing, the loss of communication with the pilot and a brief secondary radar contact that he had seen in the Taunton area which he thought was the helicopter. The oncoming controller also attempted to make contact with the helicopter, but

Footnote

[1] The pilot, like a number of other operator's, had signed an indemnity agreement with the airport owners, which enabled him to depart from and land at Staverton Airport outside normal operating hours, between sunrise and sunset.

without success[2]. Exeter ATC then called Bristol ATC by telephone to establish whether the pilot had made contact with them as he flew further north but they had heard nothing. Exeter ATC put the same question to Staverton ATC. Again, Staverton had not spoken to G-BXLI but, at this stage, there was no undue concern because, being a private flight, there was no requirement for the pilot to make radio contact with an ATC unit when he was flying outside controlled airspace. Also, Staverton ATC was aware of previous instances when this pilot had flown outside controlled airspace without making contact with an ATC unit. Exeter ATC asked Staverton ATC to call them when they had made contact with the helicopter.

At about 1240 hrs, a member of the public who was standing in a field on top of the Blackdown Hills approximately 600 m to the west of the B3170 road, 5 nm to the south of Taunton, heard a helicopter flying around for approximately four to five minutes. The helicopter sounded "fine"; then he heard a 'bang'. Five minutes later he telephoned the police to report what he had heard. That telephone call was timed at 1247:48 hrs and the caller reported that the helicopter had flown over the residential camp-site where he was standing. The police received no other reports from the public and no further action was taken.

At 1435, Exeter ATC contacted the company at Staverton Airport where G-BXLI was normally accommodated and on whose Air Operators Certificate (AOC) the aircraft was operated. Staff at that company did not know of the aircraft's whereabouts and made calls to the mobile telephones belonging to the aircraft's occupants. Although the 'phones were heard to ring, and one was sent a text message, there was no response.

Footnote

[2] Exeter ATC stated that it was not unusual for the pilot of a private flight to contact another ATC agency without advising them of the change. They remarked that this was sometimes the result of the aircraft's transmissions being masked by hilly terrain if the aircraft was at low altitude.

At 1500 hrs, Staverton ATC made further enquiries as to G-BXLI's whereabouts and, having received no reports of any contact, advised the London Area Control Centre (LACC) at Swanwick of the aircraft's disappearance. In the absence of a flight plan, for which there was no requirement, there was no onus on any ATC unit to initiate overdue action on the aircraft[3].

Staff at LACC commented that they made a number of general enquiries because, often, such reports of loss of contact are resolved satisfactorily. However, at 1610 hrs, the Distress and Diversion (D&D) cell at the London Air Traffic Control Centre (Military) at West Drayton was informed of the disappearance of G-BXLI, by the Civil Supervisor at LACC, and initiated overdue action at 1645 hrs. The D&D cell obtained a radar replay, tried (unsuccessfully) to establish if the whereabouts of the helicopter was known and informed the Aeronautical Rescue Co-ordination Centre (ARCC) at RAF Kinloss. At 1740 hrs, the radar replay was forwarded to ARCC and search and rescue operations (sarops) were launched at 1755 hrs. At 1900 hrs, the SAR helicopter was stood down because of unsuitable weather conditions.

At 1717 hrs, the police, who had been contacted by Staverton ATC at 1554 hrs, initiated a search for the aircraft in the area of the Blackdown Hills where there had earlier been the report of a helicopter and a 'bang'. The search continued in poor weather throughout the night and involved the police, members of the family and friends of the pilot and his passengers, and members of the general public. During the course of the night the rain turned to snow. At 0846 hrs the following morning, a member of the public reported finding the wreckage of a helicopter in a copse adjacent to the B3170, 5 nm

Footnote

[3] When a flight plan is submitted, overdue action is taken if the aircraft has not arrived at its planned destination within 30 minutes of its Estimated Time of Arrival (ETA) and its position is not known.

to the south of Taunton, having been alerted to the helicopter's presence by his two dogs. G-BXLI was severely damaged and the pilot and his three passengers appeared to have received fatal injuries. It was apparent that the predominantly white colour of the compacted wreckage merged with the recently fallen layer of snow and this made it difficult to distinguish, from even a short distance, through the trees and undergrowth. There had been no fire. The aircraft was found at an elevation of 980 ft amsl.

The post mortem reports concluded that the four occupants of G-BXLI died as a result of the injuries they had sustained during the accident.

Witness information

At some time between 1230 hrs and 1300 hrs, a witness standing in the kitchen of her house, 5 nm to the south of Taunton on the south side of the Blackdown Hills and on the east side of a valley adjacent to the B3170 road, heard a helicopter approaching from the south, flying up the valley in a northerly direction. The noise of the helicopter, which sounded very close by, faded and then returned, which prompted her to look out of the window. This witness stated that she briefly saw the tail part of a helicopter through the fog but could not distinguish the colour. The helicopter appeared to be just above and beyond the roof of the property in front of her window, travelling northwards. The roof in question is about 25 ft high. The noise of the helicopter faded again and returned a third time before moving away to the north-west. In commenting on the weather, this witness stated that fog appeared to come "in waves" and that there was drizzle and a high wind at the time.

Between 1230 hrs and 1245 hrs, two other witnesses at a neighbouring farm, some 500 m to the north of the first witness, heard a helicopter manoeuvring, apparently at low speed, very nearby. One of these witnesses, who was standing in the farm's yard, then briefly saw the tail of a helicopter approximately 200 m away over the fields on the east side of his farmhouse. The helicopter was at a height of about 30 ft and the tail, which was whitish in colour, was seen to "whip round" in a clockwise direction. The aircraft appeared to hover for about a minute before flying around to the south of the farm buildings and off in a westerly direction. The other witness, who was inside the farmhouse, had heard an aircraft overhead that sounded like a Chinook helicopter. It moved away to the back of the house, the noise "cut out and cut in again" and then the aircraft returned over the top of the house before moving away. This witness could not see the helicopter when she looked out of a window but also remarked that she was unable to see the fields on the other side of the valley, between 200 and 300 yards away. She estimated that the noise of the helicopter lasted about two and a half to three minutes.

At approximately 1245 hrs, the driver of a small van was travelling south on the B3170 and had just passed the crossroads on the top of the Blackdown Hills at North Down, near the hamlet of Holman Clavel. He was driving alongside a copse, which was on his right, and passing a lay-by on his left when he heard a loud 'whoosh' of helicopter rotor blades above the noise of his car radio and the vehicle's diesel engine. The noise came from the driver's left hand side. He estimated the visibility at 80 to 100 ft, in fog and did not see the aircraft. At about the same time another driver of a car travelling in the same direction on the same stretch of road (probably just in front of or behind the previous vehicle) had a very similar experience. A noise, which she stated was clearly that of a helicopter, flying from left to right above her, was loud enough to make her duck down inside her car. This driver was also unable to see the aircraft.

Three people who were amongst some farmyard buildings, which are situated 300 m to the east of the accident site, heard the sound of a helicopter flying low overhead at about 1230 hrs. The noise lasted about five seconds and towards the end of this period it sounded to one of these ear witnesses as if the helicopter was banking and power was being increased. The noise then ceased and they concluded that the aircraft had flown over the nearby trees and down the north side of the Blackdown Hills. In the very poor visibility and low cloud they, too, did not see the helicopter.

Meteorology

A meterological aftercast showed that, at 1200 hrs on the day of the accident, there was a warm front orientated north-west south-east, lying along a line passing through Chivenor, in north Devon, and Jersey. This front was moving very slowly north-east. Ahead of the front lay a moist, light to moderate, south-easterly flow over the Somerset area with moist, warm air overlaying colder air near the surface. The resultant surface weather included rain and drizzle with low cloud covering some hills in the accident area. The general visibility was between 3,000 and 5,000 m in slight rain and drizzle, reducing to 100 to 1,500 m in moderate rain and drizzle, with accompanying low cloud over the hills. The freezing level was at 2,000 ft amsl and the cloud cover consisted of broken and overcast stratus with a base between 600 and 1,000 ft amsl. Multi-layered cloud probably existed above that up to 20,000 ft amsl. The wind at 1,000 ft amsl was 170º/15 kt and the temperature at that level was approximately +4ºC.

The weather at Staverton Airport, when the aircraft took off, was good. The visibility was in excess of 10 km, the wind was calm, there were a few medium level clouds and the surface temperature was +1ºC. At the same time at Exeter, the visibility was 7,000 m in light drizzle; there was scattered cloud with a base at 800 ft aal and broken cloud at 1,000 ft aal.

For the weather en route, a Terminal Area Forecast (TAF) for Bristol Airport, issued at 0615 hrs, predicted a 30% probability of a temporary change during the period between 0700 hrs and 1600 hrs, when the visibility would reduce to 3,000 m, the cloud base would descend to 500 ft aal and there was the possibility of light rain and snow.

On the morning of the day of the accident, the pilot would not have had access to the meteorological facilities at Staverton Airport before he departed because the airfield was closed. It is not clear what weather forecasts he did obtain, if any, but a number of sources would have been available to him. Exeter Airport operating hours that day were notified as being between 0530 hrs and 2000 hrs, and a TAF, timed at 0752 hrs, was issued for the airfield for the period 0800 hrs to 1600 hrs. It forecast that during that period there was a 30% probability of a temporary change when the visibility would reduce to 2,000 m in rain and drizzle and the cloudbase would be scattered at 200 ft aal and broken at 400 ft aal. The pilot may have contacted ATC at Exeter by landline before he took off from Staverton to request their recent meteorological observations and any forecast, but such calls are not logged. Even if he had not, he would have been able to request that information during the flight from any ATC unit which he was in contact with at the time.

At 1220 hrs, when G-BXLI took off from the playing field at Topsham, an observation at Exeter Airport recorded the visibility as being 5,000 m in light rain and drizzle, with a scattered cloud base at 600 ft aal and broken cloud at 1,000 ft aal. The surface temperature was +7ºC.

Two automatic synoptic observations at Dunkeswell Airfield (elevation 830 ft amsl and 6.5 nm to the south-west of the accident site), taken at 1200 hrs and 1300 hrs respectively, recorded a surface wind of 140º/7 kt, changing to 140º/9 kt, visibility reducing from 1,500 m in rain to 200 m in rain and the cloud base descending from 100 ft aal to ground level. In that hour the surface temperature at Dunkerswell rose from +3.5ºC to +4.2ºC.

The pilot

The pilot started flying in June, 2000, at the age of 50 years, and he gained his Joint Aviation Authorities (JAA) Private Pilot Licence (Helicopter) (PPL(H)) a year later with a rating to fly the Robinson R22 helicopter. In December 2001, he added the rating for the Bell 206 Jet Ranger to his licence. He retained the ratings for both types until June 2004 when his R22 rating lapsed. Of the two types, he had predominantly flown the Bell 206 after July 2001. From June 2003 he flew exclusively in G-BXLI, which he had purchased with a friend a month earlier.

Between January and March 2004 the pilot completed the training for a Night Qualification (Helicopter). This included a minimum of 10 hours dual helicopter instrument instruction, which was in addition to the five hours of instrument flying instruction required during his PPL(H) training. In all he completed 11.6 hours of instrument flying instruction and the qualification entitled him to act as pilot in command of a helicopter at night. However, he had not completed the training for, or been issued with, an instrument rating. His instructor commented that the pilot would find flying in cloud difficult. Without an instrument rating he was not qualified to do so.

The pilot had a current Class Two JAA Medical Certificate, with a limitation that he '*shall have available corrective lenses'*. He was known to have had a pair of spectacles with him on the day of the accident.

The pilot was described by friends and relatives as being a 'larger than life' character for whom landing on the playing field would have been an adventure. However, it was understood that, at the same time, he would have been careful about the safety of others.

Procedures

Rule 5(1)(e) of the Rules of the Air Regulations 1996, as contained in the Air Navigation Order 2000, states that:

> *'an aircraft shall not fly closer than 500 feet to any person, vessel, vehicle or structure'.*

In paragraph (2)(d)(i) of the same rule it states that this restriction:

> *'shall not apply to any aircraft while it is landing or taking-off in accordance with normal aviation practice'.*

The accident flight was being conducted under the Visual Flight Rules (VFR). For helicopters flying at or below 3,000 ft amsl, these rules require the meteorological conditions to be such that the aircraft can remain :

> *'clear of cloud and in sight of the surface'.*

If unable to maintain these Visual Meteorological Conditions (VMC) then the pilot is required to fly according to the Instrument Flight Rules (IFR).

In order to comply with IFR, outside controlled airspace,

> *'an aircraft shall not fly at a height of less than 1000 feet above the highest obstacle within a distance of 5 nautical miles of the aircraft unless:*

> *(a) it is necessary for the aircraft to do so in order to take off or land;*
> *(b) the aircraft is flying on a route notified for the purposes of this rule;*
> *(c) the aircraft has been otherwise authorised by the competent authority'.*

The Joint Aviation Requirements (JAR) Flight Crew Licensing (FCL) requirement JAR–FCL 2.175(a), entitled 'Circumstances in which an IR(H) is required', states that:

> *'The holder of a pilot licence shall not act in any capacity as a pilot of a helicopter under Instrument Flight Rules (IFR), except as a pilot undergoing skill testing or dual training, unless the holder has an instrument rating (IR) appropriate to the category of aircraft issued in accordance with JAR–FCL'.*

The Aircraft Flight Manual states that the:

> *'engine anti-ice shall be ON for flight in visible moisture in temperature below 4.0ºC (40ºF').*

Failure to do so would eventually risk the build up of ice in the engine intake as the temperature dropped further towards and below 0ºC, with consequent reduction in power and, eventually, possible engine failure.

The helicopter was not approved for IFR operations.

ATC procedures

The aircraft was flying outside controlled airspace and the pilot was not required to communicate with ATC. However, he had called Exeter ATC after taking off from the playing field in Topsham for the return flight to Staverton and Exeter ATC provided a Flight Information Service (FIS).

The Manual of Air Traffic Services (MATS) Part 1 states that:

> *'a FIS is a non-radar service supplied, either separately or in conjunction with other services, for the purposes of supplying information useful for the safe and efficient conduct of flights. Under a FIS the following conditions apply: a) Provision of the service includes information about weather, changes of serviceability of facilities, conditions at aerodromes and any other information pertinent to safety….'. Also, 'the controller may attempt to identify the flight for monitoring and co-ordination purposes only. Such identification does not imply that a radar service is being provided or that the controller will continuously monitor the flight'.*

Under a FIS a pilot is responsible for his own navigation and collision avoidance.

Under the heading '*Section 5 Emergency Procedures'***,** MATS Part 1 states that:

> *'a controller may suspect that an aircraft is in an emergency situation when …… radio contact is lost ...... it is overdue at an aerodrome'.*

As regards radio failure procedures, MATS 1 states that:

> *'radio failure procedures shall be adopted when: a) an aircraft is observed to have selected SSR Mode A, code 7600, and the pilot does not respond to ATC communication….'*

Regarding 'overdue action', MATS Part1 states that:

> *'overdue action is not related solely to the filing of a flight plan. If, at any stage of a flight the pilot has*

> *made his intentions clear and subsequently does not arrive or report when expected, controllers should seriously consider taking overdue action.'*

Air Traffic Services in the United Kingdom also include an Alerting Service. This is explained in MATS Part1 as being:

> *'available for all aircraft which are known by the air traffic services to be operating within United Kingdom flight information regions. The responsibility for initiating action normally rests with the air traffic service unit which was last in communication with the aircraft in need of search and rescue aid or which receives the news from an outside source'.*

Further:

> *'approach and aerodrome control units, when they are aware that an aircraft is in need of search and rescue aid, shall immediately:*
>
> *a) set in motion the local rescue services and emergency organizations…. and/or*
> *b) notify by telephone the watch supervisor at the parent ACC'.*
>
> *At the ACC 'whenever it is reported from any source that an aircraft within a flight information region is in need of search and rescue aid the area control centre watch supervisor shall initiate emergency action unless it is known that the appropriate rescue organisation has already been alerted.'*

In the case where an aircraft is not known to have force landed or crashed the Area Control Centre (ACC) watch supervisor will notify; D&D, ARCC, the appropriate police authority and the aircraft operator. The ARCC controller is responsible for initiating search and rescue action. MATS Part 1 indicates that 90 minutes may elapse from the time when an aircraft was expected at a certain point, and has failed to appear, and a search and rescue operation begins. During that time enquiries will be made to try and establish the whereabouts and safety of the aircraft.

Accident site details

The aircraft had flown into a small copse of trees, coming to rest approximately 50 m west of the B3170 road. The impact track of the aircraft was 300ºM. The road marked the eastern boundary of the copse, with the southern edge some 40 m to the south, beyond which was a level grass field. It was evident that the helicopter initially had struck the upper branches of a tree before striking the ground 28 m further on. The branches were up to 5 cm in diameter and several were found close to the base of the tree, along with most of one tail rotor blade, honeycomb material from the main rotor blades, the broken-off lower portion of the vertical stabiliser and numerous fragments from the cockpit glazing. Some of these were blue-tinted, indicating that they were from the windows in the rear doors.

The height of the truncated tree was around 14 m, which, together with the ground impact position, indicated a flight path angled 26º down relative to the horizontal. The marks on the ground appeared to have been made by the skids and the fuselage underside; together they suggested that the helicopter's attitude at impact had been erect and with the nose high. The skid marks were approximately parallel to the impact track, which indicated that there had been no significant yaw angle. An additional mark, to the rear of those made by the skids, appeared to have been made by the stub of the vertical stabiliser.

After striking the ground, the aircraft had rolled to the left, breaking up as it did so, before coming to rest some 12 to 13 m further on. It was clear that the skids had splayed on impact with the ground, with the downwards momentum of the engine and transmission most probably contributing to the destruction of the cabin. The overall impression given by the disposition of the wreckage was that the helicopter had struck the ground with a high rate of descent coupled with a relatively low forward speed, estimated to have been around 30 to 40 kt. This in turn suggested that the aircraft was already in a descent at the time it struck the top of the tree.

One of the main rotor blades had been all but severed close to its quarter span position, remaining attached by the trailing edge strip. Both main rotor blades had sustained considerable damage to their undersides as a result of striking the tree branches, although there was a lack of heavy leading edge damage.

The mid-section of the tail boom, including the horizontal stabiliser, was found lying approximately 30 m to the north of the main wreckage, ie, to the right of the flight path. It was apparent that it had sustained two main rotor blade strikes. One was on the tail rotor drive shaft cover on top of the boom, with the second being a substantial impact underneath the left horizontal stabiliser[4]. On an intact aircraft, the rotor disc would have to be tilted at an angle of around 20º relative to the axis of the tail boom in order to strike the stabiliser at this point. However, the angle was measured to be around 10º, which led to the conclusion that the strike occurred on the ground as a result of the structural disintegration of the tail boom and fuselage. The near-simultaneous ground contact of the skids, rear fuselage underside and the stub of the vertical stabiliser probably initiated the tail boom failure in two places. The upwards deflection of the central section, relative to the rotors, would have allowed it to be struck by a blade, with the force of the impact throwing it to the right. The rear portion of the tail boom, which included the tail rotor and gearbox, had continued along the ground and had come to rest a few metres to the right of the main wreckage.

A one metre length of the left skid assembly was found close to the separated part of the tail boom and a heavy indentation on it suggested that this too may have been struck by a main rotor blade. It is possible that the piece of the skid broke off on impact and was thrown to the right after being struck by a blade, in a similar manner to the tail boom section. The weakened left skid assembly may have accounted for the aircraft rolling over to the left following impact with the ground.

There was no fire, although a strong smell of fuel was apparent around the main wreckage. The bladder-type fuel tank, which had been located behind and beneath the rear seats, had remained substantially intact apart from one significant hole, through which fuel had escaped into the ground.

Following the on-site assessment, the wreckage was recovered to the AAIB's facilities at Farnborough for a detailed examination.

Detailed examination of the wreckage

Airframe

As noted earlier, the severe disruption to the fuselage structure was attributed to the high descent rate. Further evidence of this was provided by the manner in which the transmission deck had been 'dished' by the mass of the main rotor gearbox. The movement of the gearbox

Footnote

4 The main rotor on a Bell 206 rotates in an anti-clockwise direction when viewed from above.

had caused failure of some of the flying control linkages between the bellcranks on the front of the gearbox and the hydraulic actuator cradle mounted on the forward part of the deck. It was also apparent that that a flange on the free-wheel unit at the rear of the gearbox had been in violent contact with the isolation mount located immediately below, to the extent that it had machined a groove in it. The resultant damage to the free-wheel assembly had allowed most of the gearbox oil to leak out after the impact. Otherwise, the gearbox was smooth in operation and the oil filter was clear.

Power for the hydraulically boosted flying controls on this type of aircraft is provided by a hydraulic pump, with integral fluid reservoir, mounted on the front of the gearbox. The vertical movement of the gearbox during the ground impact had caused the underside of the pump and its associated pressure transmitter to contact the deck, damaging the transmitter housing. The reservoir was empty, although it was apparent that the fluid had escaped after the accident via a crack in the pressure transmitter housing. The filter element was examined and found to be clear. The pump was intact, as was the drive from the main rotor gearbox.

The flying control linkage was extensively disrupted, especially those components located underneath the floor. However, there was no evidence that any of the failures had occurred prior to impact.

Elsewhere on the airframe, the instrument binnacle was reasonably intact, and the instruments were all at their normal power-off indications. The altimeter subscale was set at 1018 mb, which was the pressure setting passed to the aircraft by Exeter ATC shortly before the accident. The fuel valve ON-OFF switch was found in the OFF position, although it was clear that its associated guard, which prevents inadvertent OFF selection, had received a blow during the impact. However, the motorised valve itself was found to be in the open position. Other switches included the hydraulic power, which was ON and the engine anti-icing valve, which was OFF.

The central warning panel (CWP) caption segments had remained intact and the light bulbs were examined for evidence of stretched filaments[5]. Particular attention was paid to the LOW NR (low rotor rpm) and ENG OUT captions: however no evidence was found of any bulb being illuminated at impact. Whilst this suggested that no technical malfunction had occurred prior to impact, it should be noted that the behaviour of bulb filaments can vary according to the severity of the impact and the bulb manufacturer.

Engine

Prior to removing the engine from the airframe, the accessory gearbox oil filter and magnetic chip detector were examined and found to be clear. The fuel nozzle and its associated screen were also removed and found to be normal in appearance. When removing the nozzle it was observed that the line between the nozzle and a check valve was full of fuel, thus showing that the engine fuel system was primed. There was fuel in the filter bowl and the filter element was clean. The engine had sustained little visible damage, although the power turbine rubbed against its shroud when turned by hand; it was thus not possible to run the engine in a test cell.

The engine anti-ice valve on this type of aircraft is driven by an electric motor. It was observed that the valve was in the OFF position, which agreed with the

Footnote

[5] When bulbs are illuminated, the heated filaments become extremely ductile and an impact can result in extensive filament stretching within the glass envelope. This feature can thus provide evidence that the bulb was lit at impact.

switch position, noted earlier. It was additionally noted that the throttle twist grip was at the 'idle' setting, which agreed with the as-found position of the throttle arm on the engine fuel control unit. However, this apparently corroborative evidence was not considered reliable, as the connecting linkage had been severely disrupted in the impact.

The engine was taken to an overhaul agency and subjected to a strip examination, which was overseen by the AAIB and a representative from the engine manufacturer. No evidence of failure or malfunction was found in any of the components, although there were two noteworthy features. The first was an area of rubbing where the centrifugal compressor wheel had contacted the surface of the compressor diffuser. This was over the twelve o'clock to three o'clock area, when viewed from the front, and most probably occurred when the aircraft rolled over to the left during the ground-slide. The second feature was the presence of solidified aluminium alloy spatter in the turbine section, especially on the third stage nozzle assembly. This was caused by material shaved from the diffuser that had melted as it passed through the combustion section, before solidifying as it contacted the turbine blades and nozzles. This provided evidence that the engine was functioning at impact.

The engine fuel components, comprising the fuel control unit, the power turbine governor and the fuel pump were each subjected to a 'production test' on a dedicated test rig; no faults were found.

Recorded Data and other Recovered Information

Sources

There were several sources of recorded information used for the purpose of this investigation. The aircraft had two GPS receivers fitted, a digital camera was recovered from the wreckage and Burrington radar, some 30 nm to the west of the accident site, had recorded the aircraft's movements. Also, the ATC radio conversations with the helicopter had been recorded, and the appropriate tapes were impounded and replayed.

GPS

The two GPS receivers fitted to the helicopter, a Garmin GPS150 and Skyforce Skymap IIIc, were examined. The GPS150 did not record track information but the Skymap IIIc, although damaged, was successfully downloaded at the manufacturer's facility, using donor parts to replace damaged components. The download yielded flight logs, the last position fix of the unit and a screen shot of the map display at the final fix position. The flight logs covered flights from 10 October 2004 up to the accident flight, and recorded snapshots of GPS latitude, longitude, GPS altitude, ground speed and magnetic track once every 30 seconds. On this type of GPS receiver, flight logs are initiated when the ground speed exceeds 20 kt and terminated when either the aircraft speed drops below 3 kt, power is removed from the unit or the unit can no longer detect a valid position for reasons that include loss of sight of sufficient satellites or disconnection of the antenna.

Figure 1 shows the two GPS tracks recorded on the day of the accident. The first flight of the day departed from Gloucester airport, and the first track point was recorded at 0827 hrs with the helicopter in the air. The flight ended at 0929 hrs at Topsham, south east of Exeter. The second flight, during which the accident occurred, departed Topsham at 1219 hrs. The last flight log point recorded was at 1241:29 hrs just south of Priors Park Wood, approximately 5 nm south of Taunton.

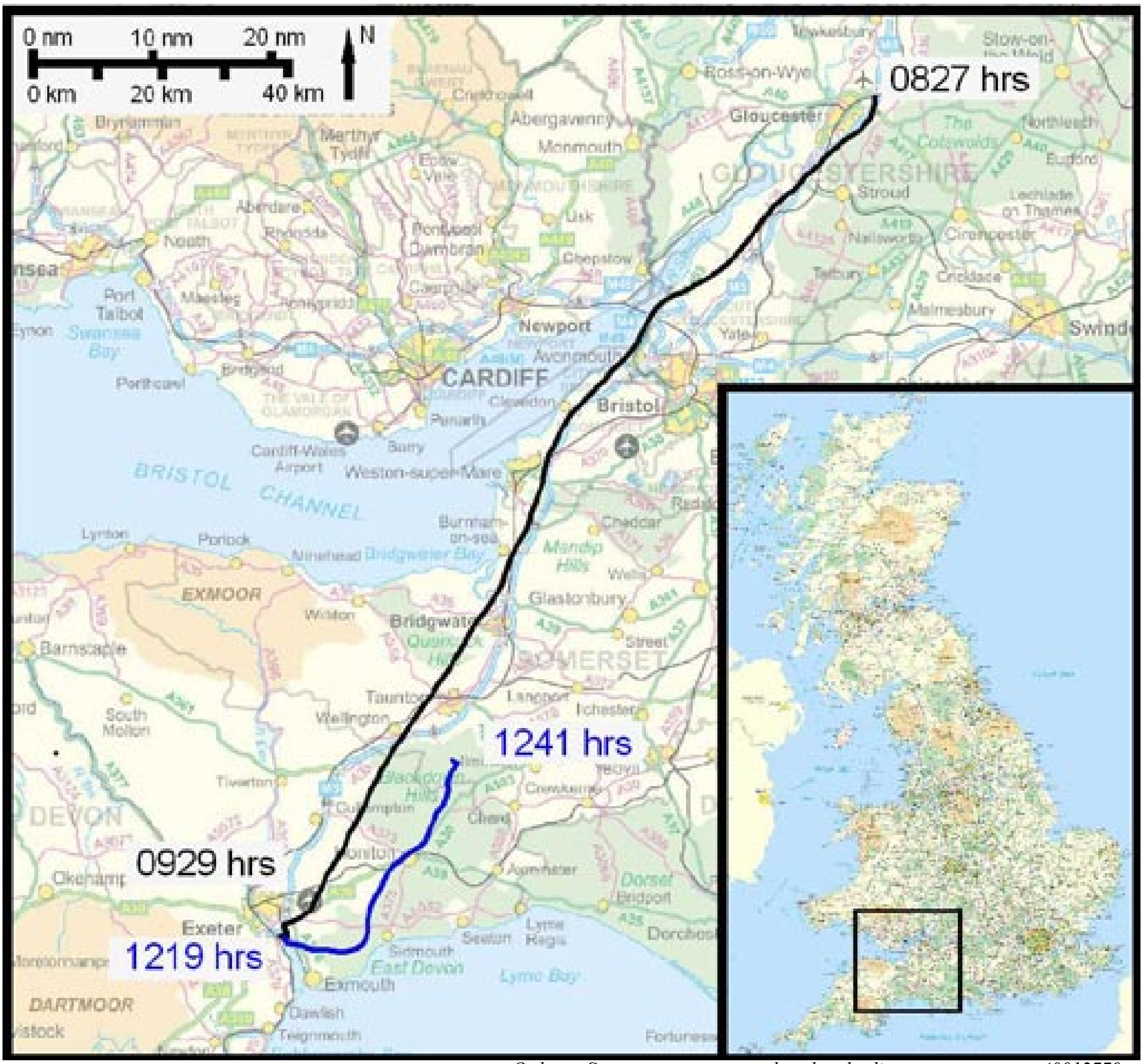


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Figure 1

G-BXLI's flight tracks on the day of the accident

Figure 2 shows the flight path of the accident flight overlaid on a map of the terrain. During this flight, the aircraft initially tracked east and crossed a ridge. The helicopter then flew north-east, following a valley floor at approximately 400 ft agl with an average ground speed of approximately 80 kt. The valley floor elevation increased as the flight progressed. The flight terminated at a location where the valley floor effectively merged with the Blackdown Hills, Figure 3, and this was the last ridge of hills on track before the terrain fell away towards Taunton and the M5 motorway. A minute or so before the flight log terminated, in the vicinity of Moor, Westhay and Walland Farms, the aircraft slowed appreciably, dropped in altitude and significantly changed its heading. The low sample rate of the GPS did not afford more detailed description of the manoeuvring at the end of the flight.

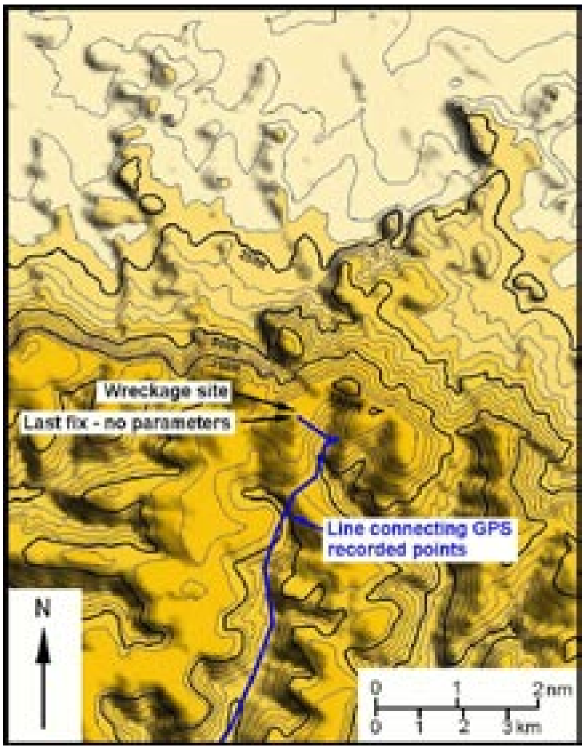

Figure 3

End section of the accident flight in relation to terrain height

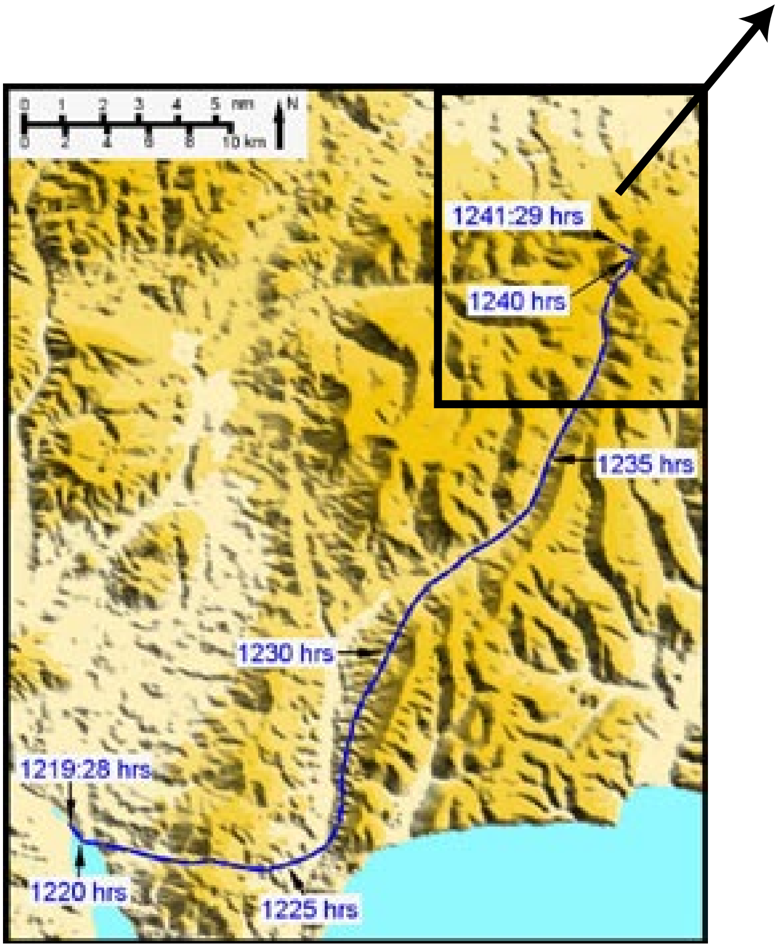

Figure 2

Accident flight track overlaid on a terrain map

The GPS map display was also downloaded and is shown in Figure 4. This represents the map display at the point of the final fix. The colour coding of the display indicates that lower ground was not far to the north-east of the final fix location.

Radar

The aircraft was tracked by Burrington radar, which is located in Devon some 30 nm to the west of the accident site. Due to the low altitude nature of the accident flight, combined with the terrain between the radar head and the aircraft, the radar track consisted of fragmented secondary radar returns with only small parts of the track covered by combined primary and secondary returns. The secondary radar recordings did not include any altitude information. This indicates that the altitude reporting capability (mode C) or the aircraft ATC transponder was not active at the time. Analysis of the limits of line of sight of the radar in the vicinity of the aircraft confirmed that the GPS altitude data, which is prone to larger errors than the GPS lateral position data, was reasonable.

Photographs

A digital camera was recovered from the wreckage which, when its flash card was downloaded, contained photographs taken throughout the day of the accident. Each image had an information 'label' listing, amongst other things, the date and time. Whilst it was clear that the date was correct, it was necessary to assess the accuracy of the clock. This was achieved by examining aerial images taken of known geographic locations en route and comparing the camera times with the accurate GPS times at those locations. The final image was taken from the rear left seat position in the helicopter,

Figure 4

Screen shot of G-BXLI's final GPS fix.

(The 'No Fix Possible' message reflects the fact the antenna is disconnected from the receiver so the location cannot be updated.) The distance between the last fix location and the wreckage was approximately 100 m.

and showed most of the windscreen and some of the instruments. The camera time was 1342 hrs, which was corrected to 1238:00 hrs ± 40 seconds, ie, approximately 4 minutes prior to the time that the helicopter struck the ground. The image showed raindrops on the windscreen but nothing distinguishable through it, other than varying shades of grey. The grey colour was slightly darker towards the bottom of the right hand windscreen. This contrasted with the earlier photographs in which the countryside, where included in the frame, could be seen outside the helicopter.

The image was subjected to an enhancing process and compared with a photograph of the same instrument panel taken on a previous occasion. From this comparison it was possible to discern the following instrument readings:

Airspeed:	70 kt
Barometric altitude:	1,120 ft
Attitude:	10º (approx) right bank, (approx) 1º nose up
Rate of climb:	500 fpm
Heading:	020º

It was also possible to determine that none of the CWP captions were illuminated. The NAV flag was in view on the Horizontal Situation Indicator (HSI), showing that there was no valid VHF omni-directional range (VOR) navigation aid tuned, but the HDG (heading) flag was out of view.

On the overhead panel, the battery and generator switches could be seen to be in the ON positions, and the instrument lights rotary selector was in the OFF position. The navigation lights were selected ON but the pitot heat was OFF and the cabin vent and blower switches appeared to be in the ON position.

The GPS display, which was mounted on top of the instrument binnacle, showed a map on which part of the north Somerset coast could be seen. The definition was insufficient to read any numbers from the display but it was sufficiently clear to compare to the downloaded GPS map display, Figure 3, from the final fix position. It was established that the photograph was taken within 0.25 nm of a position 1.8 nm south and 0.1 nm west of the final GPS fix for the aircraft. This lies on the GPS recorded path, equating to the period between 1237:55 hrs and 1238:25 hrs, ie, three to four minutes before the last recorded 'in air' position. This timing compared well with the other calculation of the timing of the photograph. This final image, together with others, also clearly showed that the front left and rear right seat passengers had their lap and diagonal straps fastened. Those of the remaining occupants were not visible.

Analysis

No evidence was discovered of any technical failure in G-BXLI before it struck the tree in the copse where the wreckage was found.

At about the time of the crash, at 1242 hrs, a helicopter was seen flying around at low level, about 50 ft agl, possibly looking for a suitable place to land. The weather conditions at the time were very poor. These sightings were consistent with the nature and timings of the data that was recovered from the GPS receivers fitted to the aircraft, and radar recordings.

Earlier in the day the pilot had landed the helicopter on a playing field in Topsham, on the north bank of the River Exe, because deteriorating weather conditions had prevented him from continuing south to his planned destination near Torquay. At Exeter Airport, three nautical miles to the north-north-west, the weather was also suitable for a landing and facilities were available for the passengers, the helicopter, flight planning and for obtaining meteorological information. Exeter Airport would have been the most suitable place in the locality for the helicopter to divert to, as the chosen landing site was an 'uncontrolled' public area. However, the pilot's decision to land at Topsham demonstrated that he was not reluctant to land off airfield due, in this case, to worsening weather conditions. In the event, a safe landing was carried out.

Having made the decision to land, it is not clear why the pilot later continued with the return flight to Staverton Airport in deteriorating weather conditions and, particularly, why he chose a route that took the helicopter over some of the highest terrain between Topsham and Staverton. His decision may have been influenced by his usual practice of flying from Torbay to Staverton via Dunkeswell, which actually lay to the west of the route taken on the accident flight. By contrast, the southbound route they had flown in the morning had notionally followed the M5 motorway over a region of lower lying terrain.

The last photograph taken on the flight, by the passenger who was sat in the left rear seat, shows the GPS display situated on the top of the instrument panel. In contrast with other photographs taken by the same camera on that day's flights, there was no visible countryside in this picture beyond the windscreen, just a general greyness, suggesting that the helicopter was flying either in cloud or in very poor visibility. In such conditions, the GPS display may well have assumed a greater significance than normal, to the pilot, as an aid to navigation.

The pilot had received a limited amount of instrument flying training in the past, consistent with his qualifications as the holder of a PPL(H) and a night rating. He did not hold a rating to fly in Instrument Meteorological Conditions (IMC) and his instructor had commented that the pilot would have had difficulty flying in cloud. Also, the helicopter itself was not approved for IFR operations. During the latter part of the accident flight G-BXLI was flying well below 500 agl and within 500 ft of persons, vehicles and structures; all the evidence suggesting that the aircraft was forced to fly ever closer to the rising ground on his track because of the cloudbase. Even though the aircraft's general drift was northbound, the pilot may, in the later stages of the flight, have been looking for a suitable place to land in the very poor visibility. With the pilot's experience and the relatively low amount of instrument flying training he had received, he would, at best, have found the conditions extremely challenging. The helicopter was last seen at very low level and, following that sighting, it appears that G-BXLI flew up the moderately steep side of the valley in which it had just been manoeuvring. It is considered possible, or even probable, that, as the ground levelled off at the top of the slope, the helicopter continued climbing into the cloud, carried on by its inertia, resulting in the pilot losing all visual cues before he could arrest the rate of climb. This seems to be the time when five witnesses briefly heard a low flying helicopter, but did not see it, in the low cloud and limited visibility. It was immediately after this that the aircraft is believed to have flown into the copse and hit the ground.

The investigation concluded that the helicopter's flight path angle was some 26º down just before it crashed. The combination of the aircraft's estimated forward speed of 30 to 40 kt and this angle, would result in a rate of descent of approximately 1,500 fpm. This suggests that either the pilot was attempting to regain visual contact with the ground or, possibly, that he was aware that the north side of the Blackdown Hills are steep sided and believed that the helicopter was sufficiently far north to be able to descend through cloud to become visual with the ground over lower lying terrain, as indicated in Figure 3.

As the helicopter descended, the pilot would have had little time to react on seeing the rapidly approaching ground. Any action he did take was likely to have reduced a higher rate of descent prior to impact. It was considered that the damage to the underside of the MRBs could have resulted from a rapidly applied aft cyclic pitch setting as the aircraft descended through the trees. Although the lack of leading edge damage could be interpreted as an indication of a low power/low rotor condition at impact, the lack of any evidence of a stretched filament in the LOW NR warning caption bulb suggested that the rotor speed was not unduly low. It was subsequently observed that the throttle twist grip was at the 'idle' setting, which agreed with the as-found position of the throttle arm on the engine fuel control unit. However, this apparently corroborative evidence was not considered reliable, as the connecting linkage had been severely disrupted in the impact.

The outside air temperature was about +4ºC in the vicinity and at the time of the accident. This is the temperature at which the engine anti-ice system should have been selected on. The switch was subsequently found in the OFF position. However, it is not believed that this was a factor in the accident since, immediately before the accident, the aircraft had sufficient power to perform low speed manoeuvres and climb out of a valley.

The responsibility for initiating alerting action:

> *'normally rests with the air traffic service unit which was last in communication with the aircraft in need of search and rescue aid or which receives the news from an outside source'.*

However, there were a number of understandable reasons why there was a delay in starting this procedure following the accident. The pilot had not submitted a flight plan and had not given an estimated time of arrival other than the original plan to return to Staverton at about 1800 hrs. Under the FIS service that he was receiving from ATC, he was responsible for his own navigation. Although MATS Part 1 states that:

> *'a controller may suspect that an aircraft is in an emergency situation when radio contact is lost ......',*

it is not unknown for aircraft undertaking private flights, as G-BXLI was, to leave a radio frequency without advising ATC. ATC personnel did not have the benefit of knowing that a member of the public had reported hearing a helicopter, and then a bang. Conversely, the police were not aware that Exeter ATC had lost radio contact with G-BXLI or that they had experienced intermittent radar contact with the helicopter, which disappeared at approximately the same time as the bang had been heard. Had each agency been aware of these facts, it is more than likely that a search and rescue operation would have been initiated at that point. Bearing in mind that the helicopter had also landed away from an airfield earlier in the day because of poor weather, it was understandable that the loss of radio contact was followed by general enquiries by ATC, rather than any assumption that it had crashed. In addition, the nature of the terrain where the pilot might have chosen to land could have masked any radio calls from the helicopter advising Exeter ATC of his intentions.

In the event, it was Staverton ATC who alerted LACC following the unanswered calls made to the helicopter occupants' mobile 'phones and the lack of any other contact. One hour and ten minutes after LACC were alerted, the D&D cell at West Drayton was advised and they initiated overdue action a further 35 minutes later. With the benefit of hindsight, it is possible to appreciate that if the search and rescue action had been started at the time when the one member of the public had reported hearing a bang, and the search had been centred on the position of the last radar contact, then the aircraft might have been found much more quickly

The CAA's General Aviation Safety Sense Leaflet 17c, entitled *Helicopter Airmanship*, contains advice on the meteorological factors to consider when planning a flight. Included is the advice to:

> *'not let 'Get-there/home- itis' influence your judgement. Establish clearly in your mind the current en-route conditions, the forecast and the 'escape route' back to good weather. Take account of the freezing level. Plan a more suitable route if you are likely to fly over high ground which may be cloud covered'.*

Safety Recommendations

The helicopter had originally been issued with a Certificate of Airworthiness in the Transport (Passenger) category by the Civil Aviation Authority, and would have been defined as a Commercial Air Transport (CAT) aircraft. However, at the time of the accident, G-BXLI possessed a valid EASA Certificate of Airworthiness (CoA) in the 'Standard Category', and would be defined under the terms of the UK Air Navigation Order (ANO) as a 'Public transport aircraft'[6]. Even so, it was not in the weight category of helicopter which requires a cockpit voice recorder to be installed.

Although there are no requirements for helicopters such as G-BXLI to carry any equipment for recording flight parameters or cockpit audio information, on this occasion data retrieval from the Skymap IIIc GPS yielded altitude and positional information that would otherwise have been unavailable or less detailed. This enabled an understanding of the last flight, but not the reason for the pilot's decision to return to Staverton on a track which took him over high ground in poor weather conditions. The investigation of this accident would have been enhanced had audio and basic flight parameter recordings been available. Thus, in accidents where there is extensive disruption of the aircraft, it may not be possible to determine the causal factors from wreckage analysis and witness evidence alone. This has proved to be the case in a number of accident investigations, including two recent ones; Hughes 369HS, G-CSPJ (AAIB Bulletin 1/2005), and Cessna 206 G-BGED (AAIB Bulletin 11/2005). In both cases, the reasons for the accident were not established. Before appropriate recording equipment can be developed, however, it is necessary to develop a minimum performance specification. To this end in the report on the accident to G-BGED the AAIB made the following recommendation:

> ***'Safety Recommendation 2005-062***
>
> *It is recommended that the European Aviation Safety Agency [EASA] develop standards for appropriate recording equipment that can be practically implemented on small aircraft.'*

Also, two safety recommendations, 2004-084 and 2004-085, were made as a result of the investigation into the accident to G-CSPJ, and these are reproduced below:

> ***'Safety Recommendation 2004-084***
>
> *The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote the safety benefits of fitting, as a minimum, cockpit voice recording equipment*

Footnote

[6] w.e.f. 28 September 2004, UK national CoAs were deemed to be EASA CoAs. The relevant definition of 'Public transport aircraft' was contained in Article 129 of the ANO 2000, which was in force at the time.

to all aircraft operating with a Certificate of Airworthiness in the Commercial Air Transport category, regardless of weight or age.'

'Safety Recommendation 2004-085

The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote research into the design and development of inexpensive, lightweight, airborne flight data and voice recording equipment.'

In a letter to the AAIB, dated 14 October 2004, the Department for Transport gave its full support to these recommendations.

With EASA now assuming responsibility for matters of airworthiness within the European Community, the following two recommendations are made:

Safety Recommendation 2005-100

The European Aviation Safety Agency should promote research into the design and development of inexpensive, lightweight, airborne flight data and voice recording equipment.

Safety Recommendation 2005-101

The European Aviation Safety Agency should promote the safety benefits of fitting, as a minimum, cockpit voice recording equipment to all aircraft operated for the purpose of commercial air transport, regardless of weight or age.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-CCHZ
No & Type of Engines:	1 Lycoming O-360-J2A piston engine
Category:	2.3
Year of Manufacture:	2003
Date & Time (UTC):	16 August 2005 at 1624 hrs
Location:	Newtownards Airfield, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damage to main rotors and fuselage
Commander's Licence:	Student Pilot
Commander's Age:	50 years
Commander's Flying Experience:	61 hours (61 on type) Last 90 days - 61 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The student pilot had completed a navigation exercise, flying from Newtownards to Enniskillen, St Angelo Airfield before returning to Newtownards. The weather was good with the surface wind at Newtownards from 190º at 10 kt; the visibility was greater than 10 km with scattered cloud at 3,000 ft. On his left leg, the pilot was wearing a plastic knee board on which his map was folded. The kneeboard was attached with a 'Velcro' strap which passed around his leg. Prior to departure from Newtownards, the pilot had carried out a full and free control check of all the flying controls with the kneeboard in place. The controls had not contacted the kneeboard or map.

Following an uneventful landing at St Angelo the pilot departed and returned to Newtownards. There he made a normal approach, parallel to Runway 22 and came to the hover just beyond Runway 16, over the grass area known as 'Heli West'. The pilot did a spot turn to the right and commenced hover taxiing to his parking area on the west side of the airfield. With the wind from the left, he needed to move the cyclic control to the left and at some point the control handle caught under the kneeboard and its attachment strap. The helicopter began to drift to the right which the pilot was unable to correct due to the limited, left, cyclic-control travel. In order to try and free the control, the pilot lifted his left foot off the left tail rotor control pedal. The helicopter yawed to the right, the rate of yaw increasing rapidly. The right landing gear skid contacted the ground and the helicopter rolled to the right, causing the main rotor blades to contact the ground and stopping the engine. The helicopter came to rest on its right side and the pilot closed the fuel shut-off valve and isolated the electrical system. He suffered minor cuts and bruises to his right hand and exited the helicopter through the left door unassisted. The airfield Rescue and Fire Fighting Services were quickly on the scene.

Analysis

The pilot had ensured that adequate clearance was available between the cyclic control and his kneeboard during the full and free control checks. During his landing at St Angelo, he experienced no control restriction difficulties between the cyclic control and his kneeboard. It was only at Newtownards, when the helicopter was turned to the right to hover taxi and the prevailing wind was from the left, that significant left cyclic was used in an attempt to correct the drift of the helicopter to the right.

The left tail rotor pedal is moved forward to oppose the helicopter reaction to yaw to the right due to main rotor torque. By lifting his left foot off the tail rotor control pedal the natural right yawing motion of the helicopter developed rapidly.

Conclusion

The accident was caused by the control restriction created by the pilot's kneeboard. By removing his left foot from the tail rotor control pedal, the pilot allowed the helicopter to yaw to the right and during his attempt to maintain control, the helicopter struck the ground.

ACCIDENT

Aircraft Type and Registration:	Colt 105A Hot Air Balloon, G-BPZS
No & Type of Engines:	None
Category:	3
Year of Manufacture:	1989
Date & Time (UTC):	10 July 2005 at 1855 hrs
Location:	Farmborough, 10km SW of Bath, Somerset
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - 0 Passengers - 2
Nature of Damage:	Burnt panel and burnt through rip line
Commander's Licence:	Private Pilot's Licence (Balloons and Airships)
Commander's Age:	54 years
Commander's Flying Experience:	268 hours (of which 177 were on type) Last 90 days - 7 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

In attempting to land in a field adjacent to a main road, the balloon struck and severed several electricity cables. One of the cables caught a passenger on the back and another passenger was hit by sparks. Both were subsequently treated in hospital for minor burns.

History of the flight

The balloon took off from a site on the western outskirts of Bath at 1820 hrs. Whilst flying to the north east of Farmborough, the pilot decided to land in a field adjacent to, and to the west of, the A39 road. The pilot reported that he instructed the three other people on board (two passengers and a qualified pilot) to check for hazards, but it was not until the balloon had descended to approximately 15 ft agl that the pilot became aware of a line of power cables in his path. He attempted to initiate lift by using the burners but, when it became apparent that the balloon would make contact with the cables, the pilot instructed the passengers to get down in the basket and he turned off the propane fuel supply.

The uprights of the basket struck the cables, causing the wires to meet, short out and break. The cables then fell across the A39 road and struck a passing car, causing minor damage to the car, but no injury to the car's occupants. The pilot subsequently landed the balloon approximately 200 m from the point of impact with the cables where the envelope was deflated and the occupants alighted and were able to walk away. Local police, a police helicopter and ambulance services all attended the scene. One of the wires had caught passenger on their back and another passenger was affected by sparks. Both were subsequently treated in hospital for minor burns.

Weather

The pilot provided both his weather forecast and details of the the actual conditions at the time of the accident. Both of these were in good agreement with 'aftercast' information supplied by the Met Office. There were light north easterly winds of around 7 kt, no cloud below 5,000 ft and the surface visibility was in excess of 15 km. Sunset was at 2024 hrs.

Accident site

Aerial photographs, taken by the police Western Counties Air Operations Unit, revealed that the pole supporting the cables near to their point of contact with the basket was located about approximately 10 m to the east of the A39 road and was obscured by trees, making both the pole and wires difficult to see from the air. The pilot noted that he had elected to land in the field close to the road in order to facilitate easy access for the recovery vehicle, and to minimise damage to the field. Had he chosen to land close to the centre of the field this incident would most likely not have occurred since the field was relatively large and its central area was free from obstructions.

ACCIDENT

Aircraft Type and Registration:	Ikarus C42 FB UK, G-IAJS
No & Type of Engines:	1 Rotax 912 ULS piston engine
Category:	1.4
Year of Manufacture:	2005
Date & Time (UTC):	30 August 2005 at 1910 hrs
Location:	Kinderton Farm, Middlewich, Cheshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 Passengers - none
Nature of Damage:	Substantial damage to right wing, cabin floor, propeller and landing gear
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	237 hours (of which 34 were on type) Last 90 days - 8 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft had completed its first three flights without incident with a PFA check pilot. During a subsequent high speed taxi run made by the owner the aircraft became airborne, so he elected to take off and fly a circuit. On touchdown, the aircraft yawed to the left and the pilot decided to go-around. However, the engine speed decayed, probably due to carburettor icing, and the aircraft stalled from a height of around 50 ft.

History of the flight

The aircraft had been constructed in the pilot/owner's garage and the initial checks and subsequent start-up were carried out with the assistance of a Rotax service centre engineer. The aircraft was transported to Fern Farm for final assembly and there the owner carried out fuel flow checks. A Popular Flying Association (PFA) registered check pilot performed low and high speed taxi tests and also the first three test flights, which were uneventful and which totalled 40 minutes.

The aircraft was then de-rigged and moved to Kinderton Lodge Farm on 29 August 2005, where it was re-assembled. Although it was planned to resume the flight test programme on 30 August 2005 with the PFA check pilot, the pilot/owner decided to carry out some ground runs and taxi the aircraft the evening before. Engine ground runs and some low speed taxiing were completed to his satisfaction and he subsequently decided to perform some high speed taxi runs with a passenger aboard. The pilot/owner completed one uneventful high speed taxi run but, during the second run, he reported that the aircraft "hit a bump" on Runway 07 and "bunny hopped and bounced", causing him to nudge the throttle forward. This resulted in an increase in engine speed. Rather than try to land the aircraft in the limited runway length available, the pilot/owner elected to take off and therefore applied full power. He then flew a left hand circuit without incident and lined up for a landing on Runway 07. As the aircraft touched down, it yawed to the left and the pilot decided to go-around and applied full power. He estimated that the aircraft had reached 50 or 60 ft above the ground when the engine speed decayed, the aircraft stalled and the right wing dropped, resulting in the aircraft striking the ground in a right turn.

The passenger exited the aircraft and was uninjured. The pilot, however, was admitted to hospital having fractured several vertebrae. The aircraft sustained substantial damage, most significant being damage to the propeller, landing gear, cabin frame and the right hand rear wing spar. A general view of the aircraft is shown in Figure 1.

Local conditions

Kinderton Lodge Farm is an unlicensed grass airfield. The pilot was using Runway 07, which is 374 m long and there are trees along the northern edge of the field.

An aftercast supplied from the Meteorological Office, valid for nearby Shawbury and Manchester Airport, indicated that the wind was likely to have been 080º/110º, 3 to7 kt, and the temperature and dew point between 21º/24ºC and 15º/16ºC, respectively. The latter combinations are consistent with conditions that are favourable for serious carburettor icing at low power settings and it is considered that this was a likely factor in the decay in engine speed as the pilot attempted to climb.

Further information

The pilot/owner later reported that he had purchased a carburettor heating system for the Rotax 912 engine but had decided not to fit this to the aircraft.

Figure 1

ACCIDENT

Aircraft Type and Registration:	Microflight Spectrum, G-MWKW
No & Type of Engines:	1 Rotax 503 piston engine
Category:	1.4
Year of Manufacture:	1990
Date & Time (UTC):	23 August 2005 at 1830 hrs
Location:	Sutton Meadows, Cambridgeshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - Nil
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Private Pilot's Licence with Flying Instructor Rating
Commander's Age:	59 years
Commander's Flying Experience:	6,809 hours (of which 128 were on type) Last 90 days - 134 hours Last 28 days - 45 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The 'Spectrum' is a 3-axis microlight aircraft with conventional rudder, aileron and elevator controls.

The instructor and student were involved in a session of circuits on Runway 24, which had a dry grass surface and was 480 m long. The weather was good with a surface wind of 240º/08 kt. The student had previously flown some 55 hours in flex-wing aircraft and, more recently some 40 hours in 3-axis aircraft. His instructor considered that the student was very close to solo standard and the instructor had not been required to make any inputs during the flight, which had involved some six to seven circuits. However, on the final takeoff, the aircraft started to turn to the right and the student failed to correct this movement with rudder. The instructor was unable to intervene before the aircraft left the runway, crossed a drainage ditch and came to rest in a beet field. Colliding with the far side of the ditch damaged the aircraft beyond economic repair.

ACCIDENT

Aircraft Type and Registration:	Thruster T300, G-MYAP
No & Type of Engines:	1 Rotax 582-2V piston engine
Category:	1.4
Year of Manufacture:	1992
Date & Time (UTC):	28 July 2005 at 0800 hrs
Location:	Blowfield, Norwich
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - Nil
Injuries:	Crew - 1 (Minor) 1 (Serious) Passengers - N/A
Nature of Damage:	Substantial damage to the fuselage and wings
Commander's Licence:	Private Pilot's Licence with Microlight Instructor rating
Commander's Age:	48 years
Commander's Flying Experience:	958 hours (of which 700 were on type) Last 90 days - 0 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot plus a video recording of the approach

Background

On Saturday 23 July, the student had been given a trial lesson in the microlight aircraft as a gift. He and his family arrived at the private operating site which was a grass field. The grass strip was orientated north/south and was estimated by the instructor to be between 250 m and 300 m in length, with a width of 45 ft at the narrowest point between the trees. The site was bordered by high trees on the west, north and east sides and open at the south end with a low fern hedge approximately 4 ft high, through which there was an opening to permit vehicle access. Takeoffs were made towards the south with approaches and landing carried out from the south, over the fern hedge.

The aircraft required maintenance prior to the trial lesson and the instructor carried out a short test flight before the student boarded the aircraft. During the flight the engine developed a technical problem resulting in a loss of power and the aircraft was landed back at the strip. Because the lesson had not been completed due to the technical problem, the student was told he would be given another trial lesson.

History of the flight

On the day of the accident the student arrived at the strip with his family and he departed on a local area flight with the instructor. The weather was good with the wind light and variable, good visibility and no cloud. At the end of the flight the instructor carried out the approach and in the latter stages, descended below his normal approach path. He applied power and attempted to clear the fern hedge but the aircraft struck it, yawed to the right and collided with trees. The student was trapped in the wreckage and had to be released by the emergency services following which, he was taken to hospital. Although both occupants were wearing four-point harnesses, the instructor suffered a cut leg and the student suffered two broken legs.

Video evidence

A relative of the student made a video recording which showed the accident and previous approaches. The video confirmed that the aircraft was low on the approach and power was heard to increase but the right wing of the aircraft struck the hedge.

Conclusion

The instructor considered that the accident was caused by the aircraft becoming too low on the approach and his not correcting this in time to prevent the aircraft contacting the fern hedge.

AIRCRAFT ACCIDENT REPORT No 3/2005

This report was published on 15 December 2005 and is available on the AAIB Website www.aaib.gov.uk

REPORT ON THE SERIOUS INCIDENT TO BOEING 757-236, G-CPER on 7 SEPTEMBER 2003

Registered Owner and Operator:	British Airways PLC
Aircraft Type and Model:	Boeing 757-236
Registration:	G-CPER
Place of Incident:	During the climb after departure from London Heathrow and on approach to land at London Gatwick
Date and Time:	7 September 2003 at 1805 hrs (All times in this report are UTC, except as stated)

Synopsis

The incident to the Boeing 757 aircraft occurred on the first flight following a 26-day major maintenance check. Shortly after takeoff on a scheduled passenger flight from London Heathrow to Paris, a hot oil smell, that had been present in the cockpit on engine startup, returned. The flight crew donned oxygen masks and immediately diverted to London Gatwick Airport. During the autopilot-coupled ILS approach to Gatwick, the aircraft drifted to the right of the localiser after selection of Flap 30. When the autopilot was disconnected, a large amount of manual left roll control was needed to prevent the aircraft from turning to the right. It was necessary to maintain this control input until touch down. The aircraft landed safely despite these difficulties, with no injuries to any of the passengers or crew.

The investigation determined that the incident had been caused by maintenance errors that had culminated in the failure to reinstall two access panels, 666AR and 666BR, on the right-hand outboard flap and incorrect procedures being used to service the engine oils. The events were the result of a combination of errors on the part of the individuals involved and systemic issues, that had greatly increased the probability of such errors being committed.

The following immediate causal factors were identified:

1 The tasks of refitting the panels to the right wing and correctly certifying for the work carried out were not performed to the required airworthiness standard.

2 Ineffective supervision of maintenance staff had allowed working practices to develop that had compromised the level of airworthiness control and had become accepted as the 'norm'.

3 There was a culture, both on the ramp and in the maintenance hangar, which was not effective in ensuring that maintenance staff operated within the scope of their company authorisation and in accordance with approved instructions.

4 The maintenance planning and task instructions, relating to oil servicing on the Boeing 757 fleet, were inappropriate and did not ensure compliance with the approved instructions.

5 The Airline's Quality Assurance Programme was not effective in highlighting these unsatisfactory maintenance practices.

Eight safety recommendations are made in this report, with the intention of preventing similar incidents in the future.

Findings

1 The roll control problem on the approach to London Gatwick was caused by the asymmetric aerodynamic effects induced by the absence of flap access panels 666AR/666BR on the right wing outboard flap.

2 Access panels 666AR/666BR had not been replaced during recent maintenance.

3 The technician who incorrectly certified for fitting flap panels 666AR and 666BR was appropriately trained and qualified for the level of task being performed.

4 The technician responsible for certifying for the fitting of the flap panels had misinterpreted the panel diagram in the 757 Aircraft Maintenance Manual and did not recognize that the panels 666AR/666BR are hidden by the flap drive fairings when the flaps are retracted.

5 The same technician assumed incorrectly, after inspecting the right wing on a number of occasions and seeing no 'holes' in the wing, that flap panels 666AR/BR had already been fitted and proceeded to certify for their fitment.

6 In certifying for their fitment, the technician exceeded the scope of his certification privileges, as specified in company procedure TP-Q-8.1.1-01, in that he was only permitted to certify for work that he had performed.

7 The missing panels were not identified during an inspection of the hangar racks at the end of the maintenance activity.

8 The missing panels had been placed on the same shelf as panels removed from the leading edge slats that were similar in size and appearance and were not required to be refitted to the aircraft.

9 The missing flap panels, not being clearly visible when the flaps are retracted, were not noticed prior to the aircraft re-entering service, or during the pre-flight inspection prior to the departure from London Heathrow.

10 A non-procedural approach was used to refit the panels on the right wing whereby all of the panels were installed prior to stamping the job cards.

11 The remoteness of the job card racks from the work area encouraged a non-procedural approach to fitting the panels.

12 Maintenance staff frequently did not certify for tasks they had performed prior to going off shift, placing the responsibility on other maintenance staff and thereby encouraging the practice of 'blind stamping'

13 Maintenance staff were often willing to certify for tasks performed by others without verifying that the task had been completed correctly.

14 The culture of 'blind-stamping' was reinforced by the duplication of panel job cards.

15 Some maintenance staff did not fully appreciate the role that certification plays in the chain of airworthiness control.

16 No defects were found that could explain the oil/burning smells in the cockpit/cabin.

17 Incorrect procedures were used to service the engine oils during maintenance.

18 The incorrect servicing of the engine oils possibly caused the oil smells in the cockpit and cabin.

19 The technician who performed the 'Daily Check' engine oil servicing task and the LAE (Licenced Aircraft Engineer) who certified for the task were appropriately trained and qualified.

20 The technician who performed the engine oil servicing task did not comply with the Aircraft Maintenance Manual instructions.

21 The 'Daily Check' oil servicing task instructions were inappropriately engineered for an aircraft docked in a hangar on heavy maintenance and could not be accomplished practically in accordance with the Maintenance Manual instructions.

22 The LAE who certified for the oil servicing task did not have sufficient oversight of the task and certified for it's completion based purely on assumption that the task had been performed correctly.

23 Both the technician and the LAE involved in the engine oil servicing task exceeded the scope of their authorisation by certifying for work that had not been performed in accordance with approved procedures.

24 The 'Daily Check' engine oil servicing task was not being consistently performed on the ramp as a result of inadequate maintenance planning, which failed to ensure that the time limitations for engine oil servicing were complied with.

25 A culture existed within parts of the Airline's Maintenance Organisation in which LAEs and technicians deviated from approved maintenance instructions and company procedures, without being aware of the airworthiness implications and without a perceived need to seek approval from higher authority.

26 Ineffective supervision of maintenance staff had allowed working practices to develop that had compromised airworthiness control.

27 The Quality Assurance Programme was not wholly effective in highlighting unsatisfactory practices on the shop floor.

28 The established number of Quality Engineers and the broad scope of their responsibilities limited the amount of time they were able to spend in the maintenance environment.

29 There was no consistent policy in the Maintenance Organisation's approach to human factor's issues and its conduct of Maintenance Error Investigations (MEI).

30 Maintenance staff did not believe that the MEI process was objective and saw it as being a means only to effect disciplinary action.

31 The Maintenance Organisation took corrective action following the incident, however, this information was not entered on the Airline's

'eBASIS' safety database to enable the safety management loop to be closed.

32 The Maintenance Organisation had not responded in a timely manner to safety recommendations issued by the Safety Services department's 'BASI 4' investigation into this incident.

33 The Safety Services department's method for tracking safety recommendations to ensure the implementation of timely and appropriate safety actions lacked robustness.

34 The Airline's 'BASI 4' procedure lacked clarity in defining that the Safety Services department's investigation took precedence over other company investigations, with the result that two independent, uncoordinated investigations were carried out.

35 The management of quality standards had been heavily devolved to the various sections of the Airline, with a limited degree of central control.

Safety Recommendations

The following safety recommendations are made as a result of this investigation:

Safety Recommendation 2005-116:

British Airways Maintenance Organisation should take suitable action to ensure that maintenance tasks are certified for in a sequential and timely manner. All maintenance staff should also be reminded of their professional responsibilities, the limit of their authorisation, and that approval from the appropriate authority is required when it becomes necessary to deviate from approved instructions and procedures.

Safety Recommendation 2005-117:

British Airways Maintenance Organisation should review job card rack placement ergonomics to ensure that their positioning does not have a detrimental effect on the sequential and timely certification of maintenance tasks.

Safety Recommendation 2005-118:

British Airways Maintenance Organisation should review their 'Maintenance Error Investigation' process, in order to ensure consistency, traceability and accountability in its application, with a view to restoring the confidence of maintenance staff in the process.

Safety Recommendation 2005-119:

British Airways Maintenance Organisation should review the level of supervision on the 'shop floor' to satisfy itself that it is adequate to maintain the required standards of airworthiness.

Safety Recommendation 2005-120:

British Airways should review their structure and procedures for the management of quality, to satisfy themselves that there is sufficient degree of centralised control over the standards of quality within each section of the organisation.

Safety Recommendation 2005-121:

British Airways Maintenance Organisation should review its maintenance planning and production control procedures, for the servicing of B757 engine oils, to ensure compliance with the Aircraft Maintenance Manual at all times, in both operational and heavy maintenance environments.

Safety Recommendation 2005-122:

British Airways Maintenance Organisation should take suitable actions to ensure that the Engineering Quality Services department has a better oversight and understanding of the day to day practices in the areas where maintenance is carried out.

Safety Recommendation 2005-123:

The European Aviation Safety Agency (EASA) should consider introducing a requirement to carry out a duplicate inspection on aircraft access panels, removed and refitted or opened and closed as part of a maintenance procedure, that could significantly affect airworthiness if incorrectly secured and should they detach in flight, endanger either the aircraft, or persons on the ground.

The responses, by British Airways, to the above recommendations are included in the full report.

FORMAL AIRPORT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2003

3/2003 Boeing 747-2B5F, HL-7451
near Stansted Airport
on 22 December 1999.

Published July 2003.

4/2003 McDonnell-Douglas MD-80, EC-FXI
at Liverpool Airport
on 10 May 2001.

Published November 2003.

2004

1/2004 BAe 146, G-JEAK
during descent into Birmingham
Airport on 5 November 2000.

Published February 2004.

2/2004 Sikorsky S-61, G-BBHM
at Poole, Dorset
on 15 July 2002.

Published April 2004.

3/2004 AS332L Super Puma, G-BKZE
on-board the West Navion Drilling Ship,
80 nm to the west of the Shetland Isles
on 12 November 2001.

Published June 2004.

4/2004 Fokker F27 Mk 500 Friendship,
G-CEXF at Jersey Airport,
Channel Islands on 5 June 2001.

Published July 2004.

5/2004 Bombardier CL600-2B16 Series 604,
N90AG at Birmingham International
Airport on 4 January 2002.

Published August 2004.

2005

1/2005 Sikorsky S-76A+, G-BJVX
near the Leman 49/26 Foxtrot Platform
in the North Sea on 16 July 2002.

Published February 2005.

2/2005 Pegasus Quik, G-STYX
at Eastchurch, Isle of Sheppey, Kent
on 21 August 2004.

Published November 2005.

3/2005 Boeing 757-236, G-CPER
on 7 September 2003.

Published December 2005.

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