Aircraft Type and Registration:	Airbus A320-231, G-JOEM
No & Type of Engines:	2 IAE V2500-A1 turbofan engines
Year of Manufacture:	1993
Date & Time (UTC):	17 March 2004 at 1540 hrs
Location:	Birmingham Airport, West Midlands
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 168
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to forward left cabin door
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	7,000 hours (of which 4,400 were on type) Last 90 days - 155 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

History of the accident

Passengers were boarding the aircraft through the forward left cabin door, via an airbridge (see Figure 1). When approximately two-thirds of the passengers had embarked, the cabin crew noticed that the bottom of the door, which opens outwards and forwards, was in contact with the floor of the airbridge. The crew contacted their handling agent and one of their staff attended the aircraft.

On arrival at the airbridge the ground agent noticed that the airbridge 'autolevel' alarm had activated. This indicated that there was an autolevel malfunction or that the 'travel timer' had tripped, or both. (Note: The autolevel circuit includes an adjustable timer that permits the airbridge's vertical travel motor to operate continuously for a maximum of six seconds.) She also saw that the autolevel 'safety shoe' (see Figure 2) was not in place on the airbridge floor beneath the aircraft door. The safety shoe is designed to create a 'signal' that triggers the airbridge to descend when the bottom of the aircraft door touches the shoe, thus preventing contact between the door and the airbridge.

The ground agent pressed the autolevel reset button, which was flashing on the airbridge control panel, and passenger boarding was stopped. She stated that the airbridge then moved up slightly and she immediately hit the emergency stop button, thus cutting power to the airbridge and freezing its position. The passengers who had already boarded were disembarked, to reduce the pressure on the bottom of the aircraft door; the airbridge controls were reset and the airbridge was moved away from the aircraft. The forward left door of the aircraft had sustained damage to its hinges and its bottom edge.

Examination of the autolevel sensor on the airbridge (see Figure 3) showed that the wheel had rotated to its full extent and jammed, indicating that the aircraft had descended relative to the floor of the airbridge. Once the wheel had been freed, the autolevel system was tested and found to operate correctly.

Previous activity

The airbridge had been driven into position and deployed when the aircraft had arrived on the stand earlier in the day. The operator of the airbridge, at that time, had noticed that there was no 'safety shoe' available to place beneath the aircraft door. However, in the absence of any report that the airbridge had been taken out of service, he continued to disembark the passengers. On completion, the airbridge remained in position against the aircraft for approximately three hours to await the next departure.

The dispatcher for the departing flight also noticed that the safety shoe was missing when he arrived at the aircraft. He reported the fact to the Building Maintenance Centre and continued to arrange for passenger boarding to commence. He stated that he had then returned to the handling agent's office, while the passengers were boarding, to obtain some paperwork and was away from the airbridge for about 20 minutes. It was during that period that the accident occurred.

The airport's Building Maintenance engineers had removed the safety shoe on 9 March 2004 when it was found to be damaged. However, the airbridge remained in service until the accident, eight days later. The airbridge was subsequently taken out of service pending the replacement of the safety shoe on 18 March 2004.

Operation of the Airbridge

The autolevelling system

The airbridge is equipped with an autolevelling system which automatically follows small changes in the height of the aircraft door sill. This 'autoleveller' includes a wheel and sensor unit mounted on the end of a retractable arm located on the airbridge head floor. The wheel rests against the aircraft fuselage and rotates as the aircraft rises or falls with respect to the airbridge (see Figure 4). The autolevel circuit also contains an adjustable timer, which permits the vertical travel motor to operate continuously for a maximum of six seconds. At the end of this time all power to the system is removed, an audible alarm sounds and a warning light is energised at the control panel.

The autolevel mode is activated by the "AUTOLEVEL OUT" pushbutton on the control panel and deactivated by the "AUTOLEVEL IN" pushbutton. Pressing these buttons extends and retracts the autolevel arm, respectively.

The Safety Shoe

The safety shoe detects and automatically corrects for an insufficient gap between the aircraft door and the airbridge head floor, protecting the door from damage due to excessive lifting forces. When the airbridge has been correctly positioned against the aircraft, the operator places the safety shoe on the bridge head floor under the aircraft door. If the door comes into contact with the safety shoe, the bridge head is driven down and an alarm sounds. The alarm remains until manually reset. There is no provision in the manufacturer's instructions for operating the airbridge without the safety shoe in position, although it is possible to do so.

Manual Operation

The airbridge can be operated manually, without the autolevelling system, by retracting the autolevel sensor and activating the up and down commands on a joystick on the control panel. The manufacturer's instructions state that if an autolevel or safety shoe alarm is activated in the autolevel mode, then, having pressed the appropriate fault reset pushbutton, the "AUTOLEVEL IN" pushbutton is to be pressed and the airbridge is to be controlled manually.

Operator Training and Licensing

The airport authority issues instructions for the operation of this airbridge and administers the training given to operators. The training itself is delegated to the handling agent and, on completion, operators are issued with a licence by the airport authority, valid for three years.

Both airbridge operators had been trained and were currently qualified in accordance with the airport's procedures. Their training included a demonstration of the safety shoe and the actions to take in the event of an airbridge malfunction. Both their licences were valid, with the dispatcher's licence due to expire on 27 August 2004.

Discussion

The autolevel system sensor wheel had rotated to its fully 'down' position and jammed, suggesting a protracted movement of the aircraft in that direction. The autolevel alarm had activated and this indicated that there was a malfunction in the autolevel system or that there had been continuous 'levelling' of the airbridge for a maximum of six seconds. Following this alarm, the correct procedure would have been for an operator to operate the airbridge manually. Why the airbridge moved up slightly after the autolevel rest button had been pressed, as reported, is not clear. Nor was it apparent which of the two causes had triggered the alarm.

The absence of a safety shoe on the airbridge head floor removed the 'secondary' protection which would have prevented the airbridge from exerting excessive vertical loads on the aircraft door. Activation of that protection feature also initiates an alarm, which, when it occurs, requires cancellation by the operator and reversion to manual control. There is no provision in the manufacturer's instructions for operation of the airbridge without the safety shoe in place.

Following the accident, the airport authority took the airbridge out of service until the safety shoe had been replaced. They also issued a new Airport Operating Instruction which stated that;

> *No airbridge must be left unattended whilst in the "Auto-Level" condition when docked to an aircraft. A qualified operator must remain in attendance to respond to any audible alarm that may occur. During the period between completing disembarkation and boarding passengers for the next flights, if the airbridge is to be left unattended, the aircraft door should be closed, the jetty withdrawn clear of the aircraft side and shut down.*

The handling agent has reduced the period between refresher training courses for airbridge operators from every three years to annually. He has also instructed dispatching staff that if a safety shoe is missing and should be present, as with this design, then the airbridge is unserviceable.

Figure 1

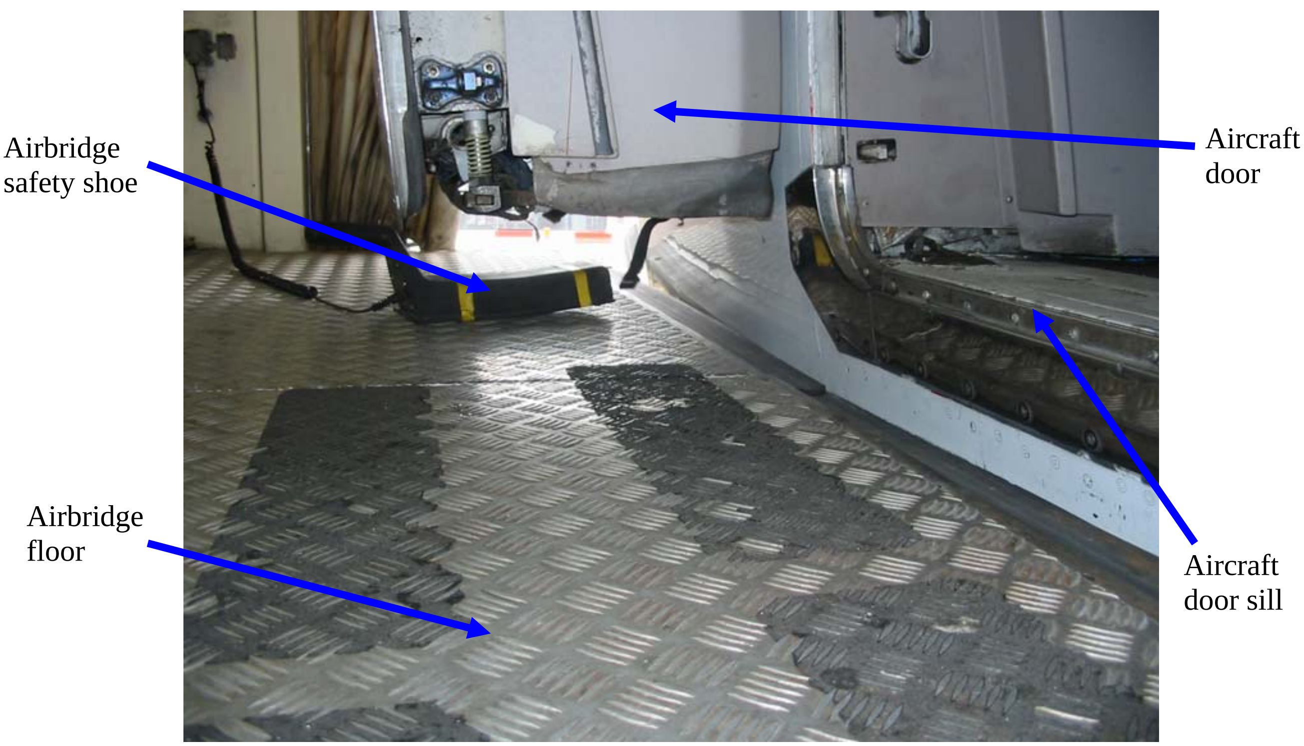

Figure 2

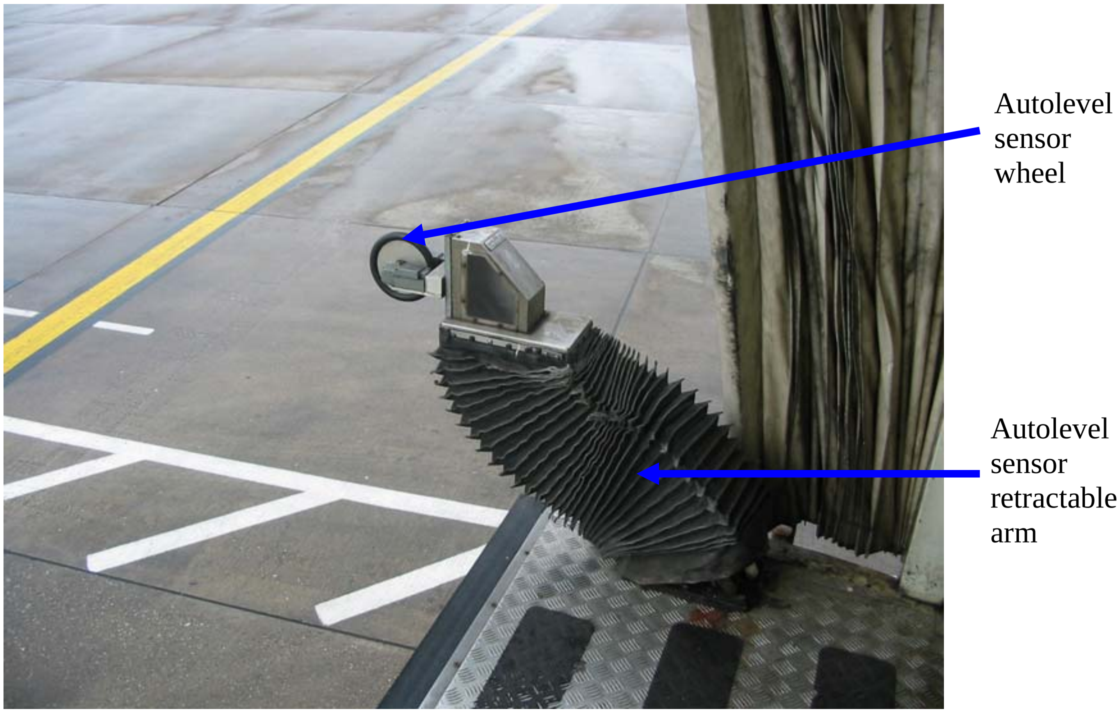

Figure 3

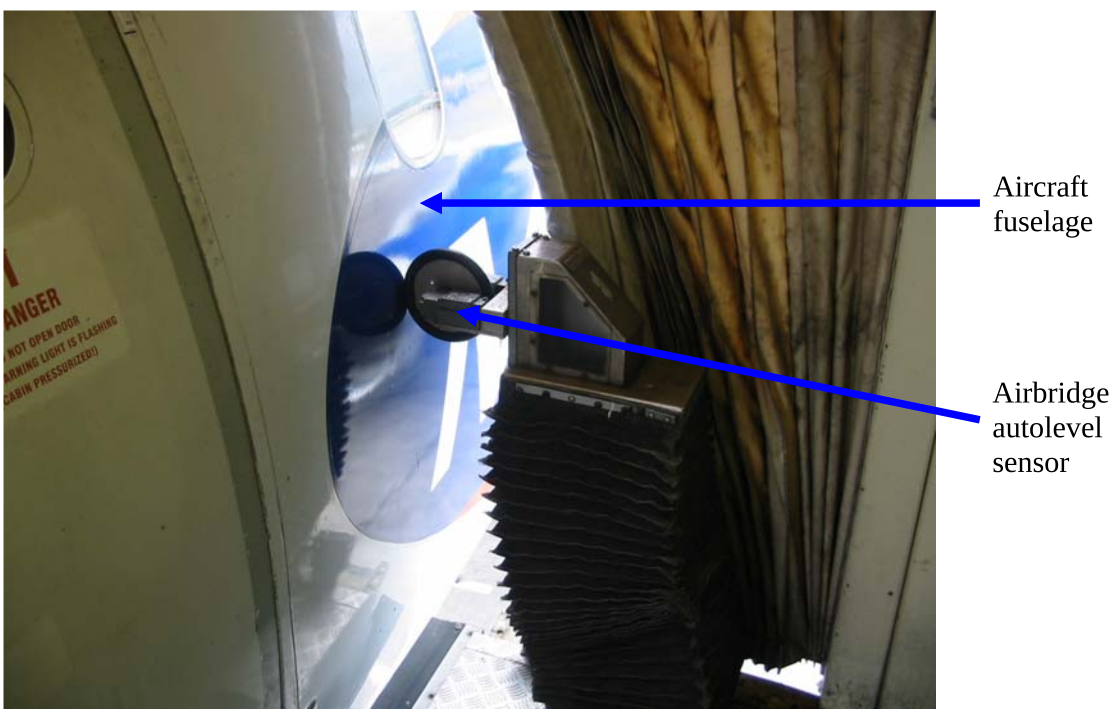

Figure 4

Aircraft Type and Registration:	Falcon 50, CS-DFI	
No & Type of Engines:	3 TFE-731 turbofan engines	
Year of Manufacture:	1982	
Date & Time (UTC):	16 September 2004 at 1035 hrs	
Location:	London City Airport, London	
Type of Flight:	Commercial	
Persons on Board:	Crew - 2	Passengers - 4
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Nil	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	6,465 hours (of which 498 were on type) Last 90 days - 118 hours Last 28 days - 42 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

After landing at London City Airport the aircraft was taxied to a parking area on the busy general aviation apron and manoeuvred under the guidance of a marshaller. The commander instructed the First Officer to monitor the right wing tip and slowed the aircraft almost to a halt as it passed a parked Cessna Citation. The First Officer considered that there was adequate clearance between the two aircraft and the Falcon continued straight ahead in accordance with the marshaller's instructions. Shortly afterwards, the commander felt a gentle impact as the right wing tip struck the nose of the Citation. Neither aircraft was visibly damaged and there were no injuries.

INCIDENT

Aircraft Type and Registration:	MD-83, SE-RDL
No & Type of Engines:	2 Pratt & Whitney JT8D-219 turbo-fan engines
Year of Manufacture:	1990
Date & Time (UTC):	17 July 2003 at 2314 hrs
Location:	Londonderry, Northern Ireland
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 134
Injuries:	Crew - None Passengers - None
Nature of Damage:	Stone damage to underside of starboard wing and fuselage
Commander's Licence:	Air Transport Pilot's Licence (Norwegian)
Commander's Age:	61 years
Commander's Flying Experience:	15,744 hours (8,000 on type) Last 90 days - 257 hours Last 24 hours - 5 hours
Information Source:	Investigation performed by Swedish Authorities with AAIB assistance

This incident was reported to the UK Air Accidents Investigation Branch by the Londonderry Airport Air Traffic Control.

Since this was considered to be an operationally related incident occurring to a Swedish registered aircraft operated by a Swedish based company, the Swedish investigation authority was approached and they agreed to conduct this investigation. The AAIB assisted by performing the Flight Data Recorder replay and analysis and providing the necessary meteorological and airfield data and some photographic evidence.

The English version of the Swedish report on this investigation is available on the Swedish Accidents Investigation website at www.havkom.se. After selecting the 'English' button at the top of the Home Page, the PDF report designated RL 2004:30e can be selected.

Aircraft Type and Registration:	Raytheon 390 Premier 1, N200PR	
No & Type of Engines:	2 Williams FJ-44 turbo-jet engines	
Year of Manufacture:	2001	
Date & Time (UTC):	7 April 2004 at 0932 hrs	
Location:	Blackbushe Airfield, Hampshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	FAA Private Pilot's Licence with Instrument Rating	
Commander's Age:	39 years	
Commander's Flying Experience:	4,511 hours (of which 413 were on type) Last 90 days - 60 hours Last 28 days - 12 hours	
Information Source:	AAIB Field Investigation	

Synopsis

After takeoff the pilot was unable to raise the landing gear and was presented with failure indications affecting both the lift dump and anti skid systems. Following a successful landing at Farnborough, and discussions with the aircraft's maintenance organisation, the aircraft was flown to Blackbushe for further technical investigation. After landing on Runway 26 the aircraft left the runway, struck a series of obstructions and was destroyed: there was no fire and the pilot was uninjured.

The support bracket for the right main landing gear weight-on-wheels switch was found to have sustained a pre-impact failure which accounted for the indications reported by the pilot. Five recommendations have been made as a result of this investigation.

History of the flight

The following has been compiled from witness statements and evidence retrieved from the Cockpit Voice Recorder (CVR) and the Enhanced Ground Proximity Warning System (EGPWS).

It was planned that the aircraft should undertake a series of flights originating from Luton Airport, Bedfordshire. The first flight from Luton to Humberside Airport was uneventful, and the aircraft took off for the second flight from Humberside to Dublin with the pilot and six passengers on board. Once airborne the pilot selected the landing gear control handle to UP, but although the control handle moved the landing gear remained in the fully extended position with three green lights illuminated on the landing gear indicator. The pilot attempted to re-cycle the landing gear but without success; later he noticed that he also had indications of LIFT DUMP FAIL and ANTI SKID FAIL.

Since the aircraft had insufficient fuel to continue to Dublin with the landing gear extended the pilot decided to divert to Luton, where he knew engineers familiar with the aircraft would be available. After further consideration he subsequently diverted to Farnborough and arranged through ATC for ground engineers from the aircraft's maintenance organisation, who were located at the nearby Blackbushe Airfield, to meet the aircraft. Whilst en route to Farnborough the pilot consulted the checklist for LIFT DUMP FAIL and noted that with this system inoperative the landing distance required (LDR) was increased by 53%; the landing distance available (LDA) at Farnborough of 1,800 metres was greater than this increased LDR. He also thought that he had consulted the ANTI SKID FAIL checklist, but contrary to this checklist Flap 30° was used for landing and the anti skid switch was left in the ON position. Conscious of the increased LDR he requested permission to land short of the displaced threshold on Runway 24 at Farnborough. After touchdown the pilot attempted to deploy the lift dump system but, as expected, the lift dump spoilers failed to extend. Nevertheless, the landing roll was uneventful and, in particular, the braking seemed effective; at one stage, and despite the ANTI SKID FAIL indication, the pilot thought that he felt the anti skid system operate.

The aircraft taxied to the parking area and was met by an engineer from the aircraft's maintenance organisation. After discussions with the pilot the engineer carried out a visual inspection of the landing gear weight-on-wheels (WOW) switches and utilised the built in test equipment to conduct checks of the spoiler control system and the anti skid system. There were no obvious problems with the WOW switches and neither system test revealed any fault but the engineer, aware of a history of lift dump system problems with the aircraft type, suggested that the aircraft should be ferried to Blackbushe for further technical investigation. The pilot arranged for his passengers to travel to their intended destination by alternative means and then verified that sufficient landing distance was available at Blackbushe, including an allowance for the continuing failure of the lift dump system.

(In the prevailing conditions this calculated LDR was almost exactly the same as the LDA.) The pilot then agreed to fly to Blackbushe and decided to complete the short flight without attempting to retract the landing gear.

The takeoff from Farnborough was uneventful, but shortly after becoming airborne the pilot noticed a recurrence of the LIFT DUMP FAIL indication. Since this had been expected, and allowed for, the pilot continued to Blackbushe but decided not to attempt to deploy the lift dump system after landing. Having consulted the abnormal checklist for LIFT DUMP FAIL on the previous flight the pilot did not attempt to refer again to that checklist. The pilot could not recall seeing the ANTI SKID FAIL indication during the flight to Blackbushe.

The meteorological conditions at Blackbushe were good with a surface wind of 350°/10-15 kt and no significant weather. The pilot joined downwind for a visual approach and landing on Runway 26 and the touchdown, which was witnessed by several people on the ground, appeared to be about 100 metres beyond the displaced threshold. After touchdown the pilot applied the brakes progressively but felt no retardation; he released and then reapplied the brakes but was still unaware of any discernible braking effect. Conscious of the poor overrun for Runway 26 the pilot decided to initiate a takeoff and applied power, but the engine response felt slow and he decided that there was now insufficient runway remaining to achieve rotation speed. The take-off configuration warning horn was recorded by the CVR and indicated that the thrust levers were forward of the 80% position for 3.7 seconds. Having now decided to abandon the attempt to take off the pilot closed the thrust levers and reapplied the brakes, but once again perceived no effective braking. The end of the runway was now rapidly approaching and he decided to steer the aircraft off the paved surface and on to the adjacent grass in an attempt to increase the retardation. After travelling across the grass for a short distance the aircraft yawed to the left, but continued in the same direction whilst skidding sideways and crossed a parallel taxiway before hitting a small embankment. The aircraft eventually came to a halt pointing roughly in the opposite direction to travel and with the wings detached from the fuselage; there was no fire. The fuselage came to rest on its left side and the pilot, who was uninjured, was therefore unable to vacate the aircraft through the main access door which was situated on the left side of the aircraft. The emergency exit, however, located on the right of the fuselage had opened during the impact and the pilot made his way aft into the passenger cabin to make his escape. Upon reaching the exit he realised that one of the engines was still running and he returned to the cockpit to shut down the various aircraft systems before leaving via the emergency exit.

Pilot's Experience

The pilot started flying in the mid 1980's and after gaining sufficient flying hours he obtained a commercial pilot's licence. Since then his professional flying had been conducted predominantly on light twins and business jets, although he had flown the BAe 146 for two years with an airline. In recent years he had been flying a Cessna Citation for the owner of the accident aircraft, but in April 2002 the owner changed aircraft and bought a new Raytheon Premier 390 (manufacturer's designation RB 29). Type training was provided by a training organisation in the USA under contract to the manufacturer. The aircraft was registered in the USA and the pilot therefore needed to obtain a FAA flying licence. Since the aircraft was to be used only for private flights the pilot obtained a FAA PPL on the basis of his UK licence. At the time of the accident the pilot had accumulated 413 hours on type most of which had been on RB 29.

The pilot reported that, as expected, there had been a number of teething problems with the new type, but whereas these would normally be resolved as the aircraft matured, in the case of RB 29 the problems persisted. A number of these problems included the lift dump system but, in general, there seemed to be no common factor; however, many involved spurious indications. The owner grounded the aircraft for a period to allow the engineers time to address the problems and changed the maintenance organisation, but although these measures produced some improvement the aircraft continued to perform below the owner's expectations. In November 2003 the manufacturer agreed to replace RB 29 and a new aircraft, RB 79, was delivered. The pilot indicated that although RB 79's reliability was somewhat improved over that of RB 29, some problems remained. The pilot stated that the continuing difficulties with the aircraft's reliability had affected his confidence in the machine and, in particular, he lacked confidence in the authenticity of the aircraft's warning systems.

Accident Site

The aircraft had come to rest at the end of Runway 26, in the fuel bund[1]. Examination of the runway, at the point of touchdown estimated from witness evidence, did not reveal any tyre markings and therefore it was not possible to determine the exact point at which the aircraft had touched down. A later download of the EGPWS revealed the point at which the aircraft had passed through 50 feet on the approach, and from this and data provided by the manufacturer, the estimated touchdown position was derived, this is shown on Figure 1. Some 580 metres from the threshold of Runway 26, tyre markings were evident which were continuous and followed a path that met an area of ground marks on the grass to the left of the runway. These were grey in appearance with the tyre tread pattern also visible. The initial marks were of two lines, one to the left and the other to the right of

[1] Bund. An embankment constructed to protect the fuel storage area

the runway centre line, with the distance between them matching that of the distance between the left and right main wheels of N200PR. These marks followed the centre line of the runway for around 180 metres, after which they deviated toward the left. At this point the nose wheel tyre markings became more prevalent. During this left turn, the left tyre mark was wider than the mark deposited by the right tyre, indicative of the crosswind lifting the right wing. The markings showed the aircraft had left the runway surface to the left and entered soft ground and then followed a track of 224°. Some 170 metres after leaving the runway the nose wheel marks crossed with the left wheel ground marks, indicating a progressive yaw to the left with the aircraft maintaining the same track. A short distance later the aircraft passed over the taxiway at the end of Runway 26, leaving black marks from the main landing gear tyres and no mark from the nose, indicating that the nose gear left the ground at this point. The aircraft had now yawed to the left through 90° and the right wing was pointing in the direction of travel. The nose gear then fractured, following which the right wing contacted the banking of the fuel bund; the right forward section of the fuselage then contacted a tree. Figure 1 shows the path of the aircraft during the accident.

When the wing was abruptly stopped by the fuel bund, the aircraft rolled and pivoted about the tree to the right, in the process detaching the entire wing due to the fracture of the wing to fuselage attaching tie rods. When the aircraft finally came to rest the wing had become airborne and landed on top of the fuselage, just aft of the cockpit area. In the final accident sequence the right main gear had also collapsed and the right engine had detached from its pylon, but was retained to the aircraft by fuel and control lines.

The aircraft had come to rest with the fuselage lying on its left side, thus preventing easy access through the main door. Fortunately, the emergency exit was located on the right of the aircraft and the pilot was able to egress through it. The emergency exit door was found lying in the aircraft on the left passenger seat directly opposite the door and in a position indicating that it had fallen into this position after the aircraft came to rest.

There was no fire, but the right wing fuel tank had been ruptured and had leaked a significant amount of fuel before it was staunched by the fire service. The aircraft had come to rest within a few metres of entering the fuel storage area, which contained three fuel trucks full of aviation gasoline and several propane cylinders; this was all within a few metres of the busy A30 trunk road.

Aircraft Description

General

N200PR was a light business jet powered by two turbojet engines. The monocoque fuselage of the aircraft was made of composite material, with the wing constructed of metal. The interface between the wing and the fuselage was by the use of four metal tie rods and a shear attachment fitting at the front of the wing centre section. Access to the aircraft was through a main access door located on the left of the fuselage, with an emergency exit on the right side of the aircraft. The aircraft had been certified by the FAA under Regulation 14 CFR Part 23, which allowed the aircraft to be operated by a single pilot under instrument flight rules.

Weight On Wheels (WOW) Switches

To provide an indication of whether the aircraft was in the air (IN AIR) or on the ground (ON GND), WOW switches were installed on each of the main landing gear torsion links: their operation is depicted in Figure 2. Each switch consisted of a plunger that operated four internal microswitches. The WOW switch was mounted on the upper torsion link and the target used to depress the plunger was installed on the lower torsion link of each main landing gear. When the aircraft was ON GND the landing gear strut would be compressed, opening the torsion links and moving the target away from the plunger of the WOW switch. In this condition the microswitches would be open indicating to the various systems that the aircraft was ON GND.

Once the aircraft was in the air the gear strut would extend and the torsion links expand, allowing the target to depress the plunger of the WOW switch and close the microswitches. Therefore, to provide an IN AIR indication to the various systems, the microswitches are closed.

The adjustment (rigging) of the WOW switch, so that the target correctly contacted the plunger IN AIR, was accomplished by lower and upper adjustment nuts which had to be tightened and loosened in unison to prevent undue stress on the WOW switch and bracket (Figure 4). Once adjusted the nuts would be wire locked together.

Landing Gear Retraction

The tricycle landing gear was retracted by the operation of the cockpit landing gear lever. When the aircraft was on the ground a locking solenoid prevented the lever from being moved to UP. Once the aircraft was in the air, the left WOW switch commanded the locking solenoid to de-energise allowing the handle to move freely.

Upon selecting the landing gear control handle to UP the first action was for the inboard landing gear doors to open. However, for this to occur the right WOW switch must indicate IN AIR; this prevents the operation of the door retraction circuit on the ground. Once the doors had opened the landing gear selector valve would port hydraulic pressure to the retract actuators of the three landing gears. After the gears had retracted, the inboard doors would then return to their faired position.

The warning system provided an indication of the gears being down and locked by the use of three green light indicators, located beside the gear selector lever. Red gear transition lights provided an indication that the gears were not in the commanded position.

Lift Dump System (Figure 3)

N200PR was equipped with six spoiler panels, three on each wing. The two outboard spoiler panels on each wing provided the speedbrake function as well as roll augmentation. The inner spoiler panel on each wing, in combination with the two outer spoiler panels, accomplished lift dump. A spoiler control unit (SCU) electronically controlled the speedbrake/lift dump function with the panels being hydraulically actuated.

Speedbrake operation only occurred if certain aircraft configurations were met: these being either left or right WOW switch indicating IN AIR, both engine thrust levers advanced beyond 80% N1 and the flaps at a position less than 23°. The speedbrakes would then operate as commanded by the speedbrake switch located on the centre pedestal.

Lift dump is utilised to rapidly reduce the lift during landing thereby assisting the aircraft to stop. On N200PR, lift dump was provided by the use of a manual lever located to the rear of the centre pedestal. Prior to touchdown, the system is 'armed' by moving a LOCK/UNLOCK switch to UNLOCK. This removes a solenoid lock on the manual lift dump lever allowing it to move freely. On landing the lift dump handle is then moved aft to EXTEND, the spoiler panels are then deployed. No other conditions are required to be met: it is therefore possible to operate the lift dump system in the air.

The SCU monitors the system to detect any malfunctions. Incorporated in this monitor function is a built in test (BIT) which is carried out prior to each flight after the aircraft electrical and hydraulic systems has been powered. This BIT checks the entire system and, if it is successful, allows the system to operate. Any failure during this test renders the system inoperative with an associated warning on the cockpit warning display. Included in this test is the WOW switch status. For the BIT to operate the aircraft had to be on the ground with ON GND indications from both the left and right WOW switches.

The SCU continues to monitor for faults throughout the flight, if a fault is detected it provides a warning in the cockpit and renders that system inoperative. Faults can only be reset once the aircraft is on the ground and the BIT test have been completed. One such monitor is for a WOW disagree: if a discrepancy between the left and right WOW switches persists for more than six seconds then the SCU will fail the lift dump system. The LIFT DUMP FAIL light will illuminate on the cockpit warning panel and the system will be rendered inoperative, although the speedbrake function will remain. Any attempt to operate the lift dump with LIFT DUMP FAIL annunciated would result in a warning light in the lift dump handle and an aural warning tone in the cockpit.

Braking and Anti Skid System

The aircraft was equipped with multi-disc, hydraulically operated brakes on the left and right main wheel assemblies. Operation of the brakes is through the pilot's rudder pedals connected via cables to the power brake/anti skid control valve (PBCV). The PBCV converts the input from the cables to a related hydraulic pressure, which is then applied to the hydraulic actuators on the brake discs. Feedback of brake application, to provide 'feel' to the pilot, is effected by springs on the input to the PBCV.

In addition to the normal braking above, the aircraft was equipped with an anti skid system. This is commanded by an anti skid control unit (ASCU), and powered when the anti skid switch, in the cockpit, is selected to NORM. During normal operation of the anti skid system the ASCU receives inputs from the left and right WOW switches together with wheel speed transducers on each of the main wheels. The WOW switches indicate to the ASCU that the aircraft is on the ground; this is for touchdown protection and prevents the application of brakes prior to landing. Once the WOW switches indicate ON GND, the system will wait for three seconds before allowing the brakes to apply, or until the wheel speed had reached a speed above 60 kt.

The anti skid operation will commence once the brakes have been applied and the wheel speed has increased to above 60 kt. The system will then monitor the wheel speed and determine the optimum brake application by modulating the hydraulic pressure output from the PBCV. This requires the system to determine a reference skid speed; thus initially the brakes continue to apply pressure until the tyres start to skid. Once a skid had been detected, the ASCU releases the brake pressure to prevent a sustained skid. Following this initialisation, the ASCU will then regulate the brake pressure through the PBCV and modulate it to provide the optimum level for stopping the aircraft without inducing a skid. If the brakes were released and then reapplied, the system would have to repeat this initialising sequence.

For effective braking there is a need for positive contact between the tyre and the paved surface; this relies on a vertical load which, on this aircraft, is augmented by the operation of lift dump. When the aircraft ground speed reduces the vertical load increases and the brakes become more efficient. This provides a non-linear trend to the aircraft's ground speed when it is slowed by the brakes, with the greatest amount of speed being removed during the final stages of the landing roll.

Take-off Configuration Warning

To prevent the aircraft taking off in an abnormal configuration it was equipped with a system which provided an aural warning which sounded if a take off was attempted with any of the following conditions:

- Both roll/speedbrake surfaces greater than 1°
- Either speedbrake/lift dump lever sensors in the extended range
- Either lift dump surface not retracted
- Flap position greater than 22°
- Flap fail signal
- Pitch trim actuator between 3.18° and 4.39°

The system assumed that a takeoff was being attempted if either left or right thrust lever was advanced beyond 80%.

Detailed Wreckage Examination

The aircraft wreckage was taken to the AAIB facility at Farnborough for further investigation. Examination of the wreckage revealed that the landing gear was in the extended position, the flaps were fully extended and all speedbrake panels were retracted. The main landing gear tyres were fully inflated with the tread still visible and there were no flat spots or signs of aquaplaning. The nose wheel had been thrown clear of the wreckage and was found beyond the fuel depot, it had deflated but otherwise had little damage. The main wheels were free to turn and the brake pads were intact with the brake wear indicators showing little brake disc wear, there were no signs of overheating in this area.

Inside the cockpit: the manual lift dump handle was in the RETRACT position and the lock/unlock switch in LOCK, the speedbrake switch was in the RETRACT position and the anti skid switch was in NORM. The left engine throttle was in CUTOFF and free to move and the right engine throttle was stuck in IDLE.

Because the pilot had reported that he had been unable to retract the main landing gear the WOW switches were examined in detail. Checks of the electrical operation and the rigging of the switches found them to be correct. However, the right main landing gear WOW support bracket was found fractured and the fracture surface was not as expected for an overload failure associated with impact forces. The fracture was perpendicular to the landing gear torsion link it was fitted to, and ran across the bracket from a hole used to retain the tang of a washer (see Figure 4). The bracket was sent for metallurgic examination, along with the intact support bracket for the left gear WOW switch.

Metallurgy

The metallurgic examination revealed that the right WOW support bracket had cracked due to stress corrosion which had initiated at the tang washer outer tang support hole (see Figure 4). Localised galvanic corrosion had been set up at the outer tang support hole due to the presence of the dissimilar metals of the aluminium support bracket and the steel tang washer, and brought about by contact with an electrically conductive liquid such as rain water. The stress part of the mechanism was due to the tang washer having been rotated in relation to the WOW switch, causing the inner tang of the washer to become jammed in the threads of the WOW switch. This caused the outer tang of the washer to be forced against the edge of the outer tang support hole, causing the edge of the outer tang to penetrate the paint protection and apply a tensile stress on the bracket. In addition, corrosion was also discovered on the underside of the bracket where the teeth of the steel lock washer had 'bitten' through the paint and into the aluminium of the bracket; this had also set up galvanic corrosion.

The left WOW support bracket was also examined, this revealed that its tang washer had similarly rotated in relation to the WOW switch. A microscopic examination of the outer tang support hole also revealed the beginnings of stress corrosion cracking.

Component Testing

Both WOW switches were tested in-situ and were found to operate normally. The load required to operate each microswitch, via the plunger, was within the manufacturers specified limits.

The ASCU, PBCV and the wheel speed transducers were tested by the manufacturer. All of the units tested to the specification defined for the units and did not reveal any other defects.

The SCU was taken to the manufacturer for a detailed examination, including the download of its fault memory. The SCU was tested and found to conform to the required specification. The information contained in the download can be found in Appendix A. Two sets of 'NM' codes were recorded which indicate faulty WOW switches, and these occurred concurrently indicating that a BIT test and reset must have been carried out between them. It has been determined that the first set of codes related to the LIFT DUMP FAIL shortly after takeoff from Humberside. It is known that the engineer carried out a BIT test and reset of the controller at Farnborough, and therefore the second set of NM codes can be related to the flight from Farnborough to Blackbushe.

Emergency Exit Door

The emergency exit door on the aircraft was located on the right of the main fuselage. It had a plug type door which opened inwards into the aircraft cabin. Locating lugs at the bottom of the door met with pads in the lower doorframe, when it was inserted into the door aperture. Two latches at the top of the door located onto pads in the upper door aperture. Release of the door involved the pulling of a handle which retracted the latches away from the upper pads and allowed the door to pivot about the lower door pads, before being pulled upwards out of the aperture. Door adjustment, to allow a flush fitting of the door, was carried out by shimming the upper locating pads.

The emergency exit door was inspected for any signs of damage to explain why it fell inwards during the accident. The door was intact and the upper latches operated normally when the emergency exit handle was pulled, with the latches returning to their retaining position when they were released. The door was installed back into the door aperture, once installed it was obvious that the door no longer fitted the aperture snugly. There was a clear gap at the top of the door and the door was not faired to the aircraft fuselage. Also the upper locating latches were no longer aligned with the locating pads.

Examination of the structure showed that the composite structure above and forward of the door had been significantly damaged during the accident. This had caused the structure to deform and weaken to the extent that the upper locating latches no longer aligned with the locating pads.

Flight Time and Hobbs Meter

The aircraft was equipped with a "Hobbs" meter, which recorded the actual flight time. The meter was configured to start recording once the right WOW switch indicated IN AIR and then stop when the switch indicated ON GND. The last confirmed Hobbs meter reading was recorded during N200PR's last maintenance input on 2 April 2004, with a reading of 101.2 Hours.

Based on the aircraft trip log and CVR flight times it was estimated that the aircraft had flown 3.07 hours since the 2 April 2004. This would give an expected Hobbs meter reading of 104.27 Hours. The actual reading on the meter, following the accident, was 103.3 Hours, a difference of 0.97 hours or 58 minutes. This equates to the approximate flight time from Humberside to Farnborough and onward to Blackbushe and indicates a continuous failure of the right WOW switch after departure from Humberside.

Maintenance

When the aircraft arrived at Farnborough it was met by an engineer from the maintenance organisation based at Blackbushe. The engineer carried out several actions in an attempt to diagnose the problem. He checked the WOW switches on both main landing gears, by crawling under the wings and physically moving the wiring and checking the operation of the plungers. He did not feel that the switches were loose nor did he notice any problems with the switch operation. He then carried out BIT checks on the ASCU and the SCU, both of which were indicated serviceable systems. Following the BIT test on the spoiler control unit the LIFT DUMP FAIL warning also cleared.

Lift Dump System Modification

Due to a number of previous landing accidents implicating the lift dump system the FAA issued AD 2003-07-09 and AD 2003-10-05 which imposed restrictions on the aircraft landing performance. In response to these the aircraft manufacturer issued a Service Bulletin (SB) 27-3608, to modify the existing lift dump system. The FAA accepted the SB as a means of compliance with the FAA AD which then allowed the removal of the performance restrictions.

The original lift dump system was operated via the speedbrake switch; this was a manual operation which required the use of the switch at touchdown. For the lift dump to deploy it required either of the main landing gear WOW switches to indicate ON GND and the nose gear WOW switch to also indicate ON GND, as well as both engine throttles to be at IDLE. Once these conditions were met and when the speedbrake switch was placed in EXTEND it would electrically latch in this position and command the wing spoiler panels to deploy. Included within the SCU was a WOW switch disagree monitor, if the time between a main gear WOW switch indicating ON GND and the nose gear WOW switch indicating ON GND exceeded six seconds then a LIFT DUMP FAIL would occur, preventing deployment of the wing spoilers.

SB 27-3608 carried out several changes to this system. The WOW switch on the nose gear was removed and the design of the WOW switches on each of the main landing gears was changed from a rotary type switch to the plunger switch found on N200PR. In addition, a manual LIFT DUMP handle was installed at the rear of the centre pedestal. The system operation was then as described in the section above headed 'Aircraft Description'. The SB only required changes external to the SCU; all of the functions within the control unit remained, including the six second monitor for WOW disagree, but the monitor now looked for a discrepancy between each main landing gear WOW switch.

The installation of the SB was carried out based on kit drawings. These detailed the installation of the WOW switches and the LIFT DUMP handle. The WOW switch installation however omitted to provide details on the build up of the switch mounting hardware and as such omitted to show the location of the lock washer or tab washer. The WOW switches on N200PR had been installed with the tab washer between the upper nut and the bracket, and the lock washer between the lower nut and the bracket, which had led to damage of the support bracket. (See Figure 4.)

The aircraft manufacturer had completed the SB on N200PR in September 2003.

Aircraft Performance

The aircraft had been certified by the FAA in accordance with the performance criteria of Regulation 14 CFR Part 23. Performance data was presented in the FAA Approved Airplane Flight Manual (AFM) which provided the following information on the basis of the data:

> *All performance data presented in this manual is based on flight test and has been corrected for the following factors:*
>
> 1. *Engine thrust rating less installation losses, airbleed, and accessory loads.*
> 2. *Full temperature accountability with the operational limits certified.*
> 3. *Wind accountability per 14 CFR Part 23 provisions.*
> 4. *Humidity accountability per 14 CFR Part 23 provisions.*
> 5. *Take-off and landing performance based on smooth, dry, paved runways.*

It is significant that performance figures in the AFM are the figures achieved during flight test and they are not factored to allow for any operational variabilities; under the terms of 14 CFR Part 23 regulations such factoring is not required. The AFM also outlines the flight test conditions on which the published performance was based. Landing performance data was based on the following criteria:

> 1. *Thrust was set to establish a 3° approach with the airspeed stablized at V_{REF}.*
> 2. *Both thrust levers were moved to the idle position as the airplane passed 50 ft above the runway surface.*
> 3. *At touchdown, maximum braking was immediately initiated.*
> 4. *Lift dump spoilers were selected immediately after nose gear touchdown.*
> 5. *Maximum braking was maintained to a full stop.*

Landing performance charts for abnormal configurations/situations are generally not provided but ABNORMAL and EMERGENCY PROCEDURES contain increases to the normal landing distance. Thus, for example, the LIFT DUMP FAIL abnormal checklist states that landing distance will increase by approximately 53%. The manufacturer advises that since these increases are applied without taking into consideration ambient conditions or the aircraft weight they are deliberately conservative. Landing performance data for multiple failures and for wet or icy runways are not provided.

An example of the AFM landing performance chart is shown at Figure 5. The data are presented in a commonly used format, but they are of small scale and minor plotting errors can lead incrementally to significant miscalculations. The manufacturer recognised the limitations of the published charts, especially when used in the air during single-pilot operations, which is why abnormal and emergency checklists included percentage increases to normal landing distances on the presumption that pilots would have calculated their normal landing distance on the ground before departure. At the top left corner of the chart the conditions associated with the data published on the chart were listed, but the charts did not reflect all the landing performance criteria listed above. In particular the braking technique was omitted. Additionally, the pilot stated that his initial type training did not include all of the information on the actions necessary to achieve the published landing performance.

Following a series of runway overrun accidents involving non-deployment of the lift dump spoilers, the manufacturer designed a modification to the lift dump system. Pending installation of this modification the FAA issued AD2003-07-09 and AD2003-10-05; these required that no credit be taken for the improved landing performance provided by the lift dump system and all landings should be planned on the basis that the lift dump system was inoperative. Thus in March 2003 the manufacturer issued aircraft operators with a temporary change to AFMs which provided performance charts for a landing with the lift dump system inoperative (Figure 6): once the lift dump system had been modified this chart should then have been removed from the AFM. This temporary landing performance chart included lift dump spoiler status and braking technique in the list of associated conditions. The landing distances provided by this chart were significantly less than increasing the normal landing performance by 53%, which was used to represent the most conservative condition.

The aircraft involved in this accident had a modified lift dump system; however, the temporary landing performance chart for lift dump failure had not been removed from the AFM. When checking the required landing distance for Blackbushe Airport, whilst on the ground at Farnborough, the pilot had used this temporary chart.

Abnormal and Emergency Procedures

The AFM contains all emergency and abnormal procedures together with associated explanatory notes, warnings and cautions. An FAA approved abbreviated checklist is also published and is intended for quick reference in flight. The introduction to the abbreviated checklist warns that whilst the intent of all warnings are included, most explanatory items, notes and cautions are omitted for brevity.

a) The LIFT DUMP FAILURE (LIFT DUMP FAILURE ANNUNCIATOR ILLUMINATED) procedure, is identical in the AFM and the abbreviated checklist and is as follows:

1. Lift Dump .....Full or partial lift dump effectiveness is lost. Increase landing distance by 53%.

b) The lift dump fails to extend (lift dump warning tone sounds) procedure is to be followed in the event that that the lift dump fails to extend on landing and is as follows:

1. Brakes Apply and maintain maximum braking. (This procedure is printed in bold indicating that it is an 'immediate action' item.)

WARNING. *Full or partial lift dump effectiveness is lost. Nearly continuous brake system releases may initially occur due to normal cycling of the anti skid system. Do not modulate the brakes. Maximum braking effort must be maintained until the airplane has stopped. Brake effectiveness will increase as the airplane decelerates.*

The immediate action is identical in the AFM and the abbreviated checklist; however, the associated **Warning** does not appear in the abbreviated checklist:

c) The ANTI SKID FAILURE (ANTI SKID FAIL ANNUNCIATOR ILLUMINATED) procedure in the AFM is as follows:

1. Anti Skid OFF

2 Landing FLAPS UP OR 10

3. Refer to FLAPS UP, 10, or 20 APPROACH AND LANDING procedure in this section.

4. Apply Brakes Steadily, Gradually Increasing Force to Avoid Skidding Tires.

CAUTION. *Use of flaps 20 or DN for landing, with anti skid failed, is prohibited.*

NOTE. *Landing distance will increase approximately : Flaps UP – 130%, Flaps 10 – 89%.*

This same procedure in the abbreviated checklist is almost identical but does not contain the ***Caution.*** The manufacturer advises that the restriction of landing with the flaps UP or at 10 is to improve the transfer of aircraft weight from the wing to the landing gear and thus reduce the possibility of skidding whilst there is little weight on the mainwheels.

Airport information

Runway 26/08 at Blackbushe Airport was 1,335 metres long with an asphalt surface. Both runways had displaced landing thresholds with Runway 26 having a declared LDA of 1,065 metres. At the time of landing the runway was predominantly dry with a few dark patches indicating damp areas and there were isolated, small puddles of standing water.

A partial assessment of the runway friction levels had been carried out the day before the accident. The assessment report indicated that the runway surface had less friction in the 26 direction and recommended that a full classification be conducted. The average friction value for the strips of runway 1.5 metres either side of the runway centreline (roughly the position of the mainwheels of the Premier when the aircraft is on the centreline) was 0.54. If this reading had been confirmed by the results of a full classification then that portion of the runway would normally require the runway to be promulgated by NOTAM as "liable to be slippery when wet". By comparison the overall friction level for the central portion of Runway 24 at Farnborough was 0.78, indicating the good friction properties of the recently laid porous friction course.

Tests and research

As a result of this accident together with other landing accidents and incidents the manufacturer has introduced a Supplemental Pilot Familiarization programme for existing owners to be conducted on the aircraft and designed to "ensure that you (owners) are familiar with both the aircraft systems and proper procedures necessary to deal with ….landing during adverse conditions". As part of this investigation a pilot from the AAIB participated in this training programme and flew with one of the manufacturer's demonstration pilots.

The programme includes a period of ground discussions covering swept-wing jet flying characteristics, an overview of previous landing accidents and a refresher on performance calculations. The training programme culminates with a two to three hour flight during which the owner is given the opportunity to practise a full stall and various landings, including use of the emergency brakes. Included in these landings are a max effort full stop landing with all systems operating and a final landing with a simulated lift dump system failure.

For the purposes of the AAIB flight the aircraft weight was adjusted to replicate that of the accident aircraft as closely as possible. However, with two pilots on board and the demonstration aircraft's higher basic weight the final landing was conducted about 500 pounds above the accident aircraft's landing weight. The AAIB pilot made the following observations during the flight:

'The brake system is cable operated with little effective feedback to the pilot of how much brake is being applied. It therefore takes some practice to achieve smooth braking during taxiing and, when applying maximum braking on landing, a conscious effort is required to ensure that the brake pedals are at full forward travel. During the max-effort landing with all systems operating normally retardation was impressive almost immediately the brakes were applied. Probably as a result, anti skid brake release was very noticeable.

During this flight the performance calculations for the landing with a simulated lift dump failure indicated an excess of about 1,000 feet of LDA over the LDR. The landing was made in accordance with the AFM technique outlined above with touchdown just beyond the landing threshold at a calculated speed of 114 kts. Maximum braking applied after touchdown achieved little or no discernible deceleration, and the pilot likened the feeling to that of landing on an icy runway. Unlike the max-effort landing with all systems operating the anti skid operation was not noticeable during the initial stages of the landing roll. Retardation was hardly noticeable and the end of the runway appeared to be approaching rapidly. However, as the speed reduced to about 80 kts the retardation increased dramatically and the aircraft came to a halt well within the calculated landing distance.

During flight the times for an engine acceleration were measured. The results indicated that the engines accelerate from flight idle to full power in about 4.5 seconds.

Subsequent to this accident the manufacturer issued Safety Comminque No 246, Landing Performance Awareness. Of particular relevance to this accident is the following extract covering the pilot's perception of braking efficiency:

For a maximum performance landing as stated in the AFM…….During the first ⅓ of the braking distance, the airplane speed will be reduced by approximately 8% of the touchdown speed. The pilot may perceive that this deceleration is not adequate, and that the projected stopping distance exceeds the available landing distance……As the airplane enters the middle ⅓ of the braking distance, the deceleration rate increases, resulting in a speed reduction to about 59% of the touchdown speed. The perceived stopping distance, although shorter now, may still appear to be in excess of the available runway. It will not be until the final ⅓ of the braking distance that the deceleration rate will increase to a level where a pilot will clearly perceive that the stopping distance is within the available runway length.

In the same Communique the manufacturer made known its intent to publish landing data for wet and contaminated runways.

Other accidents/incidents

The following is a list of worldwide reported accidents/incidents that have affected the Raytheon Premier 1 and that have similar circumstances to those of N200PR. In most cases, these are still under investigation and therefore, so that these investigations are not prejudiced in anyway, the information provided is based on limited factual evidence.

Las Vegas, Nevada, USA on 27 May 2004

After landing at Las Vegas airport, the aircraft overran the end of the Runway 07. The recorded surface wind four minutes prior to the accident was 160° at 15 kt gusting 20 kt. There were no faults reported on the lift dump system prior to approach, but it did not deploy during the landing roll. The aircraft was equipped with the pre SB 27-3608 lift dump system. This accident is still under investigation by the National Transportation Safety Board of the USA.

Sao Paulo, Brazil on 14 March 2004

The aircraft landed at Sao Paulo airport in heavy rain, with about 0.10" of standing water on the runway. After landing the lift dump was deployed successfully and the brakes were applied, but this did not seem to slow the aircraft. The emergency brake was then used which caused the aircraft to hydroplane off the end of the runway. This accident is currently under investigation by the Brazilian Departamento de Aviacao Civil.

Cannes, France on 20 Feb 2004

After landing at Cannes, France the aircraft overran the end of Runway 35. The aircraft was fitted with the post SB 27-3608 lift dump system, similar to N200PR. The wind at the time was 090° at 15-17 kt gusting 22 kt. After touchdown, the lift dump system did not deploy and the braking appeared ineffective. This accident is currently under investigation by the Bureau d'Enquetes et d'Analyses (BEA) of France.

Reno, Nevada, USA – 13 November 2003

Following the landing, the brakes appeared to have failed. The emergency brake was used which locked the main wheels and burst the tyres. During the flight, the pilot had received several warnings including LIFT DUMP FAIL and ANTI SKID FAIL. The wheels and brakes were subsequently replaced and the aircraft was then taken for a test flight during which the aircraft exhibited the same problems, including an inability to retract the landing gear. The pilot diverted to

Van Nuys, California where it was discovered that there was a mechanical defect with the rotary WOW switch. This aircraft had the pre SB 27-3608 lift dump system installed.

Windham, CT, USA on 17 April 2003

After landing the lift dump system failed to deploy. Emergency braking was then used to stop aircraft and it came to rest 300 feet before the end of the runway. The damage to the aircraft was limited to left gear, which had departed the runway hard surface. This aircraft had the pre SB 27-3608 lift dump system installed

Santo Domingo, Dominican Republic on 7 Jan 2003

Following the landing the aircraft overran the end of Runway 19 at Herrera Airport and came to rest in a car park. During the landing, the lift dump system failed to deploy and the LIFT DUMP FAIL light had illuminated. This aircraft had the pre SB 27-3608 lift dump system installed. The accident is currently under investigation by the Direccion General De Aeronautica Civil of Santo Domingo.

Norwood Memorial, MA, USA on 18 August 2002

On landing at Runway 28, with flap 10 selected, several attempts were made to deploy the lift dump and in each case the switch failed to 'latch' in position and the lift dump panels did not deploy. The pilot also felt that the braking was ineffective. The aircraft was then intentionally steered off the runway to the left, which then resulted in minor damage. This aircraft had the pre SB 27-3608 lift dump system installed.

Analysis

Survivability

Following the accident the aircraft had rolled onto its left side, possibly making it difficult to open the main access door. Fortunately, for the uninjured pilot, the emergency exit door, on the right side, had fallen into the aircraft and enabled his escape. However, as the door had fallen inwards during the accident, if passengers had been seated in the rows adjacent to the door, they may have been injured when the door fell inwards. The reason for the door falling in was due to distortion of the composite airframe during the accident sequence. This had allowed the upper latches of the door to become misaligned to the upper locating pads. With this lack of support of the upper part of the door it had fallen inwards and pivoted about the lower lugs before finally falling into the aircraft. There was no indication of any mis-rigging or defects with the emergency exit door.

Despite the distortion to the fuselage, the living space of the aircraft had not been compromised showing the relative strength of the composite structure. The metal wings had detached from the fuselage, not at the metal to composite interface but due to tensile bending failures in the mid point of the attaching rods. All of which were attributed to the abrupt halt of the right wing and subsequent rolling of the fuselage during the final stages of the accident.

Fortunately there was no fire; but had there been a post impact fire then the proximity of the aircraft to the fuel storage area and the main trunk road, in addition to the composite structure could have resulted in a much more significant event.

Engineering Issues

WOW switch Failure

After takeoff from Humberside the pilot was unable to raise the landing gear despite normal movement of the landing gear lever. This suggested a failure of the right WOW switch, providing a continuous ON GND indication, whilst the aircraft was in the air. A similar failure of the left WOW switch would have restricted movement of the cockpit landing gear lever when attempting an UP selection, but this lever moved without restriction.

The LIFT DUMP FAIL and ANTI SKID FAIL both resulted from discrepancies in the indications between the left and right WOW switches: following the takeoff the right WOW switch continued to show the aircraft ON GND and the left switch correctly showed the aircraft IN AIR. Both systems contained monitors for this disagree and, after the pre-requisite delay time, provided the cockpit illumination. A further confirmation that the failures were related to the WOW switch was the discrepancy between the Hobbs meter reading, which is active when the right WOW is IN AIR, and the actual flying hours. With this information it was possible to confirm that the right WOW switch failed to indicate IN AIR following the takeoff from Humberside.

Tests later revealed the right WOW switch was electrically functioning correctly, placing suspicion on its fitting to the right main landing gear leg. Inspection of the switch installation had revealed that the support bracket for the WOW switch had fractured due to stress corrosion cracking. For the switch to indicate IN AIR, the target must compress the switch plunger. The progressive fracture of the bracket would have allowed flexure of the bracket. When the target, at takeoff, contacted the switch plunger the load imparted by the target transferred through the switch and to the bracket. But, instead of the bracket reacting these loads and operating the plunger the flexure allowed the switch to move upward, thus preventing operation of the microswitches. This would have led to a constant ON GND indication to the systems served by the right WOW switch.

The engineer who inspected the aircraft at Farnborough, following the flight from Humberside, indicated that the right WOW switch and support bracket were intact when he inspected them. However, the WOW switch had already failed to indicate IN AIR from Humberside. An explanation could be that the crack had not progressed enough to completely fracture the bracket, nor had it cracked enough to show movement during the physical examination. In addition, the bracket would have been very dirty and in a position of poor lighting, making it difficult for a detailed examination in these conditions. It can be concluded from this that the final fracture of the bracket was after the departure from Farnborough and may have occurred during the runway excursion and accident sequence at Blackbushe.

The switch installation was such that when the aircraft is airborne the switch is engaged and any failure to operate the plunger results in an ON GND indication, be it from a failed bracket or incorrect rigging. When the aircraft subsequently lands, all the WOW switches would show ON GND and would therefore be in the correct sense. Any BIT checks conducted at this point are being conducted with the switches in their expected state and will therefore pass, as was the case at Farnborough. The only way of isolating such a problem would be to jack the aircraft to simulate IN AIR. However, most of the tests can only be conducted with the aircraft on the ground, which makes for difficulty in troubleshooting a potential WOW switch failure.

The bracket had failed due to stress corrosion cracking, a mechanism which requires a corrosive environment to develop. This had been provided by the use of dissimilar metals, with the use of aluminium alloy for the support bracket and steel for the WOW switch mounting hardware. These had set up galvanic corrosion and provided the initial mechanism for the crack. The second mechanism for the cracking to develop is stress and this had been provided by the outer tang of the tang washer that had been forced against the edge of the tang support hole of the bracket. The reason for this had been due to the inner tang riding out of its key way and finding its way into the threads of the switch. This can only have occurred during the installation of the WOW switch and was most probably because of the tightening of the lower nut for rigging purposes without the concurrent adjustment of the upper nut. This rigging adjustment placed a torque on the switch body, which then caused it to rotate in relation to the fixed tang washer.

It was also discovered that both the left and right WOW switches had been installed with the lock washer between the lower nut and the bracket, and thus allowing its teeth to dig into the metal of the underside of the bracket. Again, this set up a similar galvanic corrosion mechanism, which could have contributed to the stress corrosion cracking. It is common engineering practice not to put a lock washer immediately against the structure due to the possibility of damage. The WOW switches had formed part of a modification to the lift dump system, and were installed based on the SB and kit drawings, however neither of these provided any clarity on how to install the switch with the attaching hardware in the kit.

Since this accident, Raytheon have issued SB 32-3678 which requires inspection of the WOW switch support brackets for cracking and provides information on the correct installation of the switch, placing the lock washer between the tang washer and the upper nut. Nevertheless, some features of the design are, in the opinion of the AAIB, unsatisfactory and could still lead to corrosion and or cracking and therefore the following recommendation is made:

Safety Recommendation 2004 - 95

It is recommended that Raytheon Aircraft Company review the design and installation of the weight-on-wheels switches and support hardware fitted to the Premier 1 aircraft, with a view to reducing the possibility of stress corrosion cracking.

Response to Recommendation 2004 - 95

Raytheon Aircraft Company has accepted this recommendation. In addition to the Mandatory Service Bulletin 32-3678 Raytheon Aircraft Company have revised the appropriate engineering drawings and production planning data to specify the correct assembly of the switches and attaching hardware. Finally, for new production aircraft (beginning at serial number RB-143), and spares, the switch attach bracket material has been changed to 4130 steel to improve corrosion protection.

Lift Dump Fail

The LIFT DUMP FAIL indication, on both the flight from Humberside and from Farnborough, was due to the right WOW switch failing to indicate IN AIR. This was confirmed by the read out of the memory of the SCU.

The system operation on N200PR was such that it was fully manual with the use of the lift dump handle to deploy all the spoilers which could be achieved during any phase of flight. With this modified system there was no reliance on the WOW switches for its operation, except for ground BIT testing. However, the modified system used the existing SCU with changes only being made externally to the unit, and with the manual handle serving as a method of fooling the control unit that the aircraft was on the ground, with engines at idle and the speedbrake switch in extend. However, the SCU still contained the monitor logic for a WOW disagree, and the inputs from the left and right WOW switches remained to facilitate BIT testing of the system. So, although the WOW switches are no longer required for the actual operation of the lift dump spoilers they will still provide a LIFT DUMP FAIL indication if there is a disagree for greater than six seconds. Therefore, following a

WOW switch failure the LIFT DUMP FAIL light will illuminate and render the system totally inoperative; although the system itself will still be operable. This logic seems flawed in that a serviceable system, essential for optimum braking, is inhibited for a failure unrelated to its operation. The following recommendation is therefore made:

Safety Recommendation 2004 - 96

It is recommended that Raytheon Aircraft Company review the logic of displaying a LIFT DUMP FAIL and inhibiting the system due to a weight-on-wheels switch disagree on the Premier 1 aircraft, and modify the system so that lift dump remains available.

Response to Recommendation 2004 - 96

Raytheon Aircraft Company has accepted this recommendation and has reviewed the lift dump system to evaluate weight-on-wheels (WOW) logic related to lift dump operation. The Spoiler Control Unit (SCU) controls all functions of the spoiler system: roll control, speed brakes, and lift dump. The SCU must successfully complete a Built-In-Test (BIT) prior to each flight in order to enable the various functions. The BIT sequence results in movement of the spoiler/lift dump panels, and thus must not occur whilst airborne. The WOW logic is required to inhibit BIT in flight. While it may be possible to modify the system design to eliminate annunciation of LIFT DUMP FAIL in the event of squat switch disagreement, such a modification would require changes to SCU hardware, software, and aircraft wiring. As noted below, Raytheon Aircraft Company is adding information to the Model 390 FAA Approved Airplane Flight Manual to clarify and expand landing performance information, including detailed procedures for use in the event of LIFT DUMP FAIL annunciation. Thus, Raytheon Aircraft Company considers that changes to SCU WOW logic may be appropriate as a product improvement at a later date.

Anti Skid Fail

The illumination of the 'ANTI SKID FAIL' light, during the flight from Humberside, can be directly attributed to the right WOW switch failing to indicate IN AIR following takeoff. The ASCU WOW monitor would have seen a mismatch between the left and right WOW switches, after takeoff, and 60 seconds later, provided a discrete indicating that discrepancy. The warning logic, defined by the aircraft manufacturer, interpreted the discrete and illuminated the ANTI SKID FAIL light in the cockpit.

However, when the ASCU diagnoses a WOW switch failure, it only removes the touchdown protection function, with all the remaining operations of the anti skid system still available. For the anti skid to become operational the system relies on either the wheel speed or the WOW switch indication. This means that even with a WOW switch disagree, once the wheel speed has reached 60 kt, the anti skid system will operate and provide the normal protection as long as the anti skid switch in the cockpit is still in the NORM position.

The pilot of the accident aircraft reported that he felt the anti skid operate at Farnborough, despite the ANTI SKID FAIL indication, so the anti skid switch is presumed to have been to be in NORM. At Blackbushe, the tyre markings, left by the accident aircraft, indicated normal operation of the anti skid, and the anti skid switch was found in NORM. Subsequent tests of the anti skid components did not reveal any faults with the system.

The checklist for an ANTI SKID FAIL requires the cockpit switch to be moved to OFF, which would remove the anti skid protection, although full braking would still have been available. With a WOW failure, the logic of the aircraft is to illuminate the ANTI SKID FAIL despite the fact that the anti skid system is still functional, with the exception of touchdown protection. If the checklist is followed then a perfectly serviceable system is switched off. Other aircraft types, fitted with a similar anti skid system from the same manufacturer, do not indicate an ANTI SKID FAIL to the crew in the event of a WOW switch failure but store this failure information in a maintenance memory instead.

The anti skid system does not contain any memory, which means it is not possible to carry out any post flight analysis or troubleshooting following a failure. The only action is to carry out a BIT check, which shows the serviceability of the system at the time it is tested. With a WOW switch failing to indicate IN AIR, then a ground BIT test will always pass, as the switches would now be in the correct sense (ON GND). The only way to find this fault would be to jack the aircraft to simulate an aircraft in the air. This makes it difficult to isolate the WOW switches as a cause of the ANTI SKID FAIL, unless there are other indicators such as a maintenance memory or other system faults that can be cross related.

Safety Recommendation 2004 - 97

It is recommended that Raytheon Aircraft Company review the logic of displaying ANTI SKID FAIL for a weight-on-wheels switch disagree on the Premier 1 aircraft, when the system is otherwise still operational.

Response to recommendation 2004 - 97

Raytheon Aircraft Company has accepted this recommendation and has reviewed the anti skid system to evaluate WOW logic related to anti skid operation. While it is possible to modify the system design to eliminate annunciation of ANTI SKID FAIL in the event of squat switch disagreement, such a modification would require changes to anti skid system hardware and software. As noted below, Raytheon Aircraft Company is adding information to the Model 390 FAA Approved Airplane Flight Manual to clarify and expand upon the anti-skid system, including detailed procedures for use in the event of ANTI SKID FAIL annunciation. Thus, Raytheon Aircraft Company considers that changes to the system related to WOW logic may be appropriate as a product improvement at a later date.

Operational issues

After taking off from Humberside the pilot was presented with a series of indications that created a high cockpit workload and necessitated a diversion and landing with two critical systems apparently unserviceable. The pilot referred to the LIFT DUMP FAIL abbreviated checklist, which simply advised that the landing distance would be increased by 53%. With 1,800 metres of LDA Farnborough had sufficient runway for landing with a failure of the lift dump system and had some operational advantages. However, the large increase in LDR when landing with anti skid inoperative in addition to the increased LDR required for the lift dump failure would have exceeded the LDA at Farnborough. The pilot believes that he also referred to the ANTI SKID FAILURE checklist, but given the checklist requirement to turn the anti skid switch OFF and to land with Flap UP or Flap 10 it seems possible that these items may have been missed in the high workload environment. Fortunately, as outlined above, the ANTI SKID FAIL indication was indicative of a touchdown protection failure only and the anti skid system was in fact serviceable, but this was not known to the pilot before he landed.

The landing at Farnborough was largely uneventful and to some extent would have conditioned the pilot's attitude and decision making for the subsequent flight to Blackbushe. The pilot had been cleared to land short of the displaced threshold on Runway 24 at Farnborough and after touchdown the braking appeared effective, despite the fact that maximum braking was not used and, confusingly for the pilot, the anti skid system appeared to work. To a certain extent the latter would have added to the pilot's low confidence level in the authenticity of the aircraft's warning systems. The LDA was more than sufficient for the lift dump failure, and the aircraft cleared the runway with adequate landing distance remaining.

The checklists for the technical problems experienced during the flight from Humberside left the pilot short of some critical information. There was no checklist to cover the landing gear failing to retract after a normal UP selection. The LIFT DUMP FAILURE (LIFT DUMP FAIL ANNUNCIATOR ILLUMINATED) abnormal checklist gave no advice on braking technique required nor did it provide the very helpful **Warning** about braking effectiveness found in the emergency checklist for LIFT DUMP FAILS TO EXTEND (LIFT DUMP WARNING TONE

SOUNDS). There was no advice on how to apply performance decrements for multiple failures and the ANTI SKID FAILURE (ANTI SKID FAIL ANNUNCIATOR ILLUMINATED) in the abbreviated checklist did not contain the **Caution** that landings with flaps 20 or DN were prohibited. On the other hand the pilot did not use all the checklist information that was available, and there appears to have been an element of good fortune in the uneventful landing at Farnborough.

The engineer's suggestion that the aircraft be taken to Blackbushe for further technical investigation was sensible given the aircraft's history. The pilot checked the LDR and calculated that there was just sufficient LDA with the lift dump system inoperative and, given his recent experience of landing at Farnborough, it is perhaps not surprising that he decided that a successful landing was possible. However, in retrospect it appears that the pilot had less than a full understanding of the actions required to achieve the published landing performance and certainly he was not aware of the braking effectiveness profile that was to be expected. Although the AFM contained some of this information, there were deficiencies in the way that it was presented.

Witness evidence together with recorded data from the EGPWS indicates that when landing at Blackbushe the aircraft touched down at about the correct point on the runway and there is no evidence to counter the pilot's perception that the aircraft touched down at the correct speed. Apart from the WOW faults outlined above no other fault was found with the aircraft systems. Using this evidence, performance calculations, supported by the AAIB flight test, indicate that the aircraft should have been able to stop in the available distance at Blackbushe provided the correct techniques had been applied. In the event, the pilot did not apply maximum braking immediately after touchdown and released and reapplied the brakes in an attempt to achieve perceived braking. Both these actions would have reduced the braking effectiveness and the deceleration would have been significantly less than that achievable had the correct braking technique been applied. It is also possible that the initial deceleration achieved at Blackbushe was lower than that at Farnborough as a result of the lower friction of the runway and the significantly reduced aircraft weight for the landing at Blackbushe. All of these factors would have added to the pilot's perception that the brakes were not functioning.

In the circumstances the pilot's decision to go-around was understandable and it appears likely that if he had kept the throttles at full power for just a fraction of a second longer, a successful go-around might have been achieved. However, once the decision to abort the go-around attempt had been made the runway overrun became inevitable.

Safety actions

This accident, together with similar accidents to the same type, have revealed a number of weaknesses in both pilot awareness of the aircraft's landing performance and the AFM, the abbreviated checklist and the presentation of performance data. The manufacturer has published a very useful Safety Communique on landing performance and has offered all current owners of the type a Supplemental Familiarization programme to help increase awareness of the issues. In addition the manufacturer has made changes to its initial flight training programme. The AFM issues remain and the following recommendation is therefore made:

Safety Recommendation 2004 - 98

It is recommended that Raytheon Aircraft Company should carry out the following amendments to the Airplane Flight Manual for the Premier 1 aircraft:

1. Revise the Lift Dump Failure (Lift Dump Annunciator Illuminated) abnormal checklist to include recommendations on required braking technique and to include the **Warning** of braking efficiency published as part of the Lift Dump Fails to Extend (Lift Dump Warning Tone Sounds) emergency checklist.

2. Review all Airplane Flight Manual and abbreviated checklists to ensure that flight critical items included in **Warnings** and **Cautions** in the Airplane Flight Manual are included in the appropriate abbreviated checklists.

3. Expand the Performance section of the Airplane Flight Manual to include advice and, where appropriate, data for multiple system failures.

4. Amend, where appropriate, performance charts to include all associated conditions on which the published performance is based.

Response to Recommendation 2004 - 98

Raytheon Aircraft Company has accepted this recommendation and is finalizing an extensive revision to the Model 390 Pilot's Operating Manual, FAA Approved Airplane Flight Manual, and FAA Approved Abbreviated Pilot Checklist. The revisions include the following:

> Expanded information about lift dump and anti skid systems. The information includes details of operation and procedures to be followed in event of LIFT DUMP FAIL and ANTI SKID FAIL annunciation, both alone and in combination. Procedures for identification of, and response to, WOW switch failure have been added. Detailed information about braking technique and performance is included for these conditions.

Consistent information between the Airplane Flight Manual and abbreviated checklist regarding failure annunciations and related procedures.

Guidance for application of performance factors in response to failure annunciations.

Clarification and consistent presentation of the conditions under which performance data was derived. Detailed information about the effects of variations in those conditions has been included.

Addition of wet and contaminated runway landing performance data. The data will be presented as supplementary, non-approved data.

Finally, the performance charts used in this aircraft's Airplane Flight Manual are widely used but nevertheless are of a scale and complexity such that mistakes can easily be made, particularly during single-pilot operations. In this accident, the pilot interpreted the graphs correctly, but the potential for human error in the use of these graphs is significant and could be the cause of future incidents and accidents. The following Safety Recommendation is therefore made:

Safety Recommendation 2004 - 99

It is recommended that Raytheon Aircraft Company review the presentation of performance data in the Airplane Flight Manual for the Premier 1 aircraft to render it less susceptible to errors in interpretation.

Response to Recommendation 2004 - 99

Raytheon Aircraft Company has accepted this recommendation. The Airplane Flight Manual and abbreviated checklist performance data is to be presented in tabular format, and will include corrections for runway gradient and wind component. The Pilot's Operating manual, Airplane Flight Manual and abbreviated checklist revisions are presently in process and it is expected that the revisions will be published at the end of 2004.

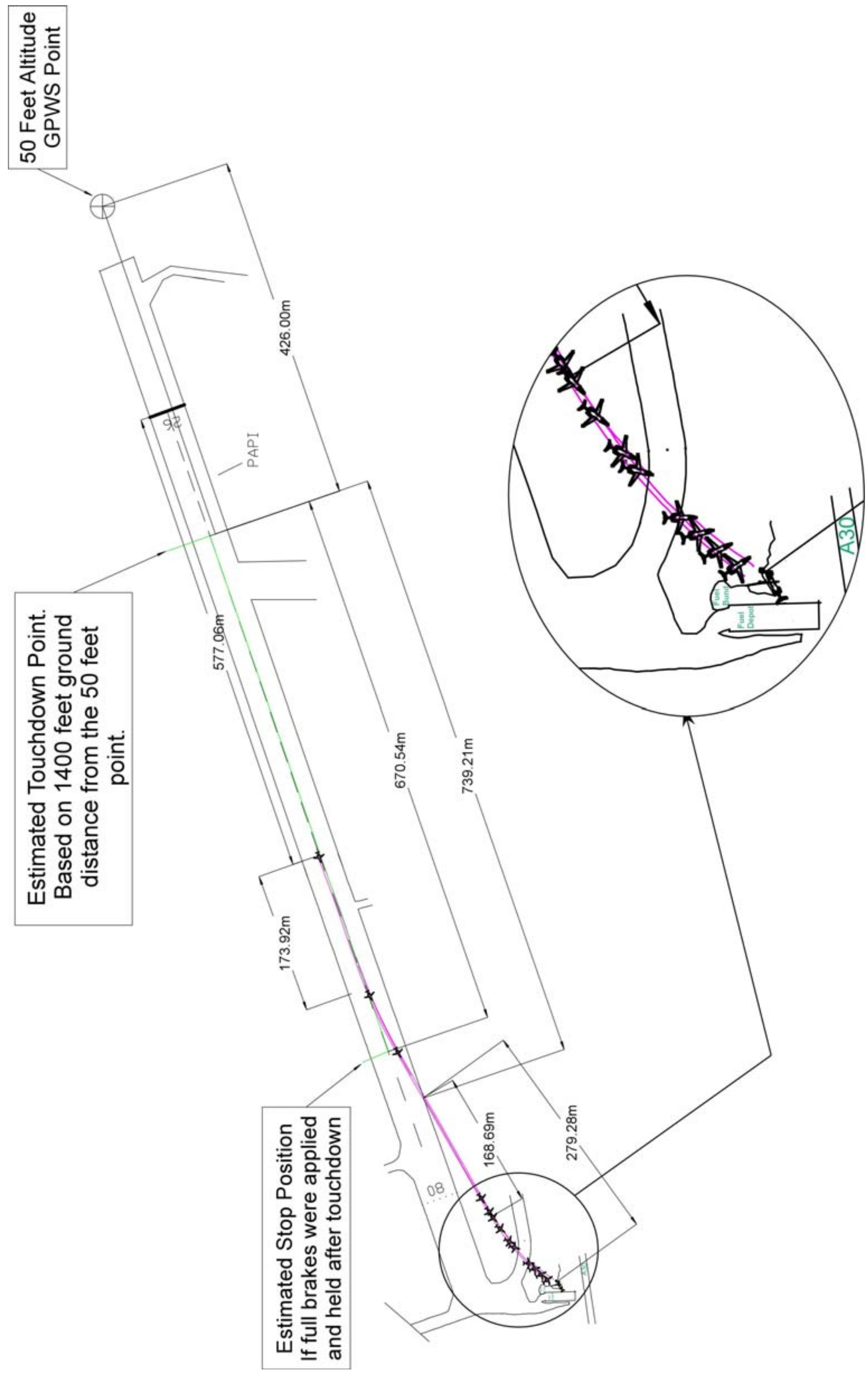

Figure 1 - Accident Sequence

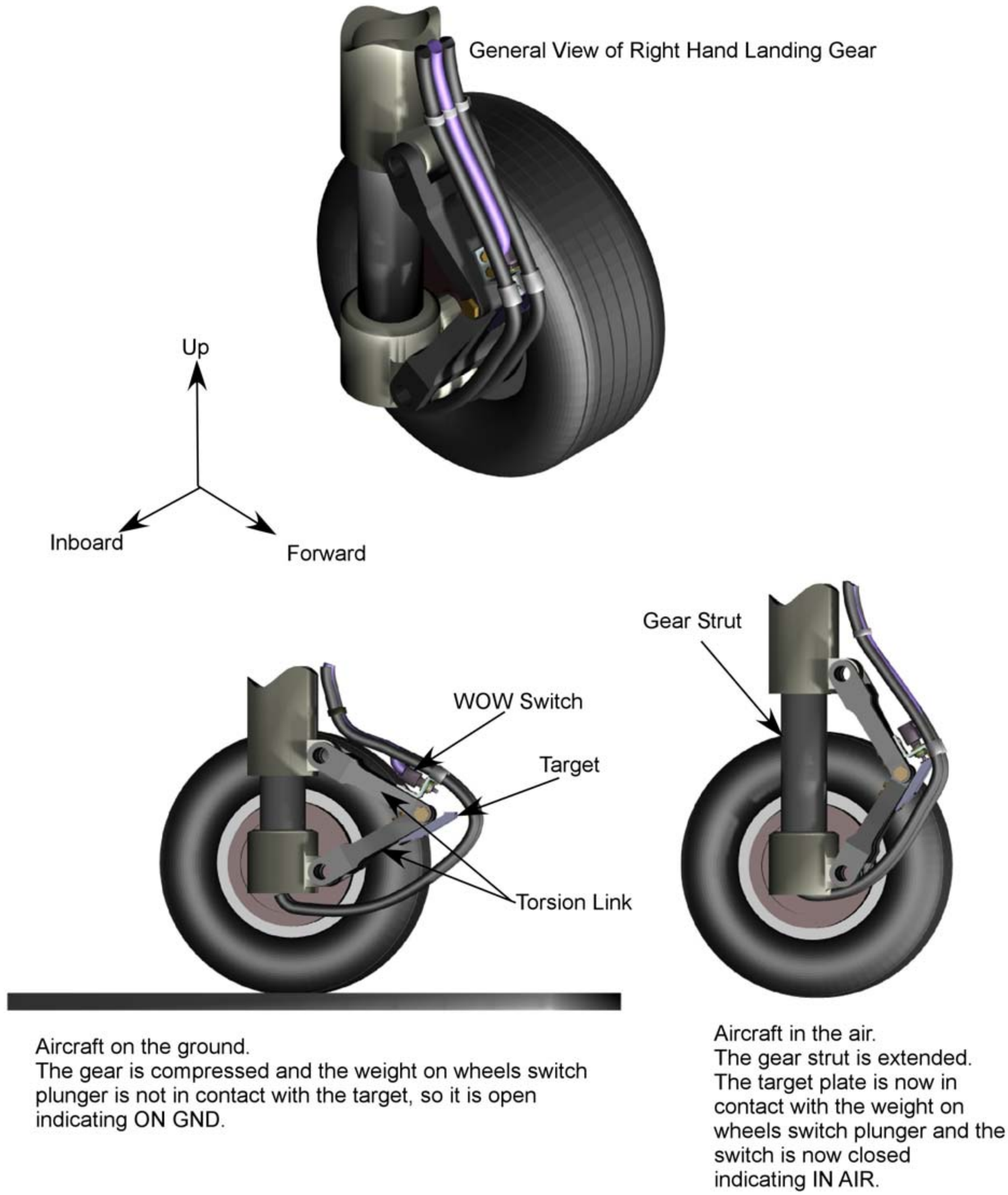

Figure 2 – WOW Switch installation.

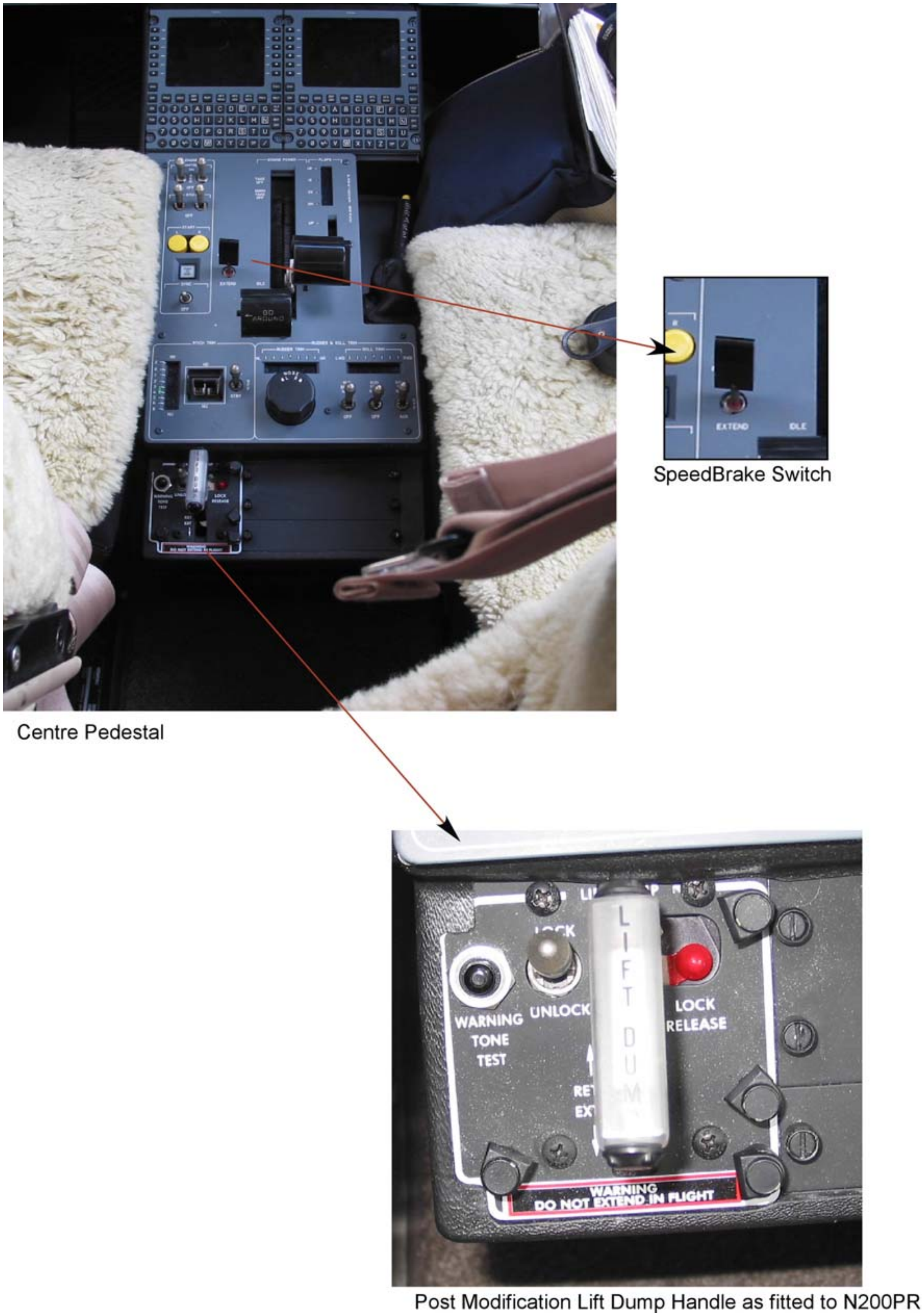

Figure 3 - Lift Dump and Speedbrake components

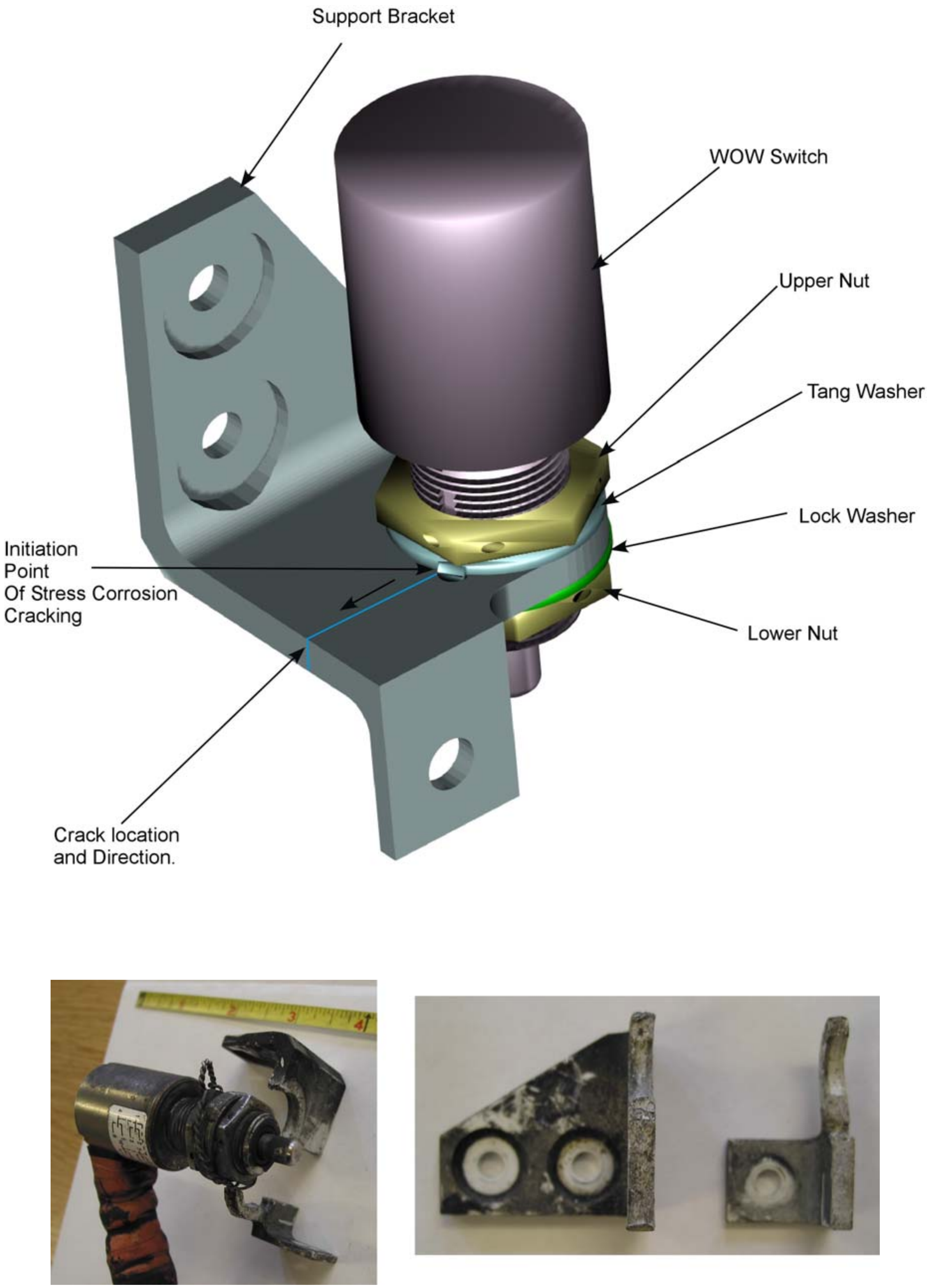

Figure 4 – WOW switch bracket.

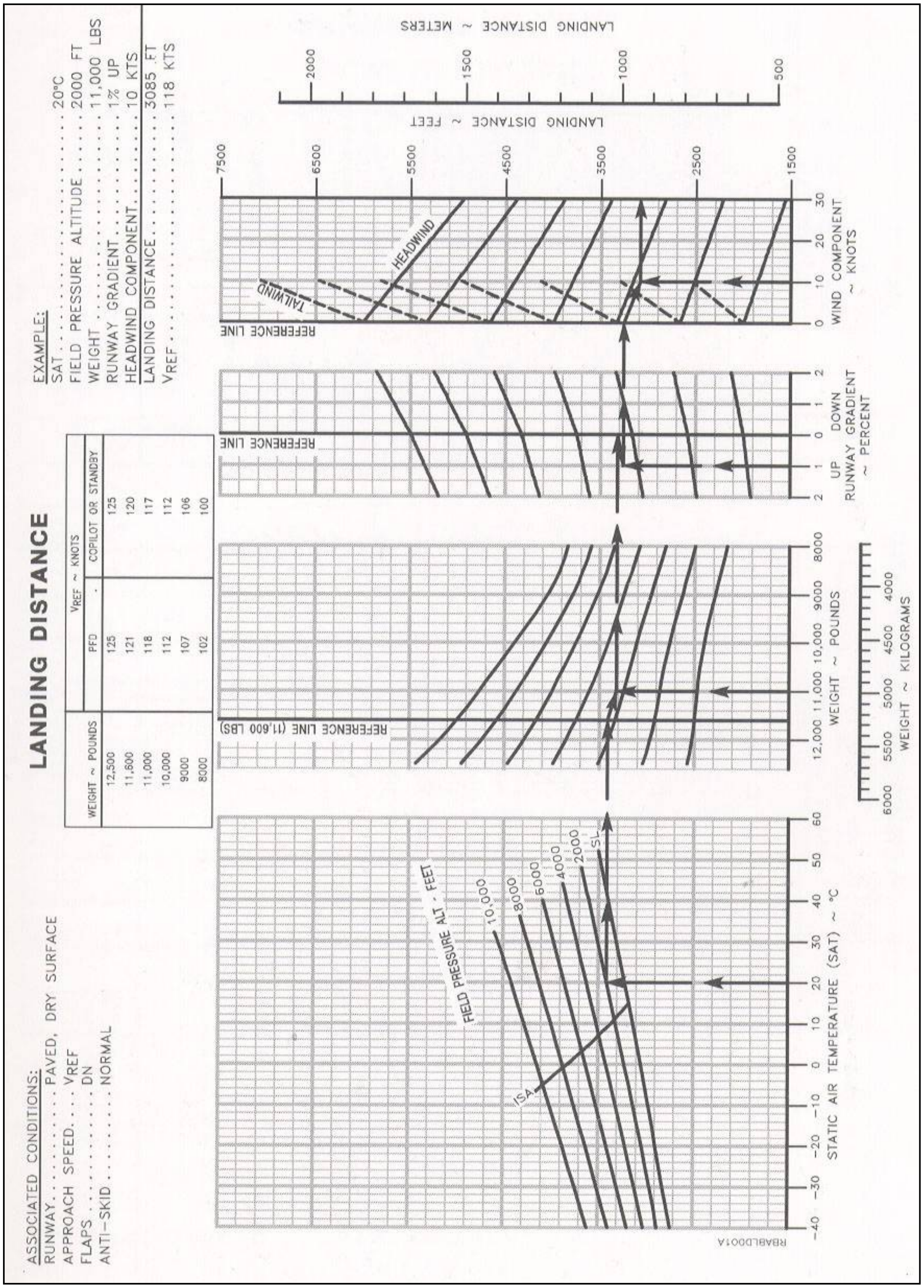

Figure 5 - Normal Landing Performance Charts

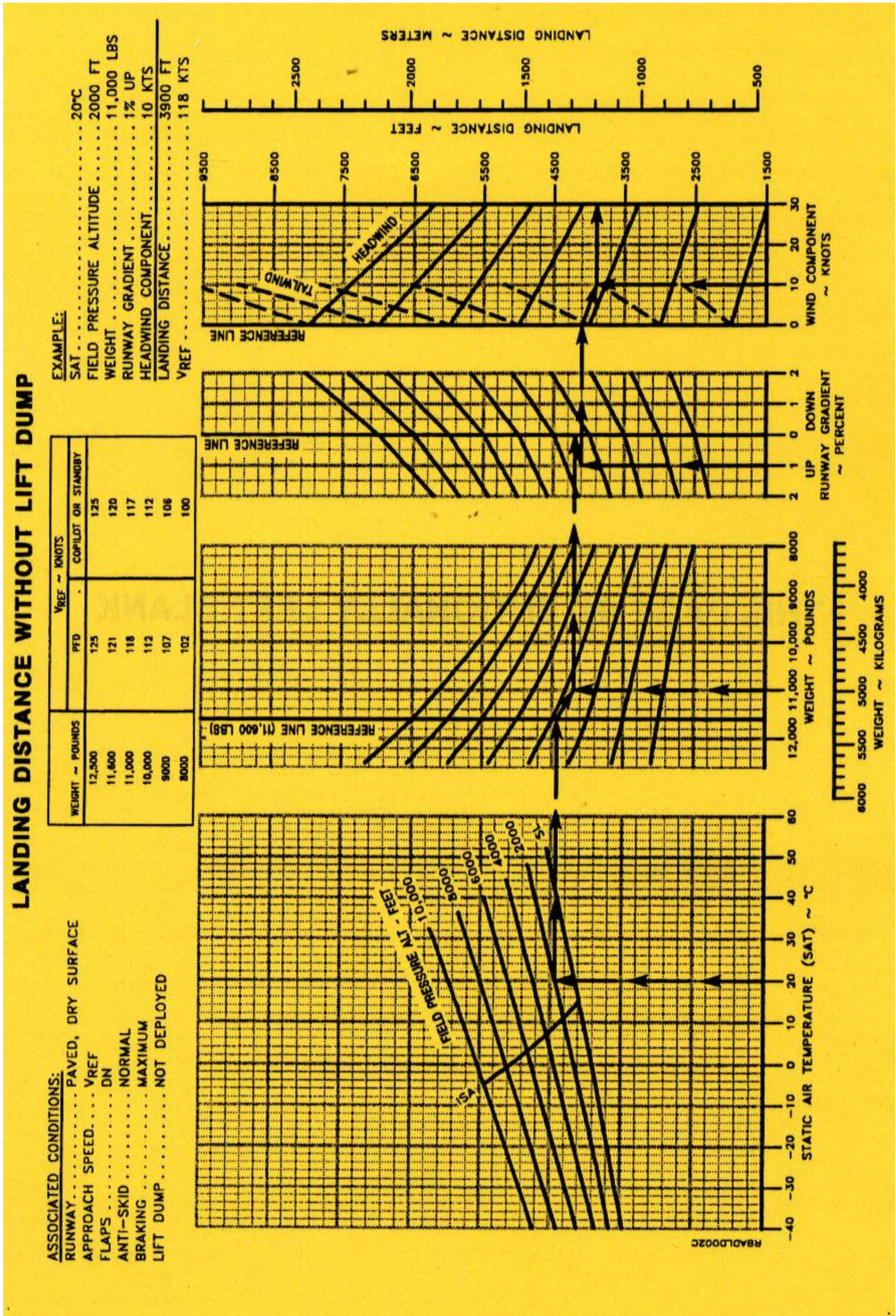

Figure 6 - FAA AD imposed Landing Performance Chart without Lift Dump

APPENDIX A – SCU FAULT MEMORY DOWNLOAD.

The fault memory download of the SCU revealed the following, with the latest fault recorded first and spaces inserted for clarity.

Fault Code	Meaning	Possible reason for fault code
2	Monitor CCA 1	Power loss
1	Control CCA	Power loss
V	Aircraft Power	Power Disconnect
Q	Right throttle at power sw	Wiring being pulled out during accident
O	Right throttle at idle sw	Wiring being pulled out during accident
R	Left throttle at power sw	Wiring being pulled out during accident
Q	Right throttle at power sw	Wiring being pulled out during accident
P	Left throttle at idle sw	Wiring being pulled out during accident
O	Right throttle at idle sw	Wiring being pulled out during accident
N	Left WOW switch	Unknown
M	Right WOW switch	Unknown
J	Right pneumatic out of limits.	Wing impact with fuel bund
G	Right pull down/hold down actuator	Wing impact with fuel bund
1	Control CCA	Unknown
N	Left WOW switch	WOW discrepancy out of Farnborough
M	Right WOW switch	WOW discrepancy out of Farnborough
		BIT test reset in between flights
N	Left WOW switch	WOW discrepancy out of Humberside
M	Right WOW switch	WOW discrepancy out of Humberside
V	Aircraft Power	Test
V	Aircraft Power	Test
U	Left i/b panel stow sw	Unknown
-	No more data	Data cleared at maintenance
-	No more data	
-	No more data	

Aircraft Type and Registration:	Boeing A75N1 Stearman, G-BAVO	
No & Type of Engines:	1 Continental W-670-6N piston engine	
Year of Manufacture:	1945	
Date & Time (UTC):	1 August 2004 at 1545 hrs	
Location:	Old Buckenham Airfield, Norfolk	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1	Passengers - None
Nature of Damage:	Severe, including broken undercarriage, damaged engine frame and fire to forward fuselage and upper wing	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	48 years	
Commander's Flying Experience:	4,308 hours (of which 10 were on type) Last 90 days - 142 hours Last 28 days - 46 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot plus telephone enquiries and witness statements	

Background

The Boeing 'Stearman' biplane was the USA's primary basic trainer during World War II. The airframe may have been fitted with any of the following radial engines: a 225 HP Lycoming R680, a 220 HP Continental W670-6 or a 225HP Jacobs R7557 engine. Many later aircraft were converted with a 450 HP Pratt & Whitney R985A61 radial piston engine to equip them for crop spraying.

History of the flight

The pilot completed all his pre-flight checks successfully and began the take-off run from Runway 07, a grass strip. At the time the surface wind was light and variable, the air temperature was +25°C and the aircraft was about 200 lb below its maximum authorised take-off weight of 2,950 lb. The field at the end of the runway was covered in dry straw.

The pilot reported that acceleration and power indications were normal during the initial take-off run. The aeroplane became airborne but failed to climb satisfactorily, prompting the pilot to attempt a landing in the field immediately ahead. This field, containing hay, was furrowed across the line of flight, causing the aircraft to lose its undercarriage and nose over onto its back. Fire then broke out around the nose of the aircraft and both occupants vacated the aircraft without assistance and moved clear. The emergency services attended promptly and extinguished the fire.

Pilot's assessment

The pilot had flown the same aircraft one hour earlier in the day, in similar weather conditions and from the same runway. On the accident flight, he reported the tail wheel lifting and aircraft becoming airborne at the appropriate speed. The aircraft then failed to gain speed or altitude, despite a stick-forward action lowering the nose. At this point the pilot recounts closing the throttle and setting the mixture to the idle cut off position to attempt the emergency landing.

Witness accounts

Four witness accounts were subsequently gathered, at least one from an experienced pilot. Two of the three witnesses who observed the initial takeoff stated that the aircraft appeared to become airborne in a 'three-point' attitude with the main wheels and tail wheel leaving the ground simultaneously. The aircraft then appeared to be flying close to a stall, with each of the witnesses observing the aircraft dropping first one wing, then the other, a number of times. From there the witness accounts support the inability of the aircraft to gain altitude and its subsequent descent from around 100 feet agl into the field bordering the airfield, although they observed that the engine sounded as though it was producing full power until the point of impact.

Discussion

The accident bears strong resemblance to an accident involving a similar aeroplane, registered N55175, in the USA on 13 June 2003. This accident occurred in very similar weather conditions to G-BAVO's accident, and with similar loading, the aircraft failed to gain height after an abnormally long take-off run, including two bounces on the runway. The pilot twice considered aborting the takeoff and, shortly after leaving the airfield, the aeroplane sank into trees. In both cases the pilots, with a relatively high number of hours of light aircraft, had recently converted to the Stearman.

G-BAVO's pilot considered that the reflected heat from the dry straw in the field where he was forced to land may have had an adverse effect on the local air density. The possibility of thermal activity in the area was investigated by the AAIB, with a local gliding club reporting that the day was thermic, but not strongly so. As thermals develop there is a component of horizontal air movement along the ground inwards towards the rising column of air, which can be noticeable on a still day. An aircraft taking off may experience a sudden slight tailwind for this reason. However this induced wind is normally low speed, in the order of three to four knots, and is present only for a short distance, after which the direction changes to become a headwind component. It is considered possible that this effect may have played a minor part in the accident to G-BAVO but that this effect would be insignificant in comparison with the high-drag take-off attitude reported by the eye witnesses.

Aircraft Type and Registration:	Grob G115, G-RAFA
No & Type of Engines:	1 Lycoming O-235-H2C piston engine
Year of Manufacture:	1989
Date & Time (UTC):	26 September 2004 at 1555 hrs
Location:	Cranwell, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Propeller tip and nose landing gear damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	1,850 hours (of which 5 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

While carrying out a touch-and-go at Cranwell, the aircraft encountered a gusting wind on short finals. The pilot was surprised by the sensitivity of the controls and characterised the subsequent landing as "poor and probably nose wheel first". He decided not to continue the touch-and-go and completed a full stop landing.

The aircraft was difficult to keep straight when it was taxied back to the apron and a visual inspection, carried out after shutdown, revealed damage to the nose leg and the tip of one of the propeller blades. The pilot assessed the cause of the accident as mishandling of the aircraft in the gusty conditions.

Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior II, G-BJYG
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1981
Date & Time (UTC):	4 July 2004 at 1139 hrs
Location:	Offshore, in Liverpool Bay, 2 nm north of Wallasey, Merseyside
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	440 hours (of which 65 hours were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The aircraft departed from Liverpool Airport for a local flight. About 30 minutes into the flight the pilot broadcast a 'PAN' call, shortly followed by a 'MAYDAY' call, informing Air Traffic Control (ATC) that he had an engine problem. The aircraft ditched about 2 nm offshore and rapidly became submerged. Neither of the two persons on board survived.

History of flight

On the day before the accident the pilot contacted the flying club at Liverpool Airport, from where the aircraft was operated, and booked a flying slot for midday on Sunday 4 July. On the Sunday morning he visited the airport to check that the weather was suitable for his flight. It is not known whether he went out to where the aircraft was parked at this time. He left the airport and returned about one hour later, accompanied by his wife.

On his return he carried out a pre-flight inspection of the aircraft. After a while he came back to the clubhouse bringing with him a fuel strainer which contained a fuel sample drawn off from the aircraft's fuel system. (No one present could recollect where exactly he said the sample had come from.) In the sample could be seen a considerable amount of water and some black debris. He remarked that this was the third or fourth sample he had taken from the aircraft containing mainly water, and he asked that the strainer be retained at the club to be shown to the owners of the aircraft whom he knew were planning to fly later in the day. He then borrowed another fuel strainer and returned to the aircraft to complete his pre-flight inspection. He was followed out by a club instructor who noticed that he drained off several more samples from under one wing of the aircraft before a pure fuel sample was obtained.

The pilot booked out for a local flight by telephone and then departed. The aircraft took off at 1106 hrs from Runway 27 and then turned left, climbing towards Chester, a visual reporting point to the south. As he departed from the vicinity of the airport he was instructed to change to the Liverpool Approach frequency and he later reported on that frequency that he was leaving the zone at Chester.

Just over half an hour later, at 1138 hrs, the pilot made a 'PAN' call on Liverpool Approach frequency in which he passed information that he was "OFF WALLASEY" losing altitude and losing power. In reply the pilot was given heading information for a direct return to the airport. Half a minute after his 'PAN' call the pilot broadcast a 'MAYDAY' call saying that he was ditching the aircraft.

There were two training aircraft from Liverpool Airport in the immediate area where the aircraft ditched. They flew overhead the site and although they could see the spot where the aircraft entered the water there was no sign of it, or of any wreckage. Two nearby lifeboats launched and were on scene very quickly but were not able to find any evidence of the aircraft in their search of the area. As the tide fell the aircraft was located and at 1845 hrs the two bodies were recovered by divers.

Pilot information

The pilot learned to fly at Liverpool Airport and qualified for his Private Pilot's Licence (PPL) in 1992. Since then he had flown regularly, both on club aircraft, including G-BJYG, and on a group aircraft of which he owned a part share, although recently the shared aircraft had not been available for him to fly because it was undergoing maintenance.

The pilot was described as a keen club flier and was often accompanied by his wife when flying. However, in the three months preceding the accident he had only recorded one flight, of one hour's duration in a Cessna 172.

Aircraft information

The aircraft was based at Liverpool Airport and had been so for a number of years. It was privately owned and flown but was also operated by a flying club on a lease-back arrangement.

The aircraft had two fuel tanks and the usual practice, as taught at the flying club, was to run on one tank for 30 minutes and then to switch to the other tank. The aircraft had previously flown on the day before the accident on a flight lasting one hour and fuel had been used from both tanks.

There were three fuel drains: one at the lower rear inboard edge of each tank, accessible from the inboard lower wing surface, and one from the engine fuel bowl, accessed at the lower left cowling. The Pilot's Operating Handbook (POH) required a pilot to operate the fuel drains as part of a pre-flight inspection. The purpose of this action is to check for water or contaminants in the fuel and to prevent their accumulation. The suggested action was to drain off sufficient fuel to remove all contaminants. It was reported that the fuel drains were checked before the flight on the day preceding the accident and that there was no evidence of water or other contaminants.

The POH did not contain a specific procedure for ditching. There was however a general procedure for a power off landing. This indicated that the best gliding speed was 73 kt and recommended that touchdown was made at the lowest possible airspeed and that the door was unlatched. The clean stall speed was 50 kt, and with full flap selected was 44 kt. The aircraft had mechanically operated flaps.

The aircraft was fitted with a Global Positioning System but it was considered unlikely that the pilot had used it and no data was recovered from it. There was a transponder fitted to the aircraft but the selector was found switched to the 'standby' position.

Previous engine failure

On the 15 May 2004, G-BJYG had an engine failure in flight, which resulted in a forced landing in a field. The aircraft was undamaged but, immediately after the incident, an attempt was made to restart the engine during which a small fire developed in the engine cowl. The maintenance organisation for the aircraft then attended to the aircraft and replaced several parts affected by the fire, including the carburettor heat box bearings and bushings and wiring to the alternator and engine starter. Whilst the aircraft was still in the field fuel was drained from the wing tanks in order to reduce its weight. None of this drained fuel exhibited any signs of water or contamination and it was later used in other aircraft with no reported problems.

The maintenance organisation ran the engine several times before the owner flew it out of the field. It was flown first to Sleap Airfield where it was refuelled and then to Barton for further maintenance and an annual inspection. No fault was found with the engine and the engine failure could not be fully explained. However, the weather at the time of the forced landing placed the aircraft in conditions that lie within the 'Moderate icing at cruise power and Serious icing at descent power' category of the carburettor icing chart reproduced later in this report.

Meteorological information

The weather conditions at Liverpool Airport recorded at 1120 hrs on 4 July 2004 were as follows: Surface wind from 290º at 15 kt, visibility 10 kilometres, scattered cloud at 2,000 feet, temperature 16ºC, dewpoint 10ºC and pressure 1012 mb. Meteorological data recorded in the 24 hours preceding the accident was examined and showed that there was no evidence of any rain having fallen in the period.

A graph to illustrate the probability of carburettor icing is reproduced below at Figure 1.

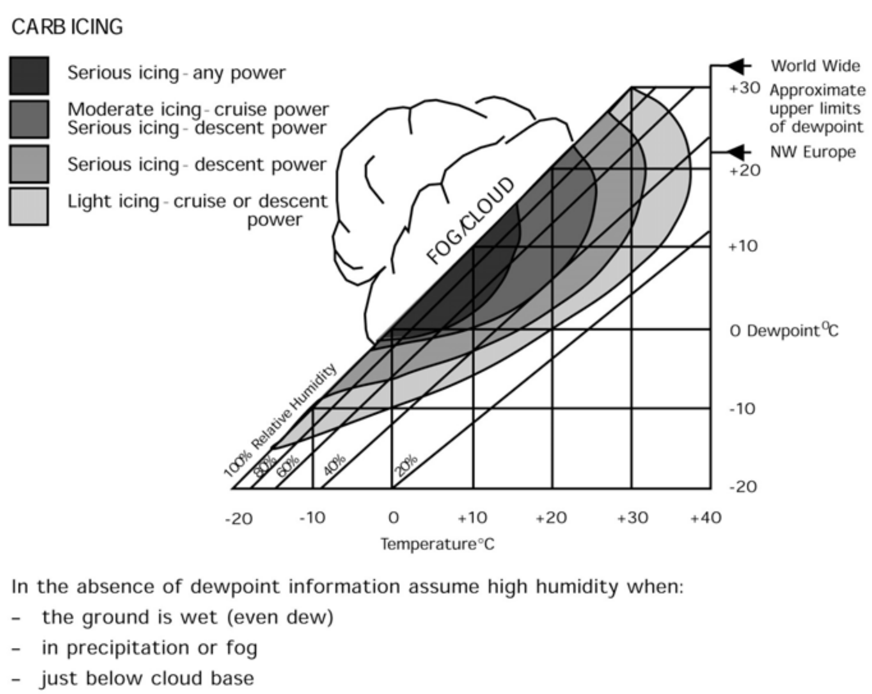

Figure 1

The conditions at the location where the aircraft ditched were described by the coastguard and an attending lifeboat as follows: Tide state, high water (8 metres depth); wind north-westerly force 4; sea state moderate and swell 1 metre. The direction of swell was reported as being confused because of the effect of sandbanks in the area.

Archived charts and meteorological data obtained from a radiosonde ascent for the 15 May 2004, the date of the previous engine failure, were examined. The weather on that day showed a light north-westerly airflow over the Shrewsbury/Liverpool area, a broken or overcast cloud layer at 4,500 feet, visibility of 10 to 20 kilometres and pressure of 1030 mb. The temperature at 2,000 feet was estimated at 12ºC with the relative humidity at 67%.

Recorded information

Air Traffic Control (ATC) voice communications with the aircraft were recorded and available to the investigation. The background noise during the pilot's transmissions was analysed and in the early transmissions it was possible to detect a specific noise which was reduced to a value of 50% of its original frequency in the 'MAYDAY' transmission. However the source of this sound could not be determined; it was of too high a frequency to be engine or propeller noise.

Recorded radar data from St Anne's Radar head (N5345:58.00 W00259:33.00), 20 nm north of the accident site) was also available. However, because the aircraft transponder was not switched to 'ON' only primary returns would have been recorded. A track of primary returns believed to be approximately the route of the aircraft were found but could not be positively identified as G-BJYG. These returns showed an aircraft tracking from an area to the south of Chester, in a north-westerly direction, then north along the estuary of the River Dee before turning right onto an easterly heading.

Accident site

The emergency services located G-BJYG about 2 nm north of Wallasey, it had submerged in the sea and had come to rest on the seabed on a heading of about 170°. At low tide, only the tip of the vertical stabiliser of the aircraft was visible and at high tide, the aircraft was about 8 metres below the surface of the sea. Recovery of the pilot and passenger, who were in the aircraft, took place later the same day, at low tide. Their lap strap and diagonal harnesses were still being worn and were secure and the only entry door, on the right of the aircraft, was found open.

Detailed aircraft examination

Following a successful recovery of the aircraft from the sea, it was taken to the AAIB facilities at Farnborough for further examination. The damage to the aircraft was extensive and indicated an impact with the sea at a pitch attitude of 20° nose down, with about 5-10° of left bank and some right yaw. The impact forces had caused the nose gear to collapse and caused extensive damage to the leading edges of both wings including separation of the right wing, and the tail had twisted to the left opening up the right rear fuselage. Due to the nose down attitude, the engine had been pushed rearwards, as had the instrument panel, causing deformation to the supporting structure around the cabin and its roof. The propeller was undamaged and indicated that the engine was not under power at the time of impact.

Inside the cockpit, the engine throttle was found at idle and the engine mixture was set to lean. Later examination of the damage to the carburettor confirmed that the throttle was at idle at impact. The carburettor heat selection could not be determined due to the damage to the instrument panel and the possibility that the cable operated control may have moved due to the damage to the operating mechanism on the underside of the engine. The starter key was still in the magneto switch and was positioned at R (right), but the key was bent with distortion to the surrounding panel; it is therefore possible that this moved from either L (left) or BOTH during the accident. The electric fuel pump switch was selected ON. Additionally the flaps were up and the pitch trim was at the neutral position.

The stall warning circuit breaker (CB) was found tripped. The stage at which this happened could not be determined; it could have occurred at any time before the accident or as a result of the impact forces.

Both fuel tanks had ruptured at impact but the left fuel filler cap remained in place; the right fuel filler cap, however, was missing and was not found. Inspection of both of the fuel tanks did not reveal any prior damage, nor were there any signs of corrosion. The seal around the left filler cap was in good condition and the cap fitted snugly to the filler. The fuel lines from the fuel tanks to the engine had also been ruptured in the accident, but there were no signs of any pre-existing damage or restriction. The fuel selector in the cockpit was found selected to the left tank and a flow test of the selector in both left and right positions did not reveal any restrictions. The fuel strainer had been compromised and was found full of sand and sea water, however the filter screen was clean. The electric fuel pump had also been damaged during the accident, but a strip examination did not reveal any problems and fuel was found in the down stream section of the pump. The engine driven fuel pump was intact and a subsequent bench check revealed a good suction force, and likewise fuel was discovered in the pump. The inlet fuel filter to the carburettor was inspected and found to be clean with a small amount of fuel in the fuel inlet pipe.

The seats were still secure and had not suffered any deformation and they had not moved forward. The pilot and passenger harnesses were securely attached to their fittings and did not exhibit any pre-existing damage. However, the instrument panel had moved aft significantly, reducing the distance between it and the occupants. There was evidence that indicated that both the pilot and passenger had come in contact with the instrument panel during the accident.

Engine examination

A specialist engine overhaul agency carried out a strip examination of the engine, under AAIB supervision. This revealed that there had not been a catastrophic engine failure, nor was there any pre-existing damage before the accident. The spark plugs showed that the engine had been running with a normal fuel/air mixture and at the expected temperatures. The oil pump operated correctly with oil found in the oil ways, and the oil filter only contained post accident debris. The only anomaly lay with the right magneto, which had incorrect timing and, during later testing, failed to produce a spark, because of a failed capacitor. Both of these magneto failures were considered to have been as a result of the impact forces and subsequent sea water contamination.

Refuelling

On the morning of the accident the refueller had arrived on shift at 0700 hours, following which he completed his checks of the AVGAS bowser that was later used to refuel G-BJYG. The checks included the testing of the fuel in the bowser for clarity, density, contamination and water content. The latter check was carried out using litmus paper that can detect water at quantities above 30 ppm. All of these checks were satisfactory.

Prior to fuelling G-BJYG, four other aircraft received fuel from the same bowser, G-BJYG was then refuelled until both its fuel tanks were full, giving a total uplift of 33 litres for that aircraft. Immediately after filling the tanks of G-BJYG, another six aircraft took fuel before the remainder, consisting of 350 litres, was used to top up another AVGAS bowser which was then utilised for fuelling helicopters. All the other aircraft and helicopters that used the same fuel supplied to G-BJYG have flown with no reported problems or indications of any water contamination.

Fuel properties

The fuel used for refuelling was AVGAS which is light blue in colour. Water is more dense than fuel so when small quantities are present clear colourless droplets are formed underneath the fuel. If agitated the water will become suspended in the fuel for a short time but will settle out within a few minutes.

Fuel and water sampling

The fuel sample taken from G-BJYG, by the pilot prior to the accident flight and handed in to the flying school, was retrieved by the AAIB following the accident and taken for specialist laboratory analysis. The sample contained about 7.5 ml of water and 1 ml of fuel, with some debris in the water and a layer of a black substance at the interface between the fuel and water. The fuel was analysed and appeared to be consistent with AVGAS 100LL. Although the sample contained debris and a substance at the interface, there was no evidence of any microbiological contamination. The water was also tested, but due to the small quantity, it was not possible to determine all of the constituents. It was found, though, that the sodium level in the water was low, thus ruling out sea water as a source.

Fuel samples were taken from the fuel tanks of the aircraft that had been refuelled immediately after G-BJYG. These samples were clear, bright blue and did not contain any water or other contamination and when tested at a specialist fuel laboratory, the fuel conformed to the specification for AVGAS 100LL.

Lastly, a fuel sample taken later in the day from the fuel bowser used to fuel G-BJYG was also tested and this did not contain any water or other contamination and conformed to the specification for AVGAS 100LL.

Maintenance

The last maintenance carried out on the aircraft was an annual inspection in May/June 2004, immediately following the previous engine failure and forced landing. No significant additional work was carried out to the fuel system, and the only additional work to the engine was to clean off corrosion and to replace the carburettor heat cable, damaged during the brief fire following the previous engine failure detailed above. All the tests carried out on the engine and fuel system were satisfactory with no defects. The aircraft left the maintenance facility on 16 June 2004 and had flown 8.5 hours before the accident flight with no reported problems.

Pathological information

Post Mortem examinations were carried out on both occupants. Serious injuries were sustained by each of them as a result of the aircraft's impact with the water, although the final cause of death was by drowning.

Witness information

Two training aircraft from Liverpool, with instructors on board, were in the immediate area of the accident and saw the splash as the aircraft hit the water. Both aircraft flew overhead the position but nothing could be seen, with the exception of a possible fuel slick. Both instructors commented that the weather and sea conditions seemed benign and found it difficult to believe that the aircraft had disappeared so quickly without trace.

Ditching procedures

There is comprehensive information published on ditching procedures in the General Aviation Safety Sense Leaflet (GASSL) number 21A, published by the Civil Aviation Authority (CAA) and available at the website address: www.caa.co.uk/docs/33/SRG_GAD_SSL21.PDF. This document includes guidance on recommended techniques for ditching an aircraft based on the sea state and wind conditions. For the wind conditions prevailing at the time of this accident it recommends ditching with a headwind component but along the general line of any swell.

From examination of previous ditching accidents there is evidence that a large proportion of people survive the initial impact and that most lives are lost as a result of exposure to cold water and drowning.

Analysis

The origin of the water in the fuel sample left at the clubhouse remains a mystery. The bowser procedures were rigorous and given that other aircraft were refuelled at the same time from the same source it leads to the conclusion that this was not the origin. The aircraft previously flew on the day before the accident when reportedly the fuel drains were operated before the flight and both tanks were used during the flight. Therefore the water would need to have entered one or both of the fuel tanks in the 24 hours preceding the accident. Meteorological records were examined for any evidence of rainfall but there was none.

It could not be determined whether water in the fuel was responsible for the engine failure. If all the water was drained out of both tanks before the flight then it should not have caused a problem. It is worth noting that the engine failure occurred about 30 minutes into the flight, which would be about the time that the pilot would be expected to change fuel tanks.

The pilot detected the presence of water in the fuel prior to flight and believed he had taken sufficient action to remove it. However the amount of water that he found is most unusual and would probably have warranted further investigation before flight.

The post accident examination of the engine did not reveal evidence of any mechanical problem that could have led to a failure. The aircraft had suffered a previous engine failure which was also unexplained. There is thus no clear reason for either engine failure but on both occasions meteorological conditions were such that there was a risk of moderate to severe carburettor icing. Such conditions are very common in the UK and although pilots are generally well aware of the risk carburettor icing cannot be discounted in this instance.

The engine failed at a time when the aircraft, although fairly close to land was out of gliding range; making a ditching inevitable. Preparation time was short but if the pilot had been able to reduce to minimum over water speed without stalling, before touchdown, it is possible that both occupants would have been able to escape from the aircraft. With the rescue services already alerted following the 'MAYDAY' call a quick rescue could have been effected.

In fact the impact forces were so great that incapacitating injuries were sustained. This was probably as a result of either an excess over water speed at touchdown or of the aircraft's stalling onto the water. The final heading of the aircraft could not be determined but the evidence of the relatively severe impact suggests that the touchdown was made out of wind. The difference in over water speed between an out of wind (tailwind) touchdown, and an into wind touchdown in this case could have been as much as 30 kt, a significant amount. The over water speed could have been reduced further by the use of flap. An aerodynamic stall would also have led to a severe impact, but if the stall warning CB had tripped out before the impact there would not have been any aural warning of an impending stall.

Assessment of the best landing direction over water is a difficult task for a pilot where he has to consider both swell and wind direction. In this case there were a number of factors that may have contributed to his decision making. The heading given in his last communication with ATC was south-easterly and with the coast in view ahead he may still have hoped to make land. Given the limited time available and the task of flying the aircraft in an emergency he may not have had the spare capacity to assess the best landing direction based on the wind strength and sea state. Also, were he to leave it too long before turning into wind there would then be insufficient height remaining in which to do so. It appears that the door was unlatched prior to impact but the absence of flap shows that only some of the vital actions were completed, perhaps a further indication of a lack of time.

The wearing of lifejackets and the carriage of a dinghy would not have prevented the deaths of the occupants in this accident. The nature of the injuries was such that it is unlikely that any attempt to escape from the aircraft was made. A ditching in reasonable conditions should be survivable and the evidence from previous ditchings is that most people do survive the impact. Many lives are lost however as a result of the time subsequently spent in the water without appropriate equipment.

Aircraft Type and Registration:	Piper PA-28-180 Cherokee, G-NINC	
No & Type of Engines:	1 Lycoming O-360-A4M piston engine	
Year of Manufacture:	1972	
Date & Time (UTC):	19 September 2004 at 1745 hrs	
Location:	Old Buckenham Airfield, Norfolk	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nose landing gear leg bent, engine shock loaded, engine mounting and engine bay bulkhead damaged	
Commander's Licence:	Australian Civil Aviation Safety Authority Private Pilots Licence	
Commander's Age:	30 years	
Commander's Flying Experience:	95 hours (of which 25 were on type) Last 90 days - 4 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries	

After a local area flight the pilot returned to the airfield to carry out a series of touch and go landings on grass Runway 25. The weather conditions were fair with a surface wind of 220º/10 kt. The first approach was flown at 80 mph with full flap, and the pilot was content with the speed and angle of approach. He flared the aircraft slightly late however, and it touched down on three points. He attempted to control the subsequent bounce, but on the second touchdown the aircraft bounced again. The pilot commented that he was over-controlling the aircraft by this stage and was established in a series of pilot induced oscillations. A third, more severe, bounce followed resulting in the aircraft touching down hard in a nose-down attitude. This damaged the nose landing gear and the firewall and caused the propeller to strike the ground. The aircraft eventually came to rest and the pilot, who was uninjured, was able to vacate it without difficulty.

Aircraft Type and Registration:	Piper PA-34-200T Seneca II, G-BRXO	
No & Type of Engines:	2 Continental Motors TSIO-360-EB piston engines	
Year of Manufacture:	1979	
Date & Time (UTC):	23 August 2004 at 1200 hrs	
Location:	Stapleford Airfield, Essex	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to left wing and propeller, shock-loading of left engine, possible damage to landing gear	
Commander's Licence:	Basic Commercial Pilot's Licence	
Commander's Age:	68 years	
Commander's Flying Experience:	3,127 hours (of which 1,710 were on type) Last 90 days - 21 hours Last 28 days - 11 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

History of the flight

The pilot had flown to Stapleford Airfield early in the morning to have a repair carried out to the aircraft's autopilot. When the repair had been completed the pilot was informed by the engineers that only the autopilot computer had been removed to effect the repair.

At midday the pilot departed for the aircraft's home base. Runway 22 was in use, which is partly asphalt (first 600 metres) and latterly grass (477 metres), with a crosswind component of approximately 15 kt from the right. Once the aircraft was airborne the pilot reported that he was "fighting to keep the aircraft's nose up". He tried trimming using the electric elevator trim system but found it did not work. The pilot therefore decided to abandon the takeoff: he landed the aircraft heavily on the remaining grassed runway length and the left propeller touched the ground.

Analysis

On subsequent inspection of the aircraft it was discovered that the elevator trim was in the full nose-down position and that the circuit breaker for the electric trim had been pulled.

The pilot candidly reported that he had not checked the trim prior to departure because he assumed that it been undisturbed during the repair. He accepts that he should have checked the trim, but he believed that the engineers should have pointed out that the circuit breaker had been pulled and they should have returned the trim to the take-off position on completing the autopilot repair work.

Conclusion

The checks carried out by a pilot are fundamentally important for an aircraft's safe operation. In carrying out checks and vital actions, there can be no justification for taking short cuts or making assumptions. Moreover, this accident also highlights the importance of accurately documenting work that has been carried out to an aircraft, especially when it has implications for its subsequent safe operation.

Aircraft Type and Registration:	Piper PA-38-112, G-BNSL	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1981	
Date & Time (UTC):	31 October 2004 at 1530 hrs	
Location:	Pembrey Airport, Carmarthenshire	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Minor damage to left wing.	
Commander's Licence:	Student pilot	
Commander's Age:	78 years	
Commander's Flying Experience:	425 hours (of which 14 were on type) Last 90 days - 12 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Following a dual circuit flight of 15 minutes with his instructor, the student pilot was briefed for a solo flight in the circuit. The weather was good with a calm surface wind. Runway 22 was in use. This runway has a concrete surface and a Landing Distance Available (LDA) of 767 metres. At the end of the runway is a wire mesh fence approximately five feet high and pilots are required to turn through 180° at the end of the landing roll to backtrack.

After approximately 45 minutes of various circuits, including go-arounds and touch-and-go's, the pilot made a final landing with full flap. Touch down was on the runway threshold and at the correct speed. No rudder application was required to maintain the centre-line and the pilot became aware that the retardation appeared less than anticipated. With the aircraft approaching the fence, the pilot attempted to turn right but the left wing tip contacted the fence. The pilot brought G-BNSL to a halt and closed down the engine.

In an honest report, the pilot acknowledged that he had misjudged the aircraft retardation in calm conditions and had applied the brakes too late.

Aircraft Type and Registration:	Socata TB20 Trinidad, G-FIFI	
No & Type of Engines:	1 Lycoming IO-540-C4D5D piston engine	
Year of Manufacture:	1986	
Date & Time (UTC):	16 August 2004 at 1626 hrs	
Location:	Kemble Airfield, Gloucestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Propeller and forward fuselage damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	64 years	
Commander's Flying Experience:	7,000 hours (of which 120 were on type) Last 90 days - 100 hours Last 28 days - 28 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

History of flight

The aircraft, having just completed its annual inspection, was flown from Denham Airfield to Kemble and after approximately 90 minutes on the ground at Kemble departed for a local flight. After a normal takeoff, the landing gear was selected up and although the green 'down' lights extinguished, the 'transit/unlocked' light remained illuminated. The aircraft was positioned downwind and the landing gear selected down. The result was that only the two main wheel lights illuminated green. Believing the noseleg to be unlocked, the pilot made a low pass in front of the ATC tower for a visual inspection. ATC confirmed that the two main wheels appeared to be in the down and locked position but that the noseleg was partially down positioned at approximately 45° from the vertical.

The aircraft was climbed to 2,000 feet agl and kept within the airfield air traffic zone (ATZ) whilst the pilot's operating handbook was consulted and emergency checklists items were actioned. The problem however, could not be rectified and a second visual inspection from ATC confirmed that the noseleg still appeared unlocked. The pilot declared an emergency and carried out two orbits whilst the emergency services were activated. After consultation with engineers, the pilot elected to make an approach to asphalt Runway 26 at Kemble, which has a landing distance available of 1,594 metres. The landing was made from a shallow approach and the nosewheel held off the ground as long as possible. Shortly after landing, the noseleg collapsed and the aircraft skidded a further 130 metres before stopping. Both the pilot and passenger were able to vacate the aircraft without injury.

Engineering Investigation

The primary method for lowering the landing gear uses hydraulic power from a motor driven hydraulic generator. There is also an emergency system that uses compressed gas struts to lock the noseleg down in the event of hydraulic failure.

Engineering investigation following this incident revealed that the compressed gas struts, used in the emergency lowering system, are not rechargeable and it appeared that there was not enough pressure in these struts to fully lock the noseleg in the down position. It also revealed that the brushes on the generator were worn to the extent that their condition probably rendered the hydraulic system inoperable. The Socata TB20 maintenance manual recommends that the brushes of the hydraulic generator should be checked every 1,000 hours. The aircraft had completed 1,030 hours at the time of the accident and had just completed its annual inspection. During this inspection however, the brushes on the hydraulic generator had not been inspected as the maintenance organisation believed that this was not required under the Light Aircraft Maintenance Schedule (LAMS).

Light Aircraft Maintenance Schedule

The LAMS is approved by the CAA for maintenance of light piston aircraft and is described in CAP 411. This schedule however, is generic in nature thus there remains a requirement for maintenance, overhaul and inspections of specified items recommended by the specific type design authority. The requirements specified in service bulletins and service letters issued by the type design authority must also be adopted to ensure continued operational safety and reliability. At present, 'inspections' recommended by the design authority are not referenced in CAP 411; these are completed at the judgement of the certified engineer. The inspection of the hydraulic generator brushes was therefore not mandatory and as the maintenance organisation believed there to be no known problem with the generator brushes, an inspection was not carried out.

The CAA are currently reviewing the contents of CAP 411.

Aircraft Type and Registration:	Hughes 369HS, G-CSPJ
No & Type of Engines:	1 Allison 250-C20 turboshaft engine
Year of Manufacture:	1976
Date & Time (UTC):	19 July 2003 at 0849 hrs
Location:	Cudham Lane South, Knockholt, Sevenoaks, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Fatal) Passengers - 2 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	112 hours (of which 8 were on type) Last 90 days - 12 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was seen to depart normally in good weather conditions. Shortly after takeoff, as the pilot acknowledged a frequency change instruction, the helicopter was seen to enter a descending left turn from which it did not recover. Eye witnesses reported seeing the helicopter 'fishtailing' and emitting unusual noises, cyclical in nature, which they thought consistent with changes in engine power. The pilot made one more RTF transmission just before ground impact but this message did not declare the nature of any problem. The machine struck the ground in a 30° nose-down pitch attitude at about 80 kt forward speed, severely disrupting the structure and imparting fatal injuries to the family on board. There was no evidence of any pre-impact technical failure and the engine was running at impact. The reasons for the accident could not be determined. However, information recovered from a Cockpit Voice Recorder (CVR) or Flight Data Recorder (FDR) could have enabled the investigators to determine the likely cause but there was no requirement for either on this rented public-transport category helicopter and none was fitted. Two safety recommendations were made concerning the installation of new technology cockpit voice recorders to all public transport category aircraft.

History of the flight

The pilot had hired the aircraft to take his wife and 14-month-old son for a local flight from Biggin Hill Airport. He had intended to fly out to the Canterbury area (40 nm to the east) and back to the airport. This was in preparation for a flight which the family was planning to make to the Isle of Wight the next day in the same helicopter. The pilot's son had flown with his father once before in a Bell 206 Jet Ranger but not in a Hughes 369HS (often referred to as the Hughes 500C). This latter helicopter presents a noisier environment for passengers, particularly those sitting in the rear seat, and the pilot and his wife wanted to ensure that their son would be comfortable in the aircraft before they embarked on a longer flight.

The family had arrived at the helicopter operator's offices at about 0745 hrs. The pilot discussed his intentions for the flight with the company's Chief Pilot and Operations Manager and confirmed his booking of G-CSPJ for the following day. The Chief Pilot was concerned that the pilot's son should have suitable protection for his ears because of the relatively high noise levels inside the aircraft. The pilot said that he had bought a headset specifically designed for a young child and it was agreed that that would be sufficient. The family, who all appeared to be in good humour, then drove to the hangar which was about one mile away on another part of the airfield.

The helicopter had already been refuelled and repositioned outside the hangar by one of the helicopter operator's own pilots to make room for a Jet Ranger that was in the hangar, in which he and another pilot were about to depart. The pilot of the Hughes was seen by the crew of the Jet Ranger to carry out a pre-flight inspection on his aircraft before strapping his son into a child's car seat which had been secured in the rear left seat of the helicopter. The Jet Ranger then took off and departed before the pilot and his wife had boarded the Hughes. Subsequent evidence showed that the pilot flew the Hughes from the front left seat, as is normal for this type, and his wife sat in the rear right seat. From his position, the pilot would have had difficulty in seeing his wife, and vice versa because of the central pillar behind and between the two front seats which contained the main rotor control runs (see Figure 1). Also, he would have had at least as much difficulty in seeing his son who was sat directly behind him.

Both collective levers and sets of yaw pedals were fitted in the helicopter but only the left seat cyclic was in place. The left collective lever was fitted with a friction control, which enabled the pilot to leave the collective in any required position if he had to take his hand off the lever, for instance while changing the radio frequency.

Having started the helicopter outside the hangar, the pilot called Biggin Hill ATC on the Tower frequency at 0843 hrs to request a Visual Flight Rules (VFR) flight "locally" to the east. He was given clearance to hover taxi to 'Pad One', which is an area of grass located on the north side of the threshold for Runway 29, and having arrived there was seen to bring the helicopter to the hover. The pilot then called to say that he was ready for departure and at 0846:20 hrs he was given clearance by ATC to take off to the east. He was advised that the surface wind was 180°/10 kt and that another aircraft, which was joining the circuit, was just passing abeam Sevenoaks (a town 6 nm to the south-east). The helicopter took off towards the south-east climbing to an estimated height of 500 feet above aerodrome level (aal), as observed by the two Air Traffic Controllers on duty in Biggin Hill ATC Visual Control Room (VCR). It was normal for helicopters to track south-east towards Sevenoaks before continuing to the east and the height at which G-CSPJ departed ensured adequate separation from the inbound fixed wing traffic, which would typically be at a height of 1,000 feet aal. The helicopter's height also kept it below the base of Gatwick's Control Area, which was further to the south.

At 0848:02 hrs the Biggin Hill ATC Tower Controller repeated the information about the inbound traffic and instructed the pilot of the Hughes to change to the Approach Controller's radio frequency. The pilot did not respond to this radio call and the Tower Controller called again 10 seconds later, reiterating the instruction to change to the Approach Controller's radio frequency. The pilot acknowledged this call but did not indicate whether he had seen the other aircraft, a Cherokee, and the pilot of that aeroplane stated later that he did not see the helicopter. The pilot of the Hughes 369 completed his radio transmission at 0848:16 hrs and to do so would have used the press-to-transmit switch located on the top of the cyclic control.

It was the helicopter pilot's normal custom to pre-set the Biggin Hill Approach frequency in the standby position on the radio frequency selector, with the Tower frequency selected in the active position, before lifting into the hover at the airfield. This meant that he only had to press the button that would move the Approach frequency to the active position when it was required. A radar recording subsequently showed that when the pilot transmitted his reply, acknowledging the frequency change, the helicopter was 2.4 nm from Biggin Hill Airport on the 139°M radial and had been tracking approximately 135°M since it had first been detected by the radar one minute earlier. The radar recording also indicated that, at or just before the pilot's radio call, the helicopter entered a turn to the left which seemed to continue until the aircraft disappeared from the radar screen at 0848:26 hrs, just 10 seconds after the pilot completed his acknowledgement of the frequency change instruction.

A witness who was standing in a friend's garden 3 nm to the south-south-east of Biggin Hill Airport had seen the helicopter approaching from the north-west. He recognised the aircraft as being G-CSPJ from his time spent at the flying club whose premises are next door to those occupied by the helicopter operator. The helicopter was observed to be flying straight and level, or possibly in a slight climb, at an estimated height of 400 to 500 feet. At about the position that the helicopter would have been when the pilot acknowledged the frequency change, this witness stated that he heard the engine noise changing from a high note to a low note and back to a high note over a three second period. He remarked to his friend that it did not "sound right" and at that point he saw the helicopter yaw to the left, possibly as much as 30°, and, seemingly, start a shallow descent at a forward speed which was considered to be slower than would be normal in the cruise. Tall pine trees on the eastern side of the garden then obscured the helicopter and "within a split second" the witness heard the 'engine' noise from the aircraft cease abruptly. He considered that this might have been a result of the blocking effect of the trees and the distance and orientation of the helicopter, as much as for any other reason.

Another witness, also a helicopter pilot, was standing in a nearby property and heard G-CSPJ approaching from the north-north-west. He saw the aircraft yaw left and right two or three times over a period of five seconds and then enter a turn to the left and start to descend. It straightened up and descended at a greater rate, pitching nose down about 45° as it flew away from his position towards the north-east. This witness concluded that the helicopter was "in trouble" when he saw it descending. He estimated that its forward speed was about 80 kt.

In the final stages of its flight the helicopter flew low over a private house on the east side of Cudham Frith (a wooded area 2.5 nm to the south-east of Biggin Hill Airport) at an estimated height of 150 feet, travelling in an east-north-easterly direction. Four witnesses in the garden of the property described the noise of the helicopter as being very loud and one of the four remembered hearing the noise "revving up and down" about two times. They all thought that the helicopter had a nose down attitude as it flew over, with one witness recalling that it pitched down 30° when it was directly above the house. It flew over Cudham Lane South, which is adjacent to the property, and just before disappearing behind the trees alongside the lane, the helicopter was seen to roll left gradually to about 15° angle of bank. Two witnesses in the garden of the property immediately to the north and two more at the stables next door to that were aware that the noise from the helicopter sounded loud but remembered it being constant.

When the helicopter was approaching and flying over the house adjacent to Cudham Frith, other witnesses half a mile to the east and north-east of the aircraft were alerted by its unusual sound. They variously recalled it sounding similar to a lawn mower engine "hunting", the engine noise from an aerobatic aircraft changing from low to high power and back again (repeated three times) or, thirdly, as if the engine power was surging (about six times over a 15 second timespan). Another witness heard a mechanical, grating noise coming from the aircraft and saw it rocking from side to side, although not violently. By all accounts, the helicopter was finally seen to enter a left turn and pitch nose down between 30° and 45° with one witness estimating the angle of descent at 40°. G-CSPJ then disappeared out of sight behind trees and a "thud" was heard. A brief transmission made at 0848:30 hrs on the Biggin Hill Approach frequency has been identified as coming from the Hughes 369. The voice is considered to be that of the pilot and the two words heard are a distressed utterance rather than recognised RTF language. This transmission coincided with the time that the helicopter is believed to have struck the ground in a field on the east side of Cudham Lane South (see Figure 2).

Many people in the vicinity heard the noise from the impact and went to render assistance but it was immediately apparent to the first witnesses on the scene that the three occupants of the helicopter had not survived the accident. Although there was a strong smell of fuel, no fire ensued despite the helicopter being very seriously disrupted.

Personnel information

The pilot started flying in September 2001 and all of his experience was gained in helicopters. He obtained his Private Pilot's Licence (Helicopters) in April 2002 and was issued with a rating for the Bell 206 Jet Ranger at the same time. That rating was renewed a year later in April 2003 and in the same month the pilot added the Hughes 369 rating to his licence, having started his training for that type in January 2003. He had further plans to continue his training in the future and gain a commercial licence. Having experienced no problems previously, he had been encouraged to pursue this idea.

The pilot had accrued a total of 112 hours on helicopters, of which eight hours had been gained in the Hughes 369. The remainder, apart from two initial lessons in a small piston-engine helicopter, had been flown in the Bell Jet Ranger. Of those eight hours in the Hughes 369, the pilot had flown as pilot-in-command (PIC) for a total of 1 hour and 40 minutes. His last flight in the Hughes was on 29 June 2003 when he flew, with a passenger, to Lydd Airport. Having landed, he shut the helicopter down for an hour and a half before returning to Biggin Hill. His previous and only other flight as PIC in the Hughes was on 6 May 2003. His last previous flight in any aircraft took place on 6 July 2003 when he flew a Bell Jet Ranger.

On a number of occasions the pilot had taken friends and family for flights in a Jet Ranger. All of them remarked on his safety consciousness, discipline and thoughtfulness towards his passengers as well as his calm attitude and ability to concentrate on what he was doing. He would habitually brief his passengers not to talk to him after takeoff until he spoke to them. Moreover, he was not reluctant to carry out a precautionary landing if he was concerned about his aircraft's serviceability. Once, when the pilot was concerned about an unusual high-pitched noise, he advised ATC that he intended to land in a field. Having done so, he contacted the aircraft operator and the problem, which was temporary, was resolved and he continued the flight.

Similarly, the pilot's wife was regarded as being calm and capable and both she and the pilot were judged to have the necessary temperament and ability to cope with any distress that their son might have experienced during the flight, even if this meant that they had to make an unplanned landing.

Radio communications

The aircraft was fitted with the Garmin GNS 430, which combines VHF communications, navigation functions and moving map graphics on a single colour display (see Figure 3). The communications and navigation frequencies are both altered by means of the same co-located rotary knobs (one inner and one outer) situated on the bottom left hand corner of the combined control panel and display. Rotating the outer knob changes the MHz frequencies and the inner knob similarly changes the kHz frequencies. Momentarily pressing the inner knob toggles the tuning cursor between the communications and navigation standby frequency displays. It is possible to do this accidentally while changing the kHz part of the communications or navigation standby frequency. Both the communications and navigation displays show their respective active and standby frequencies. Pressing separate buttons for each facility moves the standby frequency to the active position.

Fuel shut off valve

The fuel shut off valve is operated by a push-pull control on the left side of the instrument panel. The control, which is pulled out to close the valve, is in a similar but opposite position to the ventilation control on the right side of the panel (see Figure 4). In the Jet Ranger there are two ventilation controls and they are situated in comparable positions to the fuel shut off valve and the ventilation control in the Hughes (see Figure 5). Further, the shapes of the fuel shut off valve and the ventilation control in the Hughes are similar although the fuel shut off control is red in colour whereas the air vent control is black.

Meteorological information

The Terminal Area Forecast (TAF) for Biggin Hill for the period between 0700 hrs and 1600 hrs on 19 July 2003 gave a surface wind of 190°/10 kt with visibility in excess of 10 km and scattered cloud at 3,000 feet agl. At 0820 hrs an actual weather observation at Biggin Hill Airport recorded a surface wind of 160°/08 kt, varying in direction between 130° and 210°, with visibility in excess of 10 km and no cloud below 5,000 feet agl. The temperature was 22°C and the dew point was 16°C. In, general the weather was fine, typical of a good summer's day, and it remained so for the duration of G-CSPJ's flight.

Recorded data

The recorded data that was recovered was limited to the RTF tape recordings and a recording of Thames Radar (data from a radar head at Heathrow) for the period covering the flight. Analysis of the radar recording, which includes a 'contact' for G-CSPJ up to four seconds before the aircraft is believed to have struck the ground, indicates that the helicopter's average ground speed in the last 10 seconds of recorded flight was 72 kt.

Analysis of the radio transmissions from G-CSPJ indicates that the main rotor speed was a constant 490 RPM at the time of each radio call made by the pilot, with the exception that during his last brief transmission the main rotor speed had increased to 500 RPM. The normal power-on limits are 484 to 489 RPM and the power off limits, during autorotation, are 400 to 523 RPM.

Rate of descent analysis

At 0848:16 hrs the pilot acknowledged the frequency change from Biggin Hill Airport's Tower Controller. He made no mention of any problem, so it is reasonable to believe that the aircraft was at a height of approximately 500 feet agl. At the time, G-CSPJ was flying over a small valley so the aircraft may well have been maintaining 500 feet above the airfield's level (1,100 feet on the QNH pressure setting). However, the field in which the aircraft crashed has an elevation of 730 feet compared with Biggin Hill Airport's 600 feet. Taking account of that difference, it is possible that G-CSPJ descended no more than 370 feet in the last 14 seconds before striking the ground. That would give an average rate of descent (ROD) of 1,585 fpm. This compares with the helicopter operator's Training Manual figure for the ROD during autorotation, at 70 kt, of 1,800 fpm.

Description of the Hughes 369 (MD-500) helicopter

The Hughes 369 series arose from a US military requirement for a light observation Helicopter, where it was known as the OH-6. In its initial form (including the civilian version known as the Model 369HS) it had a four-bladed main rotor and V-shaped empennage. Later versions had a five-bladed rotor and T-shaped empennage, but all models used manual flying controls without hydraulic assistance. Handling is generally considered to be more responsive compared with other helicopters in the same category.

Although, as stated, there is no hydraulic assistance to the flight controls, a device known as 'the one-way lock' is fitted in the longitudinal pitch control circuit. According to the aircraft's manuals, the lock was found to be necessary to offset high stick forces which could be fed back from the main rotor into the longitudinal pitch circuit in the aft-cyclic sense at high forward speeds. The one-way lock is a self-contained hydraulic device which allows inputs from the cyclic control stick to be transmitted to the swashplate but locks if any loads are fed back by the rotor disc into the cyclic stick in an aft sense: these loads are transmitted into the structure. There are two failure modes of the one-way lock – one in which the aft loads are fed-back into the cyclic (translating as about 40 lbs stick pressure) and the other in which the same 40 lbs could be required to move the stick in either longitudinal direction every time a change is required.

All models of this helicopter are equipped with electrical actuators for longitudinal and lateral trim. Trim control is via a conventional 'coolie hat' switch on the top of the cyclic control column.

On-site examination

The wreckage of the helicopter lay spread across a field of short grass. From the initial impact mark to the furthest pieces of wreckage was a distance of 60 metres, forming a debris trail on a heading of 360°. The initial impact marks comprised a heavy depression created by the nose fuselage underside and two marks associated with the front of the landing skids. About four metres further on and to the right of the depression, a series of three main rotor blade marks could be discerned, each partly overlaying the other. After this very heavy impact, which completely disrupted the helicopter forward of the engine firewall, smaller items from the fuselage and the cabin continued to the end of the trail, where the engine, main rotor gearbox, tailboom and empennage came to rest. There had been no fire, although a strong smell of fuel persisted around the initial impact area and along the wreckage trail.

Remnants of two of the four main rotor blades had remained attached to the rotor head, another was found about one-third of the way along the wreckage trail. The fourth had been flung out to the right of the debris trail and lay in the boundary hedge of the field and was the least damaged. One of the tail rotor blades was found 35 metres before the first impact whilst the other was located about the same distance beyond it. Examination of the collective lever friction control (a rotating collar) revealed that the friction was 'off'.

Conclusions from on-site examination

The length of the wreckage trail suggested that the helicopter had been travelling at a relatively high speed (subjectively in the order of 80 kt) on a northerly heading at impact. The depth and relative aspects of the initial impact fuselage, skid and rotor marks indicated a nose-down attitude in the order of 30 degrees, this leading to immediate and complete disruption of the forward fuselage and cabin. The heavier parts of the helicopter were thrown to the furthest extent of the wreckage trail, as is common in this type of impact.

The multiple main rotor blade strikes at a single location were indicative of substantial main rotor RPM with the steep nose-down attitude causing blades to impact successively close together. The fourth blade detached and was thrown to the right before it struck the ground. Similarly, the disposition of the tail rotor blades was consistent with significant rotational speed at the time of their separation.

Thus it was concluded that the helicopter had been structurally intact at the time of ground impact and that there was evidence of high-speed rotation of the main and tail rotors. The aircraft had been travelling at considerable forward speed but descending relatively steeply (compared to normal helicopter operations) with a correspondingly steep nose-down attitude. The impact was not survivable.

Detailed examination of the helicopter

The wreckage was removed from the site and transported to the AAIB hangar at Farnborough for further examination. The airframe was examined first, in conjunction with a representative of the manufacturer. The components of the flight control system, in particular, were separated out and checked for pre-impact continuity and any signs of anomalies. The 'one-way lock' device was taken to the manufacturer's facility in the USA for testing and strip inspection, with no pre-impact defects being found as a result.

The two cyclic trim actuators were identified. Being electric motors rotating an extending screw-jack arrangement via gearing, their extensions were unlikely to have moved during the impact and it was found in both cases that they were in a position corresponding approximately to neutral trim.

The engine was removed from the airframe and despatched to an overhaul facility for strip inspection under AAIB supervision and in the presence of a representative of the manufacturer. This examination concluded that there was no evidence of any pre-impact failures or anomalies and that the engine was operating at the moment of impact. Despite the massive damage to the airframe, the engine itself was relatively intact and it was possible to test most of the associated accessories to a greater or lesser extent. Particular attention was paid to the Power Turbine Governor (PTG) which controls the power turbine (and hence main rotor) RPM. The PTG was mounted on a test rig and put through a manufacturer's test schedule. With one or two minor exceedences of limits, which were not considered to be detrimental to its operation, the unit was considered to have been capable of satisfactory function, although it was acknowledged that the test schedule may not have been effective in detecting any tendency by the PTG to 'hunt' around the selected RPM. It was advised that the best way to check for this phenomenon would be to install and run the unit on a test engine. The condition of the unit precluded this option.

The light bulb filaments from the central warning panel were examined under a microscope to determine whether they showed any signs of hot stretching, indicative of being illuminated at impact. No signs of such were found on any of the filaments.

Finally, some attempts were made to verify that all four entry doors of the helicopter were closed and latched at impact, as the operator advised that accidental in-flight opening of the doors was not unknown, albeit with no catastrophic consequences beyond the possible distraction of the pilot and/or alarming effects on passengers. The earlier models of this helicopter employed a method of latching the doors which was improved on later models, but without the ability to retrospectively embody on the earlier versions. This same lack of positive latching which could lead to incomplete closure and inadvertent opening also leads to difficulty in establishing that the doors are closed and latched prior to impact. This is because structural flexing or handle movement can allow the doors to spring out from their latch plates without leaving distinctive witness marks on either the plates or the lock plungers. The only door which appeared to yield clear evidence of being shut at impact was the pilot's (left) door, where damage and distortion could be matched to similar effects on adjacent frame and fuselage structure. Evidence of the status of the other doors was inconclusive.

Pathological information

The pathology report stated that all three occupants had died from severe multiple injuries which were received during the accident. There was no evidence of any disease or toxicological factor which could have caused or contributed to the accident.

Tests and research

A flight was carried out in a Hughes 500E helicopter, under the command of one of the aircraft manufacturer's instructors/test pilots, to establish what handling characteristics this type of aircraft possesses. Although this was a different variant of the helicopter type from that involved in the accident, the manufacturer advised that its flying characteristics were the same. The most notable differences between the two variants are that the 500E model has five main rotor blades, which is one more than the 369HS, and it has a T tail as opposed to the V shaped tail on the accident aircraft. The opportunity was also taken to try and reproduce the noises which the witnesses recalled G-CSPJ making shortly before it struck the ground. The test conditions were clear sky, light wind, 1,000 feet agl and essentially level flight at the start of each test point.

The most notable feature of the aircraft was its behaviour when the collective was lowered promptly to enter autorotation and the cyclic control was kept in the same position as it had been for straight and level flight at 70 kt. Within three seconds of lowering the collective to its full extent the helicopter had pitched down approximately 30° and rolled about 10° to the left.

The test aircraft was flown past an observer on the ground while regular variations were made, separately, on the collective, cyclic, yaw pedal and throttle controls. The results were recorded on a video camera for qualitative assessment. The inputs which gave the greatest fluctuations in audible pitch and volume were those involving the collective and throttle. Of these two, the throttle variations were most apparent to the ear. It was considered that the noise being heard was that of the rotor blades rather than the engine.

The aircraft manufacturer confirmed that the collective control would remain where it has been set, without friction applied, if the 'collective bungee' had been correctly adjusted. The 'collective bungee' is designed to render collective lever loads relatively constant throughout the full range of travel. Should the adjustment of the collective bungee alter then the collective lever could either tend to 'throw off' or 'throw on' pitch depending on whether it was above or below its midpoint of travel.

Another flight was also conducted in a Jet Ranger helicopter, the other type that the pilot was qualified to fly. This flight retraced, as much as possible, the track flown by G-CSPJ.

Analysis

When, at 0848:16, the pilot completed his radio transmission acknowledging the instruction from the Biggin Hill ATC Tower Controller to change to the Approach frequency, 129.4 MHz, there was no sign that there was a problem with the helicopter or the pilot's ability to control it. He had not responded to the first instruction to change radio frequency and this could have been because he was talking to his wife or son, or vice versa and had not heard the radio call. Possibly there was some other distraction but whatever it was that distracted him, he was not prompted to mention it to ATC and he sounded content to change frequency and continue with the flight in the good weather that existed.

The evidence indicates that G-CSPJ struck the ground 14 seconds later, at 0848:30, in an approximately 30° nose-down attitude having descended 370 feet or more and turned left through about 130°. The aircraft's ground speed was estimated by radar to be 72 kt in the 10 seconds up to 4 seconds before impact. At impact the ground speed was assessed as being of the order of 80 kt. It follows that the aircraft descended at an average rate of 1,585 fpm or greater and at a mean angle of bank of about 30° (using simple formulae) during the last 14 seconds of flight. During that time the pilot changed the aircraft's active radio frequency from 'Biggin Tower', 134.8 MHz, to 'Biggin Approach', 129.4 MHz. At the moment when the helicopter was about to strike the ground, the pilot's voice was heard on the latter frequency indicating that the press-to-transmit switch on the cyclic stick had been depressed.

It is most likely that the pilot changed the radio frequency before or while the helicopter was starting its descent and left turn. To do so, it would have been normal for him to take his left hand off the collective lever and place it on the cyclic stick thus allowing him to use his other hand to operate the controls on the radio which was located on the console to his right. This would have felt unfamiliar by comparison with the Jet Ranger, in which he had gained most of his experience. In the Jet Ranger the single pilot operates the flying controls from the right seat and retains control of the cyclic with his right hand while changing the radio frequency with his left hand. In both cases the collective lever can be held in its cruise position by applying a degree of friction while the lever is untended. It is estimated that this simple act of switching the standby radio frequency to the active position in the Hughes would have taken a matter of about three to five seconds if the 'Biggin Approach' frequency had been pre-set in the standby position.

If, for some reason, the Biggin Approach frequency had not been pre-set in the standby position, the pilot would have had to change both the MHz and kHz elements of that frequency and then transfer it to the active position. This might have taken of the order of five to ten seconds and it is possible that during that process the pilot could have accidentally pressed the inner tuning rotary knob and toggled the tuning cursor to the navigation standby frequency. In that event the act of changing frequency would probably have taken even longer and could have concentrated the pilot's attention inside the aircraft and distracted him from seeing or feeling what the helicopter was doing. The fact that the aircraft descended and turned simultaneously might have masked the gravitational cues that the pilot would normally get if the aircraft was conducting those manoeuvres separately. However, that said, the aircraft would have been quite controllable during the period of the frequency change if the pilot had maintained a frequent lookout and monitored the positions of the flying controls.

If the pilot had not applied sufficient friction to the lever and if the collective bungee had moved out of adjustment since it was last inspected, it is possible that the collective lever could have risen or fallen while it was untended. In doing so the helicopter would have yawed right or left unless the change in torque was counteracted through the yaw pedals; G-CSPJ was seen to yaw both ways at about the time that the pilot acknowledged the frequency change but it could not be concluded with certainty what caused those manoeuvres. They might have been the result of a control input or inputs, instability in the PTG or other sources of variation in the power being delivered by the engine. Unfortunately it was not possible to test the PTG for any tendency to 'hunt' around the selected RPM.

The speed of the main rotor (Nr) was calculated to be 490 RPM during all but the last, very brief radio transmission when the Nr had increased to 500 RPM. These figures compare with the normal 'power on' limits of 484 to 489 RPM and the 'power off', autorotation limits of 400 to 523 RPM. The investigation concluded that the engine was producing power at the time the aircraft struck the ground but, because it was not possible to say with certainty that the PTG was operating correctly, the increased Nr could either have been the result of the engine speed hunting about a mean figure or the aircraft flaring rapidly and the Nr increasing above the governed speed due to autorotative forces. This latter situation could have been the result of the pilot instinctively trying to pitch the aircraft nose up, with rapidly applied aft cyclic, in an attempt to avoid the ground.

The investigation revealed no pre-impact defects in the flying controls, that the engine was operating at the time it struck the ground and that the rotors were rotating within the limits required to enable controlled flight. The average ROD of the aircraft during the final 14 seconds approached the 1,800 fpm expected during a stabilised autorotative descent at 70 kt. This indicates that the collective lever was lowered during that time, either voluntarily or involuntarily. If it had been a voluntary control input, that suggests that the pilot may have been intending to land. The subsequent reconstruction flight in a Jet Ranger revealed that there were other fields ahead and to either side of G-CSPJ's south-easterly track which were possible alternatives and would have provided a more into wind approach than was flown by the Hughes. Also, had it been the pilot's intention to land immediately, it is likely that he would have advised ATC on the radio.

The investigation has revealed no technical reason for the pilot to carry out a landing away from the airfield or any failure which would have impaired his ability to control the aircraft, as might be implied by the extreme pitch attitude of the helicopter when it struck the ground. In the absence of any such fault, the aircraft's responsiveness to control inputs should have enabled the pilot to correct the helicopter's flight path and avoid it striking the ground at such apparent high speed. The implication is that he was not aware of the impending danger as the aircraft departed from straight and level flight.

It is possible that the collective lever lowered without the pilot's knowledge after he had released it to change the radio frequency. Following the accident the collective friction on the left lever was found to be off, leaving both levers free to move. If it had lowered to its full extent, the aircraft would have yawed left unless the yaw pedals were moved to take account of the reduced torque reaction. Also, the aircraft would have pitched forward and rolled left, but less markedly, unless corrective inputs were made on the cyclic. These reflect some of the aircraft's manoeuvres witnessed by observers on the ground. However, they do not account for the fluctuating noises from the aircraft and the successive yawing manoeuvres. It is possible that the collective did drop and that the pilot repositioned it, thus explaining a successive yaw movement to the left and then to the right. That said, having noticed such corrective action, the pilot would probably have been wary of the potential for the aircraft to descend, or he could have applied sufficient collective friction to prevent it lowering.

Consideration was given to the possibility that the pilot could, accidentally, have pulled and closed the fuel shut off valve, mistaking it for a ventilation control which is in a similar position in the Jet Ranger. It was a warm day and, even at that early stage in the flight, the temperature may have been rising uncomfortably, particularly for the pilot's wife and son who were sitting on the back seat. If that was the case, the pilot must have re-opened the fuel shut-off valve because the engine was producing power when the aircraft struck the ground. In addition, following such an unintentional slip, it is likely that the pilot would have been very conscious of the aircraft's proximity to the ground and, as it approached, he would probably have flared the aircraft to reduce both its rate of descent and forward speed, either to execute a forced landing or to avoid the ground. By contrast, witnesses stated that the aircraft pitched down just before striking the ground and the wreckage trail indicated that it had a high forward speed.

The fluctuating noises recalled by a number of the witnesses were best reproduced on an aircraft flown by one of the aircraft manufacturer's test pilots/instructors by repeatedly raising and lowering the collective lever, or rolling the throttle on and off. It is difficult to determine why the pilot should need to 'pump' the collective lever with the aircraft descending under power. It is possible that when he released the collective lever to change the radio frequency, with the friction set too low, the lever dropped under the influence of the collective bungee and became jammed but still allowed a degree of movement. That, however, would not explain the pilot's apparent inability to control the aircraft in pitch, unless the temporary restriction affected both the cyclic and collective controls.

In the absence of any technical fault, there appears to be no reason for the pilot to alter the throttle setting. If he had, or the engine power had been fluctuating, it should still have been possible to control the aircraft in pitch and for the pilot to make an emergency radio call, as he had when carrying out an unplanned landing once before.

Finally, the helicopter was so severely disrupted, it is possible that the damage sustained has masked a problem, fault or control restriction which the pilot was attempting to overcome. It is known that the doors on this model of the Hughes 369 can open if not correctly latched shut before flight. However, in previous incidents it has been possible to close the door again in flight or make a controlled landing and then rectify the situation. Whether this or something else distressed the pilot's 14-month-old son cannot be discounted. Having said that, the pilot and his wife were regarded as being calm and capable people who would have been able to cope with such a distraction without it affecting the safety of the flight, even if it meant making an unplanned landing.

In summary, a large number of conceivable situations were examined during the investigation to try and establish the cause or causes of this accident. Each possibility was flawed because it did not fit all the known facts and witness evidence. This is unsatisfactory from two perspectives. It is not possible to state what measure or measures would prevent such an unusual accident from happening again and, secondly, those with a personal interest may never know why the accident occurred. It is extremely likely that the pilot would have taken the necessary action to prevent the aircraft striking the ground if he had been aware of its proximity. Therefore, it seems either that he may not have realised their predicament until the final moment or there was some obscure fault within the helicopter's power train or flight controls that left no post-impact evidence.

Conclusions

The investigation revealed no evidence of any pre-impact faults in the aircraft and the pilot did not make an emergency call on the radio, although he had successfully changed the frequency from the Biggin Hill ATC Tower frequency to the Approach frequency. A number of possible explanations were explored but each was flawed. As a result of insufficient information, the cause or causes of this accident, which happened in good weather and shortly after departure from Biggin Hill Airport, remain unresolved. This might not have been the case if the aircraft had been fitted with a Flight Data Recorder or Cockpit Voice Recorder or both. No such equipment was required or fitted on this aircraft.

International Standards and Recommended Practices - Flight Recorders

ICAO Annex 6, Operation of Aircraft[1] details the Standards and Recommended Practices for the carriage of flight recorders for rotary wing aircraft. The Standard[2] for International Commercial Air Transport helicopters is that a 30 minute CVR shall be fitted for weights in excess of 3,180 kg and with a first Certificate of Airworthiness dated 1 January 1987 or later. It is a Recommended Practice[3] that, for helicopters of that weight category with a first Certificate of Airworthiness dated 1 January 1990 or later, that a CVR with two hours duration should be fitted. Although the accident occurred on a private flight, G-CSPJ had a Certificate of Airworthiness in the Transport (Passenger) category but, due to the low weight and age of the helicopter, it was not required to carry any type of flight recorder.

The Air Accidents Investigation Branch in the UK has conducted, or assisted with, investigations into the circumstances of many helicopter accidents. All of the investigations concerning larger

[1] Annex 6, Part III, Section II is applicable to International Commercial Air Transport - Helicopters. Annex 6, Part III, Section III is applicable to International General Aviation - Helicopters.

[2] ICAO definition of Standard: Any specification for physical characteristics, configuration, materiel, performance, personnel or procedure, the uniform specification of which is recognised as *necessary* for the safety or regularity of international air navigation and to which Contracting States *will conform* in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

[3] ICAO definition of Recommended Practice: Any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform specification of which is recognised as *desirable* for the safety or regularity of international air navigation and to which Contracting States *will endeavour to conform* in accordance with the Convention.

helicopters have benefitted from the information provided by the crash protected flight recorder(s) fitted at the time, whilst those without such devices, as in the case of G-CSPJ, have had to rely on witness and wreckage analysis only.

Before the UK requirement to fit both a CVR and a FDR to the larger categories of helicopter was introduced, a CVR was the sole source of information recorded onboard at the time of accidents and no dedicated parametric data, such as from a FDR, was available. In spite of this, valuable information was derived from analysis of audio recordings that assisted the investigations. The type of analysis performed then is still used in current investigations and falls broadly into two categories.

The first, and the most straightforward, is the reconstruction of the actions of the crew during the event. The method primarily concentrates on the provision of a time-related transcript of crew speech (including incoming and outgoing ATC communications). In some cases this may prove to be the *only* evidence of what the crew were attempting to do. In addition to crew speech the transcript includes reference to any audible warnings, alerts or discrete noises events such as 'sound of low rotor speed warning' or 'sound of touchdown'. Subjective analysis of the crew speech by qualified aviation psychologists is also used to provide some information regarding crew stress, workload and behavioural patterns. Combining this information gives the accident investigator a broad picture of the cockpit environment before the accident occurred.

The second area of analysis cannot be achieved through simply listening to the audio recordings but requires more specialist audio equipment. It requires the analysis of the frequency content of the recorded signals and a detailed knowledge of the mechanical and electrical systems onboard an aircraft, in particular the power train construction and usual operating regime of the aircraft. In general terms, the audio signal is separated into the amplitudes of the various frequency components through the use of Fast Fourier Transform (FFT) analysis. A determination is then made as to the origin of the frequencies that are higher than the noise floor of the recording. This method is widely used by accident investigators and, in the main, is applied to the recording made from the cockpit area microphone. It should be noted however that analysis of the recordings from the remaining CVR channels has yielded information that has proved invaluable to the investigation in some circumstances. From analysis of the area microphone recording of a helicopter, a time history of some parametric data can be produced. Main rotor speed, engine gas generator speed and engine free turbine speed are examples of parameters which are usually derived in this manner. Other transmission related parameters might be derived depending on the circumstances of the accident and the quality of the audio recordings.

An assessment of change in amplitude of a particular frequency component over time can also provide the investigator with information regarding the degradation of the performance of an element of the power plant or transmission. This latter type of analysis, conducted by investigators after an accident, is the basis for the health monitoring systems that are now fitted to UK helicopters operating in the North Sea. Although the equipment fit for these helicopters includes a flight data recorder, it should be noted that the parametric time history derived from an audio recording is continuous whereas that from a FDR is a time-sampled history. Some of the sampled points are at intervals of up to one second apart and it is thus possible for the FDR recording to 'miss' some short period event whereas it may be detected by analysis of the CVR recording. In addition, fitting a flight data recording system to any aircraft is far more intrusive and hence likely to be more costly, than the fitting of a CVR system.

It is important to note that, even with a quiet cockpit such as may be found with single crew operation, the CVR will still provide valuable evidence to an investigation.

In accidents where there is extensive disruption of the aircraft due to the circumstances of the impact sequence, it may not be possible to determine cause and effect from wreckage analysis and witness evidence alone. This has proved to be the case in a number of the investigations, including that into the accident to G-CSPJ, which the AAIB has conducted. This is in contrast to the investigations into the circumstances of those accidents where CVR recordings were available; a selection of which are listed below:

AS332	Super Puma cracked tail rotor flapping hinge bearing – spectral analysis
S61N	Heavy vibration – ditched in sea – spectral analysis
S76	CFIT no FDR fitted – crew speech gave history of flight
S76	Crew perception of change in vibration due to failing main rotor blade
S61N	Hydraulic servo failure – spectral analysis
S61N	Search and rescue crew member fatal – crew speech gave history of flight
S61N	Practice search and rescue detail – crew speech gave history of flight
S61N	Tail rotor failure loss of control – crew speech and spectral analysis
SA365N2	Nearly ditched unintentionally – crew speech gave history of flight
AS332	Severe turbulence with tail rotor strike – crew speech and spectral analysis
S61N	Engine bearing failure followed by fire – crew speech and spectral analysis

The Air Accidents Investigation Branch has recognised the value of cockpit voice recordings since their introduction and has, as part of the certification process for new recorder/airframe combinations, provided an element of quality control by conducting assessments of flight test recordings for UK registered aircraft. The AAIB has also promoted the widening of the range of aircraft (initially fixed wing) to which CVRs are fitted. To this end it has recommended that CVRs be fitted to a wider range of aircraft in order to provide investigators with this valuable source of information should a tragedy occur. For fixed wing aircraft, this recommendation[1] has been accepted by, and is awaiting formal approval from, the JAA, which now advises the European Aviation Safety Agency (EASA).

As technology becomes more compact, lighter and cheaper, consideration should be given to encouraging owners, operators and manufacturers to fit recorders to as wide a range of aircraft, however small, with special emphasis initially on those that have a Certificate of Airworthiness in the Transport (Passenger) category. This would increase the proportion of air accidents which are solved and, thereby, improve the aviation community's knowledge of how to prevent accidents. While recommending consideration of such a measure, it is appreciated that the arguments against are financial, technical, and operational. However, it is envisaged that these arguments will diminish as technological progress reduces the commercial penalties of fitting a miniature CVR. It is therefore recommended that:

Safety Recommendation 2004-84

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

It is further recommended that:

Safety Recommendation 2004-85

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 two safety recommendations.

[1] AAIB Safety Recommendation 2001-38

Figure 1
(View from rear right seat – Hughes 369HS)

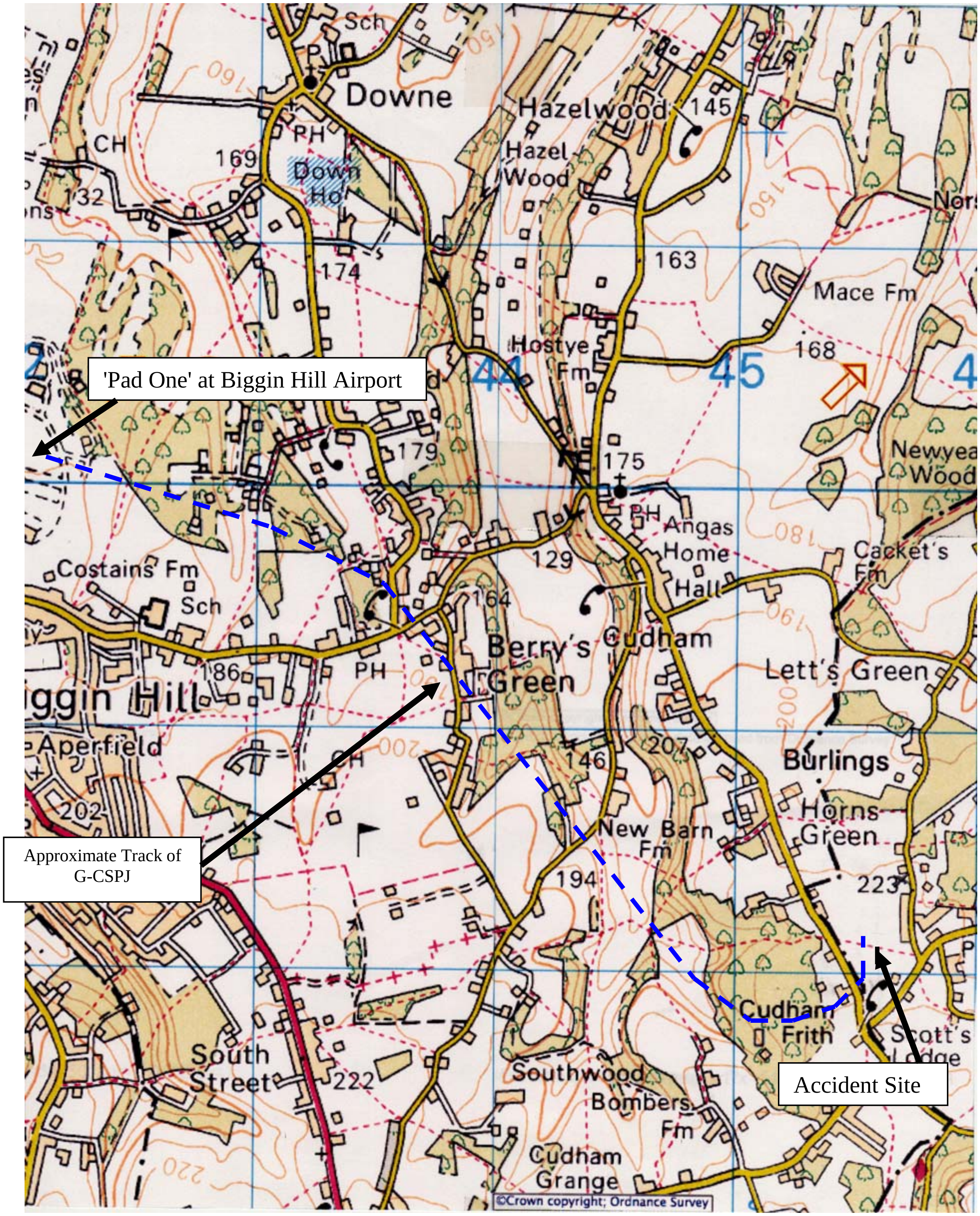

Figure 2

(Reproduced with the kind permission of Ordnance Survey)

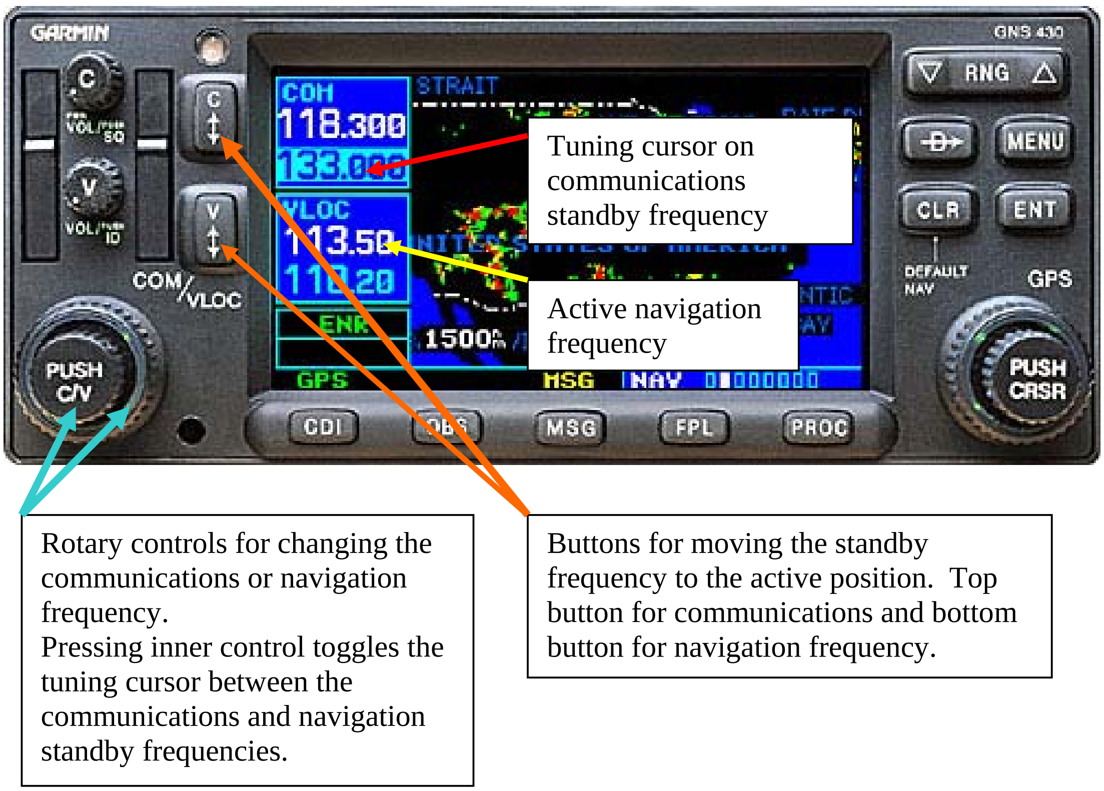

Figure 3
(Garmin GNS 430)

Figure 4
(Instrument console – Hughes 369HS)

Figure 5
(Instrument console – Bell 206 Jet Ranger)

Aircraft Type and Registration:	Enstrom 280c, G-BRPO
No & Type of Engines:	1 Lycoming HIO-360-E1AD piston engine
Year of Manufacture:	1977
Date & Time (UTC):	18 July 2004 at 1240 hrs
Location:	Near Oulton Park Racing Circuit, Cheshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Substantial damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	145 hours (of which 137 were on type) Last 90 days - 3 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

The helicopter had been undergoing maintenance and waiting for parts for six months. Following its return to service, it had flown a total of approximately 3½ hours over five flights spread over several days. A daily inspection, that included a check of the engine oil level, had been carried out by the pilot at the beginning of each day's flying.

On the day of the accident, the pilot carried out the daily check as usual before undertaking a VFR flight from Hawarden to Knutsford. Near Oulton Park the pilot called Manchester ATC to request en-route clearance. Two minutes later the ATC unit was unable to contact the helicopter and shortly afterwards received a phone call stating that the helicopter had crash-landed at Oulton Park. No distress call had been received.

The pilot reported that the first indication of a problem was light smoke in the cockpit followed shortly afterwards by the feeling of heat at his back. He initiated an emergency descent with power, as at that time there was no indication of an engine malfunction. At approximately 600 feet agl, downwind from his intended landing area, he believed that the engine stopped. He was now poorly positioned and during the subsequent landing the helicopter rolled over.

Discussing the event with an AAIB inspector some time later, he stated that he could not be sure that the engine had stopped, that he had noted no indications of engine failure, and candidly suggested that, in his concern about the fire and carrying out an immediate landing, he may simply have mishandled the landing, possibly by flaring late from a high rate descent.

The helicopter remained on its left side for six or seven hours after the accident until it was recovered. The subsequent AAIB inspection showed that there was no evidence of fire except for local overheating of the skin adjacent to the exhaust outlet. The engine turned normally, and all the drive train seemed to have been intact before the landing. The engine contained very little oil, however, when the plugs were removed large quantities of fairly clean oil were found in the cylinders. Overall, there was no indication of an engine malfunction.

The engine was turbo-charged, and the outlet from the turbocharger passes via a short exhaust pipe through an aperture in the skin to dump overboard. This pipe (Figure 1) was detached from the turbocharger, allowing the exhaust to impinge directly on the inside of the skin, resulting in the local overheating previously mentioned. The pilot had assumed that this had been dislodged in the landing, however the clamp securing it (Figure 2) had fractured in fatigue, allowing it to become dislodged in flight. This pipe also connected to a bypass pipe from the engine exhaust system, and once dislodged this allowed exhaust from close to the cylinders to be directed at the bulkhead immediately behind the pilot. The entire engine compartment would have filled with exhaust fumes, accounting for smoke in the cockpit.

The manufacturer's agent advised that fractures of this type of clamp are rare, and that in this particular case the clamp appeared to be quite old. There is, however, no requirement to change it if it appears serviceable.

It seems probable, therefore, that the pilot took the only action available to him given the symptoms of smoke and heat and that the subsequent roll-over was simply the unfortunate consequence.

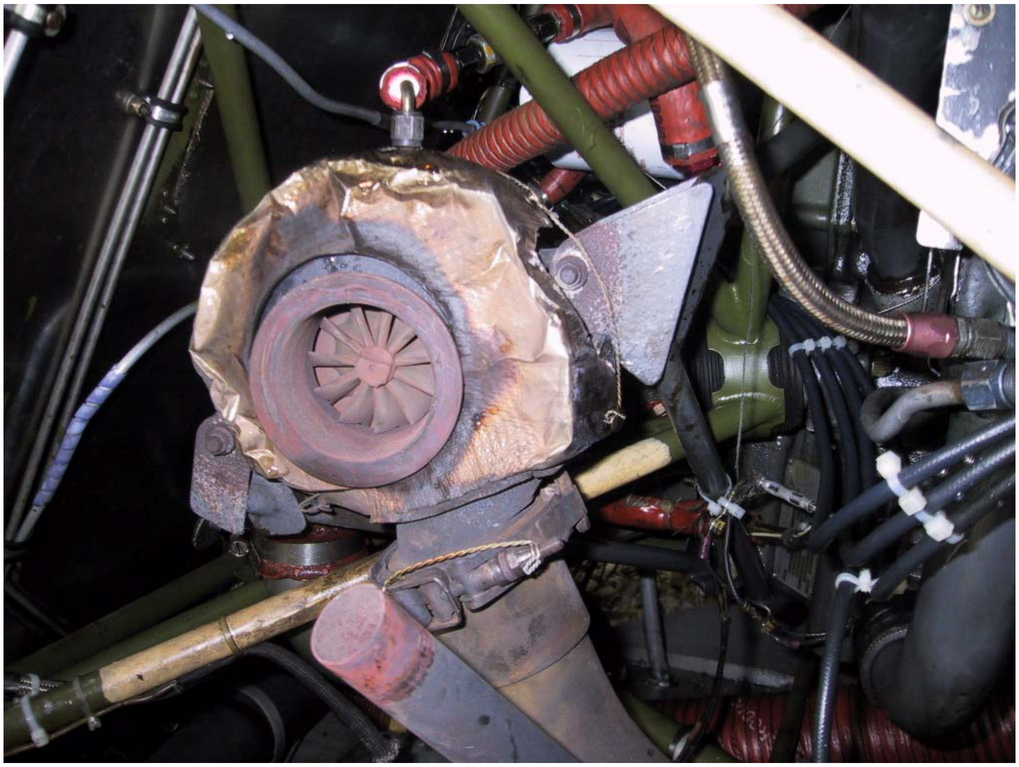

Figure 1

Turbocharger outlet and disconnected bypass pipe
(To the left is the bulkhead behind the left seat)

Figure 2

Fractured clamp and detached exhaust outlet pipe

Aircraft Type and Registration:	SZD 50-3 Puchacz Glider, HCD
No & Type of Engines:	N/A
Year of Manufacture:	1992
Date & Time (UTC):	18 January 2004 at 1320 hrs
Location:	700 metres NW of Husbands Bosworth Village, Leicestershire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 2 (Fatal) Passengers - N/A
Nature of Damage:	Glider destroyed
Commander's Licence:	British Gliding Association Assistant Instructor Rating
Commander's Age:	65 years
Commander's Flying Experience:	1,120 gliding hours (of which nine were on type) Last 90 days - 10 hours Last 28 days - 1.5 hours
Information Source:	AAIB Field Investigation

Synopsis

The flight, with an instructor and student on-board, was planned from Husbands Bosworth. Although no-one overheard the pre-flight briefing, it is likely that the primary aim of the flight was spinning training. Witnesses saw the aircraft enter a spin at around 1,500 feet agl and continue in a normal, steeply nose-down, spin with no significant change in the flight path before it impacted the ground. A number of likely explanations for the accident were considered but no conclusive evidence was found. The investigation was unable to dismiss the possibility of pilot incapacitation or of a control restriction/malfunction, and so four Safety Recommendations are made.

History of the flight

The pilots involved in this accident were members of the Welland Gliding Club (GC) who normally operated from Lyveden Airfield near Corby, Northants. Lyveden is a grass airfield and in winter is subject to water-logging that frequently renders the airfield unuseable. The Club therefore has a reciprocal agreement with the Soaring Society at Husbands Bosworth Airfield, Leicestershire, which allows Welland club members to fly from Husbands Bosworth in Soaring Society gliders on occasions when Lyveden is not fit for flying. On the day of the accident several members of Welland GC had independently arranged to travel to Husbands Bosworth Airfield to fly with the Soaring Society under the terms of this arrangement.

The weather on the day of the accident was generally fine with a light south-westerly breeze, but there had been an overnight frost and club members spent the early part of the morning removing frost from gliders.

On arrival at Husbands Bosworth those members of the Welland GC wishing to fly placed their names on a list and flew when their name came to the top of that list. Pilots under training would be paired with the next available instructor when it became the trainee's turn to fly and a suitable training aircraft became available. The student and instructor involved in this accident had arrived at Husbands Bosworth independently and had listed themselves to fly. By about 1240 hrs it had become the student's turn to fly and he was paired with the instructor to fly in glider 'HCD', a tandem seat Puchacz that had already flown five times that morning. The student had previously flown 50 flights, including two with the same instructor, and was at a stage in his training where he had already flown an introduction to spinning exercise and needed to fly further spins to complete his training in this area.

There were no witnesses to the pre-flight briefing, but the glider was towed uneventfully by a powered aircraft to a height of 3,000 feet and released normally. Several people, both airborne and on the ground, witnessed various stages of the rest of the flight. A Rotax Falke aircraft was approaching the village of Husbands Bosworth (about one mile north of the airfield) from the north-west at a height of about 1,500 feet. The right seat pilot saw the Puchacz enter a spin to the left from a nose high, wings level attitude and both pilots watched the glider complete a normal spin recovery after about one to one and a half turns. The Falke pilots then watched as the glider regained height in a moderately steep attitude before entering a second spin to the left from a "normal gliding attitude". The right seat pilot watched the spin and a normal spin recovery and both pilots recalled seeing the aircraft climbing away apparently under control. During this period the Falke and the glider had been on converging flight paths and so the commander of the Falke decided to achieve more separation and turned to his left. As the Falke rolled out of its left turn the right seat pilot looked over his shoulder and saw the glider in a "normal gliding attitude". After this, neither of the pilots saw the glider; however, both pilots recalled that the glider had descended below their height during the spin and that after the second spin recovery the glider appeared to be at or slightly above their height.

The pilot of a glider positioned about two kilometres north-west of Husbands Bosworth Airfield also saw the accident glider. He first noticed the aircraft "in a left turn" at "very low level" and his first thought was that it would have difficulty from that height in gliding back to the airfield. However, almost immediately he realised that it was much lower than his first impression and probably less than 100 feet above the ground. He watched the glider maintain its left turn, clear a hedge and then saw the left wing strike the ground followed by the aircraft nose. From his position, the impact angle did not look particularly steep.

A third group of witnesses, one of whom had flown in a glider, were carrying out road repairs to the A50 just to the north of Husbands Bosworth village. One of the witnesses saw the glider's nose pitch up steeply and enter a spin to the left. Several of the group saw the glider complete an estimated five turns before disappearing from view behind a ridge. One witness thought the rate of rotation might have speeded up slightly and all of these witnesses thought that the rotation continued until the glider disappeared from view. Some of these witnesses made their way on foot to the scene of the accident where they found the glider in a field with considerable damage to the nose and cockpit area forward of the wing leading edge. The student in the front seat was found dead at the scene while the instructor was alive when removed from the wreckage, but he later suffered a cardiac arrest and died on the way to hospital.

HCD was fitted with a radio, but no radio transmissions were received from the glider during its flight.

Pilots' Flying Experience

The instructor pilot had been flying gliders since 1986 and powered aircraft since 1998. He had amassed over 1,100 hours in gliders and about 87 hours in powered light aircraft. The Welland GC did not own a Puchacz glider, but the instructor had flown about 33 launches in a Puchacz, amassing a total of eight hours fifty five minutes on type. He had become an assistant instructor in 1994 and maintained his instructor rating up to the time of the accident. The instructor's last instructor rating renewal had been carried out in August 2003, which also happened to have been his last flight in a Puchacz prior to the accident. The renewal consisted of several flights and included a session of stalling and spinning in a Puchacz. Students who had flown with the instructor described him as being safe, punctilious and not prone to interfering unnecessarily when his students were flying.

The student pilot started gliding in April 2003 and by the time of the accident had flown 50 launches totalling about 10 hours flying. His experience in a Puchacz was limited to his last four flights before the accident, one of which was in the accident aircraft, and the latest of which was seven days before the accident. His introduction to spinning had been carried out in August 2003 in a K13 glider, but he had not spun in a Puchacz. The student had been shown one spin and had attempted to put the aircraft into a spin himself, but without success. (The K13's spinning characteristics are known to be relatively benign compared to those of the Puchacz and it can be difficult for an inexperienced pilot to persuade a K13 to spin). His instructors considered him to be a bright student who would have qualified easily for solo flying but who was, at the time of the accident, below the minimum legal age of 16 years.

Glider information

The aircraft had been given a daily inspection in accordance with BGA Operational Procedures prior to the first flight of the day and had flown five times uneventfully prior to the accident flight. The pilot of one of these flights had spun the aircraft and reported nothing unusual about the aircraft's spinning characteristics.

Accident site details

The aircraft had crashed in a steep nose-down attitude into a grass field at the base of a small hill. It had come to an immediate halt in an upright position. The presence of earth inside an air inlet in the nose suggested that the pitch attitude at impact was approximately 60° below the horizontal.

The fuselage ahead of the wing leading edge, which included the cockpit, had suffered extensive disruption in the impact, with the remainder of the aircraft substantially damaged although essentially intact. The damage had extended to the wing-to-fuselage joints, which had disrupted the aileron and airbrake controls. The left airbrake was found in the deployed position, with the right one being retracted.

The canopy had been extensively fragmented in the impact, and an examination indicated that it had been latched at the time; thus there was no indication of either of the occupants having attempted to bale out of the aircraft.

Detailed examination of the aircraft

The aircraft wreckage was recovered to the AAIB's facility at Farnborough for detailed examination.

It was established that no pre-impact disconnect had occurred in any of the primary flight control systems. The possibility of a control jam caused by a loose article was considered, particularly in the light of reports of a plastic ballpoint pen that had been observed loose in the cockpit on an earlier flight (11 January) whilst the aircraft was performing aerobatics. No trace of the item was found in the wreckage. Whilst the possibility of a control jam could not entirely be discounted, the general design of the controls was considered to be tolerant of such loose articles.

Each rudder pedal on this type of aircraft is mounted on a horizontal shaft close to the heel position. The right side pedal shaft in the front cockpit had broken off in a forward direction, which suggested that the front seat pilot's foot might have been braced against the pedal at impact. This in turn suggested that right (ie out of spin) rudder might have been applied at the time.

The elevator range of movement was assessed from wear patterns on the control rods where they passed through fairleads/steady bearings in the rear fuselage. (The disruption of the cockpit area meant that the elevator primary stops, which were located on the control columns, could not be used.) It was found that the up and down limits broadly corresponded with the maintenance manual figures.

The left airbrake was found in the extended position after the accident, which clearly could have had an effect on the ability of the aircraft to recover from a left-hand spin had it been deployed in flight. Accordingly, a detailed examination was conducted in order to establish whether the deployment occurred during flight or as a consequence of the ground impact.

The design of the airbrake system is such that fore and aft movement of the airbrake lever in the two cockpits results in the rotation of a torque tube located across the fuselage, between the wings. The torque tube ends are connected via dog-clutches to mechanisms in each wing, which transmit the drive through a bevel gear assembly to span-wise control rods. These in turn are connected, via an over-centre mechanism, to the airbrake surfaces. The over-centre mechanism provides a 'lock' and 'unlock' function respectively during airbrake stowage and deployment. As a consequence, the forces exerted by the pilot on the control linkage are considerably higher during these parts of airbrake operation.

It was found that a plywood web supporting one of the bevel gears in the left airbrake system had become disbonded from the inner surface of the wing root rib, see Figure 1. This had allowed the web/gear wheel assembly to lean away from the mating gear, resulting in the gear wheel teeth no longer being in full engagement. In addition, the reaction forces between the teeth acted to push the web-mounted wheel further away when the airbrake mechanism was operated, with an associated risk of the teeth coming momentarily out of engagement and in consequence, a loss of synchronisation.

The bevel gear assembly and the surrounding structure were examined by the composites department of QinetiQ (formerly the Royal Aerospace Establishment) at Farnborough. The plywood web had been attached to the root rib by means of adhesive applied to glass fibre cloth that overwrapped both the web and rib. Examination of the disbonded area revealed two distinct areas: one was a clean, cohesive fracture within the surface plies of the wood, with the fracture surfaces being clean, indicating that the fracture was new. The nature of the failure suggested a peeling action, indicating a span-wise load direction. The other area had been poorly bonded and had partially covered a steel flange that formed part of a fitting on the root rib. A gap was evident between the glass fibre cloth and the rib, with a long-term accumulation of dirt, indicating that this had most probably arisen during manufacture.

In addition to the support structure, the gear wheels, which were made of a Nylon material, were examined for evidence of wear patterns. This indicated that the teeth were fully engaged at the time of the impact. The range of movement of the airbrake mechanism was such that each gear wheel rotated through approximately 90° only; thus relatively few teeth meshed during normal operation. A thin film of undisturbed grease was evident on the 'unused' teeth, indicating an absence of tooth engagement outside the normal range of operation. Examination of the meshing teeth showed expected evidence of wear on the walls, but there was no scoring over the tops of any of the teeth, such as could have occurred had they slipped over each other.

The main spar of each wing extended beyond the root rib and they were off-set such that they overlapped one behind the other, and were pinned together in the fuselage aft of the cockpit. The dissimilar chord-wise locations of these spar extensions thus resulted in an asymmetric arrangement of the compartments in the inboard wing sections in which the bevel gear assemblies were located. For this reason, the gear assembly in the right wing was supported in a manner that dispensed with the plywood web; there was thus no useful comparison to be made between the left and right hand beval gear supports. All the right side bevel gear support structure had remained intact.

During the investigation, the glider manufacturer was advised of the above findings. Their response was that the disconnection of the gear support structure resulted from the crash. Thus, when all of the above evidence is considered, it seems unlikely that that there had been a loss of synchronisation of the airbrakes prior to the impact.

Weight and balance

The glider was within the weight and centre of gravity limits laid down by the manufacturer. The centre of gravity was approximately 7.63 inches aft (acceptable range is 3.6 inches aft to 13.1 inches aft).

BGA medical requirements

The British Gliding Association (BGA) is the national authority for sporting gliding in the United Kingdom, under delegation from the Royal Aero Club, and controls all aspects of gliding, including medical requirements. Apart from the Rules of the Air, defined within the *Air Navigation Order*

(ANO), aviation safety regulation does not apply to private gliding activities and the CAA has no legal powers or responsibility for the conduct of private gliding. In practice, the BGA seeks to ensure the safety of private gliding but has no legal status or legal powers.

Until 1 March 2003, medical standards in gliding were controlled simply by a medical declaration from the individual wishing to fly in which he/she declared that they did not suffer from any medical disorder that could result in their flying being a danger either to themselves or others. No renewal was required and there was no professional medical endorsement of the declaration. In response to changes in public expectations of safety and a renewed focus on safety by the European Aviation Safety Agency (EASA), the BGA decided to align the medical requirements for flying in gliders with those required to fly powered aircraft under the National Private Pilot's Licence (NPPL) scheme.

The medical standards for the NPPL are based on the standards of fitness for professional and private vehicle drivers laid down by the Driving and Vehicle Licence Authority (DVLA). DVLA Group 2 standards apply to professional drivers and DVLA Group 1 to private drivers. Pilots able to maintain Group 2 standards of fitness may carry passengers and instruct (other than professionally), while pilots maintaining Group 1 fitness standards may fly, but are not permitted to take responsibility for other persons in the air. Fitness to fly is the personal and legal responsibility of the pilot and, as with the BGA requirements, is subject to a declaration of fitness by the pilot; however, the NPPL scheme also requires a periodic endorsement of fitness by the pilot's General Practitioner (GP). The purpose of the latter is to confirm from records that the declaration is accurate with regard to serious disease.

The CAA Medical Division have taken the view, as far as the NPPL is concerned, that an accurate knowledge by a GP of a pilot's medical history is often more likely than a physical examination to predict the risk of a future in-flight medical incapacitation.

The BGA requires a medical declaration to be made before the first solo flight and periodically thereafter depending on age, or after serious illness. The GP is not required to carry out a medical examination before endorsing a pilot's declaration and, in case of doubt, the GP may obtain aeromedical advice from a BGA Medical Adviser. BGA instructors aged over 70 years of age, or who cannot maintain DVLA Group 2 fitness standards, may not fly with students who could not land the aircraft safely in the event of an incapacitation.

The DVLA scheme includes information to doctors on how certain diseases affect ability to maintain the two fitness standards. Some of the diseases have different physiological implications for flying and, under the NPPL scheme, these conditions have been highlighted and information sheets for GPs have been published. A pilot either suffering or having suffered from one of the listed diseases and wishing to obtain his GPs endorsement must present his GP with the relevant information sheet prior to requesting an endorsement.

Historically, aviation medical standards have developed for three reasons: to predict success in training, to ensure a long and productive career following expensive training and to reduce accidents from incapacity in the air. For gliding, the first two are largely irrelevant and the emphasis for a medical scheme in sporting aviation is focussed on the possibility of incapacitation. However, no medical examination, however extensive, can entirely exclude the possibility of incapacitation and the problem therefore becomes one of risk management.

The JAR medical standard is based on the risk of incapacity during the next year being no greater than 1%. This approximates to a risk of 1:876,000. The NPPL scheme accepts the DVLA standards but the NPPL is only available to non-professional pilots and licence privileges are restricted when compared to the full JAR PPL. Although the level of risk for the DVLA scheme is not defined, the BGA advises that the generally accepted level of risk for the DVLA Group 2 standard is 2% and about 20% for Group 1 standard. Statistically, this implies a level of risk 1:438,000 for Group 2 standards and 1:43,800 for Group 1 standards. However, medical advice indicates that incapacity should not be assumed in an accident simply because of a lower medical standard and that positive medical evidence should exist either in the form of pathological evidence or an indication of unusual flight characteristics pointing toward pilot incapacity.

Pilots' medical histories

The student pilot was 15 years old and in good health. Although a detailed medical history was not available to the pathologist, it is understood that there was nothing significant in the student's medical history.

The instructor pilot had a long medical history, most of which was not relevant to the possible cause of this accident. In December 2002 the pilot underwent a medical examination by an AME for a renewal of his JAA-FCL Class 2 PPL medical. During the examination the doctor found a heart condition which, after specialist consultation, was deemed by the CAA as making him "long term unfit" and which precluded him from holding a medical certificate for a PPL. At this time, there was no BGA medical requirement for glider pilots who wished to undertake solo flying, other than to 'self certify' that they did not suffer from any condition which might cause incapacitation. However, to instruct or to carry a passenger in gliders required, after the age of 60 years, that a Declaration of Medical Fitness to fly be countersigned by the GP to the DVLA Group 2 standard. In anticipation of the change that was to occur on 1 March 2003, when all glider pilots, irrespective of age were to be required to complete a Declaration endorsed by their GP to at least the DVLA Group 1 standard, the pilot approached his GP on 13 January 2003 with a request that he be 'signed off' to the Group 1 standard, which was done. However, in March 2003, the CAA wrote to the instructor advising him of the situation but also suggesting that he might still be able to fly powered light aircraft if he could meet the NPPL medical standard. The instructor contacted his cardiologist to check if his heart condition would allow him to hold the NPPL. Under the DVLA scheme, the instructor's particular heart condition allowed him to maintain a Group 2 standard, provided he was not displaying symptoms of the condition, and the CAA's information sheet on Cardiological Disease imposed no further restriction for the condition. The cardiologist confirmed that he showed no symptoms of the condition, so the pilot approached his GP for the second time for endorsement of a BGA/NPPL Group 2 Medical Declaration. The instructor's GP consulted the DVLA and the medical specialists involved and, on 28 March 2003, the GP endorsed the instructor's Medical Declaration. At the age of 65, this Declaration was only valid for one year. Thus, at the time of the accident, the instructor was allowed under the BGA rules to fly gliders with passengers and to act as an instructor.

However, between January 2003, when the pilot was described as being asymptomatic of his condition, and August the same year, when he returned for his second consultation with his cardiologist, his condition had apparently worsened, as evidenced by a change in the findings on echocardiography (ultrasound of the heart). This was described as "worsening mitral regurgitation" together with some "left ventricular enlargement". This led the pilot to be referred for further cardiac investigation (cardiac catheterisation) with a view to valve surgery. In the August consultation, it was reported that the question of fitness for driving was not discussed by the cardiologist; the consultation was purely a clinical one. Notwithstanding this, it remains the responsibility of any 'pilot-in-command' to assess their fitness to fly at any time and, if in any doubt, they should ground themselves and discuss the situation with an appropriate medical practitioner (CAA NPPL Adviser, GP etc), reference the ANO, Section 1, Part IV 26.3(a).

In January 2004, when the pilot saw the surgeon three days before the accident, his condition was now described as "severe", when previously it had been categorised as "moderate". Thus, although there been a deterioration in the pilot's condition during 2003, since his last declaration of fitness dated 28 March 2003, the pilot apparently took the view following the consultation, that under the terms of the NPPL scheme and the ANO, that he remained fit to fly.

The consultant, subsequent to this accident, has indicated that "there was a loose discussion", not recorded in his notes, principally with the pilot's wife "about the fact that he was a glider pilot" in which the consultant expressed the view that he should not fly with his heart condition. However, the pilot's wife has stated clearly that although she attended the hospital with her husband on that occasion, she did not attend the actual brief consultation and has, in fact, never spoken to the consultant. She has also stated that at no time afterwards did her husband mention any advice from the consultant that he should not fly with his heart condition, and that she would have expected him to do so, should that advice have been given.

Pathological information

Post mortem examination of both pilots found that they had died of multiple injuries. No evidence of any alcohol, drugs or toxic substance which may have caused or contributed to the cause of the accident was found. However, the pathologist stated that with the instructor's heart condition there was a risk of incapacitation or sudden death and that examination of medical literature indicated that the sudden death rate from this condition was 1.8% per year[1]. Nevertheless, the emergency services reported that the instructor was still alive when he was removed from the aircraft, and the pathologist found no evidence to support the contention that the instructor had collapsed or suffered significant distraction. However, the nature of any distraction or collapse could have involved a disturbance of the heart rhythm and this would not have been detectable at the post mortem examination. Although the instructor was asymptomatic, the medical literature indicates that the onset of symptoms is most frequently seen in patients aged between 60 and 70 years and that rhythm disturbance accounts for over half the cases where patients become symptomatic[2]. Thus, although the instructor clearly did not die in flight, it was possible that some cardiac episode associated with his condition had caused him to become distracted or incapacitated.

The pathologist investigated the medical procedures that were followed during the issue of the instructor's BGA/NPPL medical certificate and found that the instructor complied with the published medical standards and that the endorsing GP had acted properly. However, with a sudden death rate of 1.8% per year from this condition alone and an unknown frequency of heart rhythm disturbance, the pathologist believed it would be appropriate to consider whether a restricted medical certificate should be issued to pilots with a similar heart condition. He further suggested that the CAA Medical Department should take advice from a national expert in the condition to determine whether it was appropriate to issue an unrestricted NPPL medical certificate in similar cases under the NPPL scheme.

The pathologist also examined both pilots for evidence that might indicate which pilot had been in control at impact. Injuries to the hands were inconclusive, but injuries to the student's legs suggested that the right leg was extended at impact. The instructor had injuries to both legs.

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[1] Ref. Sudden Death in Mitral Regurgitation due to Flail Leaflet. Grigioni F, Enriquez-Sarano M, Ling LH, Bailey KR, Seward JB, Tajik AJ, Frye RL. Journal of the American Collage of Cardiology 1999. 2078-2085

[2] The Oxford Textbook of Medicine states: '*Ventricular ectopic beats are common with mild mitral regurgitation of any cause. Much less frequently, recurrent ventricular arrythmias mar occur; very rarely these may be life threatening. It is these unusual cases that appear to be the basis of a small number of reports of sudden death in this condition. Approximately half of these cases had a history of syncopal or presyncopal episodes* [fainting attacks]'.

Puchacz spinning characteristics

In response to three fatal Puchacz spinning accidents between 1990 and 1993 the BGA sponsored a low speed handling trial of the aircraft. The trial had four main aims:

1. To reassess the aircraft's low speed handling characteristics against the requirements of JAR 22 (Sailplanes).

2. To provide deeper flight test insight into the stall/spin handling characteristics beyond those required by JAR 22.

3. To observe pupils' and instructors' reactions to carrying out spin training with a view to examining the interrelation of training with the JAR 22 requirements or to highlight any limitations in the requirements.

4. To advise on particular aspects of the design and operating envelope with a view to improving operating safety.

The trial was flown by test pilots and instructors in early 1994 under the control of the then DRA Farnborough. The spin recovery was judged against the following standard spin recovery technique outlined in JAR 22 Acceptable Means of Compliance:

1. Check ailerons neutral.

2. Apply rudder opposite spin.

3. Ease control column forward until rotation ceases.

4. Centralise rudder and ease out of ensuing dive.

The trial confirmed that the glider was compliant with JAR 22; however, it considered that two areas were worthy of additional comment. The trial considered the aircraft to be only marginally compliant in respect of stalls during turns and noted that avoidance of uncontrolled rolling and spinning off a turn was reliant on pilot awareness and skill. The trial also noted that height loss in a spin was significantly greater than on other types and that this was largely due to the steep attitude (70° nose down) of the developed spin.

The trial also investigated the aircraft's recovery characteristics when using non-standard spin recovery techniques. The only action that appeared to delay immediate spin recovery was the retention of full aft stick. Releasing the controls or failing to apply opposite rudder resulted in a recovery from the spin, although there were other handling issues such as high sideslip angles and recoveries from very steep attitudes. Critically the report highlighted the following human factors related issue:

> *The JAR recovery procedure first introduces full opposite rudder to counter the yaw rate. This use of rudder on the Puchacz leads (to) a pitch down in the spin which reduces incidence sufficient to facilitate auto recovery at forward CG where recovery then occurs. As the established spin is already estimated at 60-70 degrees, this pitch down gives a very steep exit, perceived to be over vertical but probably not so. It also contributes to the extensive height loss during exit. In a tense or panic situation, particularly at low level, the involuntary reaction could be expected to be retention of full aft stick. This will sustain a spin against full opposite rudder at CG aft of 6.0 inches aft of datum.*

The report further stated in bold:

> ***It can reasonably be concluded that the only control mishandling of the PUCHACZ that can lead to delay in spin exit is the retention of full pro spin elevator….***

The trial made several recommendations. The following were relevant to this accident:

1. *BGA recommended practice RP 35 should be rigorously enforced. Fixed ballast installation in the forward cockpit should remain filled unless maximum all up weight limits are prejudiced.*

2. *Puchacz operators should limit the entry height of deliberate spin training to a minimum of 1,500 feet.*

In addition to the above, the AAIB approached a number of BGA instructors experienced on the Puchacz, and a BGA accident investigator flew the aircraft on a spinning sortie. The widely held view amongst the instructors was broadly that, unlike some other modern gliders, the Puchacz would readily enter a spin, but equally readily it would come out of a spin when the recovery technique was applied. The rate of rotation was higher than in other gliders and in particular the Puchacz spins with a steep nose down attitude losing about 300 feet per full rotation. One of the BGA's professional instructors noted that out-of-spin aileron tended to flatten the spin and the recovery from a flat spin can take slightly longer than a normal spin but, if the controls were held in the anti-spin position, the aircraft recovered normally.

Previous Puchacz spinning accidents

Prior to this accident, the Puchacz had been involved in five UK spinning accidents, four of which had resulted in fatalities. The majority of these accidents were the result of inadvertent spins. One accident during spin training with two instructors on board was attributed to a low level spin entry and lack of height awareness on the part of the crew. None of the UK accidents involved a deliberate spin entry in which the aircraft apparently stayed in a stable spin all the way to impact. Overseas spinning accidents follow a broadly similar profile.

Glider flying control and regulation

Although the BGA seeks to ensure the safety of private gliding and currently has no legal status or legal powers, BGA members and member clubs (which covers almost all the gliding activity in the UK) are obliged to comply with BGA Operational Procedures. Recommended Practices and Codes of Practice are not mandatory but state that*' a prudent pilot would do well to observe them'.* BGA clubs are required by Operational Regulations to maintain local (club) regulations.

Recommended Practice 18 suggests that:

> '*The CFI should lay down minimum heights for aerobatics at his club and no aerobatics should be done below this height without special permission.'*

Consultation with gliding clubs revealed that minimum heights are not normally laid down for spinning.

Paragraph 7.9 of the BGA Operational Regulation requires that:

> *'All flying instruction shall be given in accordance with the BGA regulations and syllabus'.*

Detailed requirements and procedures for glider instructors are published in the BGA Instructor's Manual. Although gliding club Chief Flying Instructors are responsible for approving individuals to instruct at his/her club, the procedures for, and standardisation of, instruction are centrally controlled by the BGA Instructors sub-committee, rather than at club level.

The following extracts from the BGA Instructors' Manual are relevant to this accident:

> *'In the initial stages of spin training, continuous spins of two or three turns are mainly to allow the trainee time to study the characteristics of the spin and give confidence that the recovery action from a stabilised spin is effective'.*
>
> *'The majority of spin training will then involve brief spins of about a half a turn with the primary aim of recognising the circumstances in which the spin can occur, correctly identifying the spin/spiral dive, and practising the correct recovery action'.*
>
> *'As this training progresses, it is necessary to introduce brief spins where the ground is noticeably close. This is to ensure that the trainee will take the correct recovery action even when the nose is down and the ground approaching. A very experienced instructor flying a docile two seater in ideal conditions may be prepared to initiate a brief spin from 800 feet. A less docile two-seater with a less experienced instructor or less than ideal conditions should raise the minimum height considerably'.*
>
> ***'The crucial action** is to move the stick forward to unstall the glider EVEN though the nose is dropping or pointing steeply downwards.'*
>
> *'Instructors should be aware that **very few pilots recover from inadvertent low level spins**, and that **stall/spin avoidance is the training's main aim.'***

The BGA Instructor's manual recommends that pre-aerobatic (HASLL) checks are completed prior to each spinning exercise. The HASLL check is published in the manual and starts as follows:

> *'Height*
>
> *Make allowance for the height used during the manoeuvre, and allow sufficient to return afterwards to the airfield……. Set a minimum height for entry to any manoeuvre, and don't be tempted to make it any lower. Some account should be taken of the height of the terrain below…..'*

Analysis

From the above, it is apparent that no conclusive evidence of a cause of the accident was discovered during the investigation. The main feature of the third spin, from which the glider did not recover, is that there was no apparent attempt at recovery. This analysis therefore concentrates upon the most likely technical and operational reasons for this failure to recover from the spin.

Engineering Analysis

Examination of the glider wreckage, both at the scene and later at Farnborough, indicated that its structure had been intact prior to impact and that no jam or disconnection of the flying controls was likely to have occurred prior to the accident. The expert examination of the fracture noted in part of the left airbrake bevel gear mounting structure, which, had it occurred prior to the impact with the ground, could have allowed the left airbrake to be deployed in flight despite being selected in, indicated that the failure was most probably the result of the impact, with corroborative evidence being provided from an examination of the gear teeth and an assessment by of the manufacturer.

The failure of the bonded joint occurred in tension, rather than shear, which would have required loading to have been applied in the span-wise direction. At the moment the aircraft nose struck the ground, it is likely that considerable deflection of the wings occurred, in the form of either a downward bending, or a shock wave which travelled along the span. Since the airbrake control rods were mounted above the main spar, these would be loaded in tension when the wing was deflected downwards, which in turn would have acted to unlock the over-centre mechanism and thus allow the associated airbrake to deploy. If the deflection was excessive, it is likely that the tensile snatch load in the control rods could have caused the bonded joint to fail.

The reaction forces between the gear teeth loaded the gear support web in a manner that imposed a shear force in the bond between the web and wing root. Since the bond would have been inherently stronger in shear than in tension, it increases the probability that the failure occurred as a result of wing deflection at impact, as opposed to a progressive failure over a period of time. Nevertheless, it was not possible to be completely certain on this issue. The dissimilar arrangement of the left and right bevel gear support structure meant that the web that was the focus of this examination was used only on the left side. It was considered that as a result, the left side gear support was less robust than the right. However, both sides are difficult to inspect, the only access being via holes in the wing root web. A Safety Recommendation (2004-68) is made later in this report to the BGA concerning inspections of the airbrake bevel gear mechanism in the left wing.

Operational analysis

Although no-one overheard the pre-flight briefing for the accident flight, the eyewitness evidence of successive spins and controlled recoveries, together with the student's stage of training and the suitability of this aircraft for spinning, strongly suggested that the primary aim of the flight was spinning training.

The total number of practice spins carried out on the sortie has not been established for certain, but given that the aircraft was towed to 3,000 feet and that two successful spins and recoveries were witnessed prior to the final spin, it appears likely that the final spin was the third of the flight. The entry height, according to the witnesses in the Rotax Falke, would have been about 1,500 feet and this appears to be corroborated by the five turns of the final spin witnessed from the ground.

Critical to an understanding of this accident is the evidence of witnesses on the ground who saw the glider spinning until it went out of sight. At this point it would have been about 90 feet above the ground. The evidence indicated that the glider was in a normal, steeply nose-down spin and, apart from the rate of spin perhaps speeding up (which would be normal in a Puchacz multi-turn spin), the flight path did not change up to the moment the witnesses lost sight of it. There was a slight conflict with the evidence of the glider pilot who saw the Puchacz hit the ground from his position to the north-west of Husbands Bosworth. He did not consider that the aircraft was in a spin and he thought the nose attitude was quite shallow. However, he was some distance away and only witnessed the last few seconds of the flight. Nevertheless it raises the possibility that the aircraft had started to recover after sight of it was lost by the ground witnesses.

The 1994 flight test report for the Puchacz stated clearly that the only "mishandling" that could lead to a delayed recovery was the retention of full pro-spin (up) elevator. Given the lack of technical evidence for such a condition it might be assumed that one or both pilots either held the stick fully aft or was unable to move the stick forward for most, if not all, of the spin.

Although there has been a previous case of lack of height awareness causing a spinning accident, it seems unlikely that the final spin was intended to be any longer than the previous two short, one and a half turn, spins. Thus, intentionally maintaining the spin with the control column fully aft due to lack of height awareness would seem an unlikely cause of the accident. Although no evidence was found of a control restriction, there remains a possibility that the control column was jammed in the fully aft position by a loose article. However, it is reasonable to assume that, had this been the case, the instructor would have attempted to use either aileron or rudder or both to recover from the spin and in all probability, this would have affected the flight path of the spin. Given witness evidence of a continuous spin with no discernible change to the flight path, the fact that no 'loose articles' were discovered in the wreckage, and the tolerant nature of the flight controls to a loose object, a control jam would also seem to have been unlikely as a cause of the accident.

There have been instances of student's 'freezing' on the controls in high stress situations and instructors have needed to intervene aggressively to regain control. This is obviously more difficult in a tandem aircraft than one with side-by-side seating. However, the student had previously been given an introduction to spinning in a K13 glider and been in two Puchacz spins during the accident flight. The only difference for the final spin was a lower entry height. Whilst this might have caused the student some concern it seems unlikely, with his experience, that it was low enough to cause him to 'freeze', particularly as it was likely that the spin would have only continued for one to one and a half turns, as with the two previous spins. Moreover, although the student was quite large for his age, the instructor was not a small man and had a weight advantage. It therefore seems improbable that the instructor would have been unable to overcome the student had the need arisen, although had he been distracted or partially incapacitated, then his full abilities to do so may have been impaired. This scenario, however, requires that the student 'froze' co-incidentally with the instructor becoming incapacitated.

Thus, there remains the more likely possibility that one of the pilots was incapacitated. The student's reported good health, the lack of pathological evidence and the arguments outlined above make it unlikely that the student became incapacitated and prevented the instructor from recovering from the spin. Although there was no evidence from the post mortem examination to indicate incapacitation of the instructor, the pathologist stated that the instructor could have temporarily become distracted or lost consciousness, and that one mechanism for this might be by way of a heart rhythm disturbance associated with his known heart condition.

It is not an unusual instructional technique in the early stages of spinning training for the instructor to brief the student to enter the spin and to carry out the recovery on the instructor's command. The evidence to support incapacitation is far from conclusive but, if the instructor had become distracted or lost consciousness, it seems credible that the student could have been in control in the spin and awaiting a command to recover that did not come. The instructor was known not to interfere unnecessarily whilst his students were flying and there was a significant inter-cockpit age and experience gradient. It is possible, therefore, to imagine that the student would have taken some time to realise that something was wrong. Even though the student was clearly a very able young man, a low level spin recovery for a pilot of his experience would have been extremely difficult. Moreover, by the time he was likely to have appreciated the problem, the glider would have been at such a low height that, as outlined in the 1994 Puchacz spinning report, he would have found it psychologically very difficult to move the control column forward as the ground 'approached'. This may explain the more or less continuous spin to impact and the possibility that the student was only applying anti-spin rudder at the time the glider hit the ground.

Safety Recommendations

Whilst the issue of pilot incapacitation in this investigation has proved inconclusive, it is questionable how well the BGA Operational Regulations, and the advice contained in the BGA Instructor's Manual at the time of the accident, contributed to situational awareness and thus how well a student of any experience level would cope with an incapacitation of the instructor in a spin. Whilst the Operational Regulations require clubs to specify minimum heights for aerobatics, it appears that this has not generally been applied to spinning. Furthermore by specifying a minimum height of 800 feet to commence a spin in a benign glider type, the Instructors' Manual gave some advice on one of the extremes of the spinning envelope but provided little advice on how situational awareness might be aided in a spin. For example, there was no requirement to specify minimum entry heights or minimum recovery heights. Clearly these will vary by glider type, but the discipline of stating each before a spin would at least raise questions in pilots' minds if they saw one or other limit approaching or passing.

Since this accident the BGA have issued the following information to their members and Clubs.

> *The BGA Instructors Committee has recently agreed that all pilots and instructors should be reminded of the need to take note of a number of factors when considering the height at which spinning should be initiated. Some gliders have particular characteristics that can sometimes cause a delayed recovery and/or a significant height loss in the recovery phase. The potential, significant height loss should be carefully taken into consideration when deciding when it is safe to initiate a spin. The glider type Flight Manual is a vital source of information. The recommendation in the BGA Instructors Manual, page 19-3, to initiate a 'brief' spin at 800 feet during pilot training will be removed by appropriate amendment action in due course. You are urged to bring this note to the attention of your club pilot and instructor colleagues. …………..'*

Notwithstanding this, the following recommendation is made.

Safety Recommendation 2004-65

It is recommended that the British Gliding Association require all Gliding Clubs to ensure that instructors and pilots establish and brief students on, minimum entry heights, minimum recovery initiation heights and minimum recovery heights, whenever intentional spinning is planned. These heights should take into account the characteristics of the glider type being flown, the experience and ability of the crew, and the possible need to abandon the glider.

The pathologist carried out a comprehensive investigation into the medical procedures that resulted in the instructor obtaining a countersigned BGA unrestricted Medical Declaration. He concluded that "it was entirely proper" that this had been done. There is a difference of recall between the consultant and the pilot's wife about the circumstances surrounding the consultation three days before the accident. Nevertheless, given some of the medical evidence regarding the rate of sudden death and the unknown rate of heart rhythm disturbance in patients with the instructor's heart condition, the pathologist remained concerned whether someone with that condition should be allowed to instruct or fly with passengers. The pathologist suggested that the Civil Aviation Authority Medical Department should take advice from a national expert in this heart condition to determine whether it is appropriate for sufferers to be issued an unrestricted National Private Pilot's Licence. Whilst the pathologist's suggestion addresses this instructor's condition, there remains the possibility that other conditions might present unacceptable risk of airborne incapacitation. The following recommendation is therefore made:

Safety Recommendation 2004-66

The Civil Aviation Authority should review the National Private Pilot's Licence medical standards to confirm that the combination of the Driver and Vehicle Licensing Agency (DVLA) Scheme and National Private Pilot's Licence Information Sheets adequately address the risk of medically induced distraction or incapacitation for instructors and pilots authorised to carry passengers.

The apparent difference of understanding over the severity of the pilot's condition between the instructor pilot and the consultants, highlights the need for any pilot to openly discuss, or initiate discussion with their treating physician and/or GP, any medical condition, or change in a condition, that might impact on their ability to fly safely. On the occurrence of such an event, pilots should be reminded that they have the responsibility to initiate such a discussion, since their medical adviser may not be aware that they are flying as a pilot. Therefore the following recommendation is made.

Safety Recommendation 2004-100

The Civil Aviation Authority should re-emphasise the advice to pilots concerning the need to discuss with their treating physician and/or GP, any changes in medical condition, treatment, or the need for additional investigations not previously thought necessary when renewing or applying for medical documentation in relation to a flying licence.

In order to possess a valid JAA-FCL Private Pilot's Licence in the UK and act as commander a light aircraft, with or without passengers, a pilot is required to hold a valid JAA-FCL medical certificate. In order to give flying instruction in such aircraft, if payment for such instruction is given, a pilot would require an appropriate 'Commercial' Pilot's Licence and Instructors Rating but, particularly, a valid JAA-FCL Class 1 medical certificate. However, if flying instruction is given, but not for payment, then a JAA-FCL Class 2 medical certificate would be required as a minimum. Apart from the obvious difference between light aircraft and gliders, in that most flying instruction in gliders is given without the use of an engine, there can be no difference in the 'duty of care' that any flying instructor has for the welfare of a passenger or student, particularly one who has not achieved a 'solo' standard of flying, and who could not be expected to land the aircraft safely, should the need arise.

This seems inconsistent with the different medical standards required by the CAA and the BGA for flying instructors in powered light aircraft and gliders respectively[1]. In the case of HCD, the instructor pilot was allowed, under the BGA system, to give flying instruction to a pre-solo standard student whilst, due to his medical condition, he did not meet the standards of the JAA-FCL Class 2 medical. This meant that had he been an instructor in powered light aircraft, the loss of his JAA-FCL Private Pilot's Licence due to his medical condition becoming known, would have prevented him from giving flying instruction to the same student, or to carry passengers, in such aircraft.

The following recommendation is therefore made.

Safety Recommendation 2004-67

It is recommended that the British Gliding Association should undertake a review of their medical standard requirements to assess whether it remains appropriate for glider pilots with any valid instructional ratings to give flying instruction in gliders whilst only in possession of a valid DVLA Class 2 Medical Declaration.

The dissimilar arrangement of the bevel gear assemblies in the airbrake actuation mechanisms of the right and left wings meant that the gear support web that was the focus of the examination by QinetiQ, was used only in the left wing. It was considered that, as a result, the left side gear support structure was less robust than the right. However, both sides are difficult to inspect, the only normal access being via holes in the wing root web. As it was not established with complete certainty that the failure of the bonded joint associated with the bevel gear support structure occurred as a result of wing deflection at impact, and that the bond appeared to be of poor quality, the following recommendation is made:

Safety Recommendation 2004-68

It is recommended that the British Gliding Association require regular inspections to be conducted on the left wing bevel gear support structure associated with the airbrake actuation system of the SZD Puchacz glider, paying particular attention to the bond between the gear support web and the inner face of the wing root rib.

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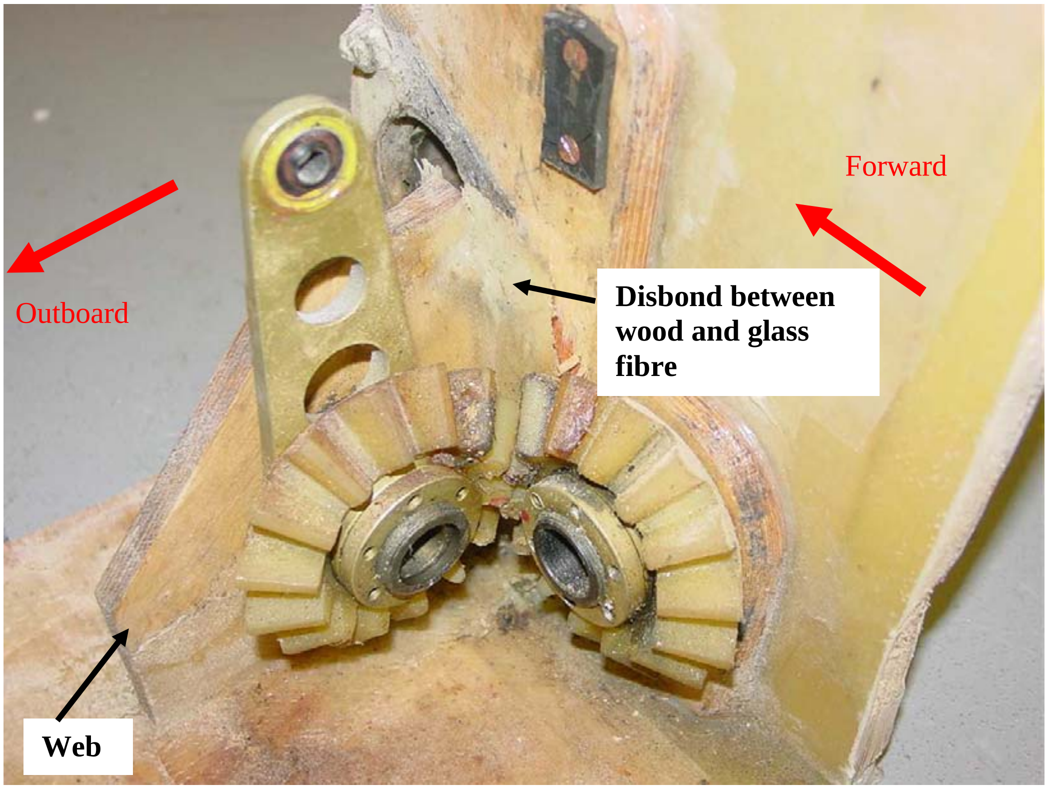
[1] N.B. Microlight aircraft instructors have been permitted to give flying instruction whilst only in possession of a '150 A/B medical form (Declaration of Health) with GP countersignature, for some 20 years.



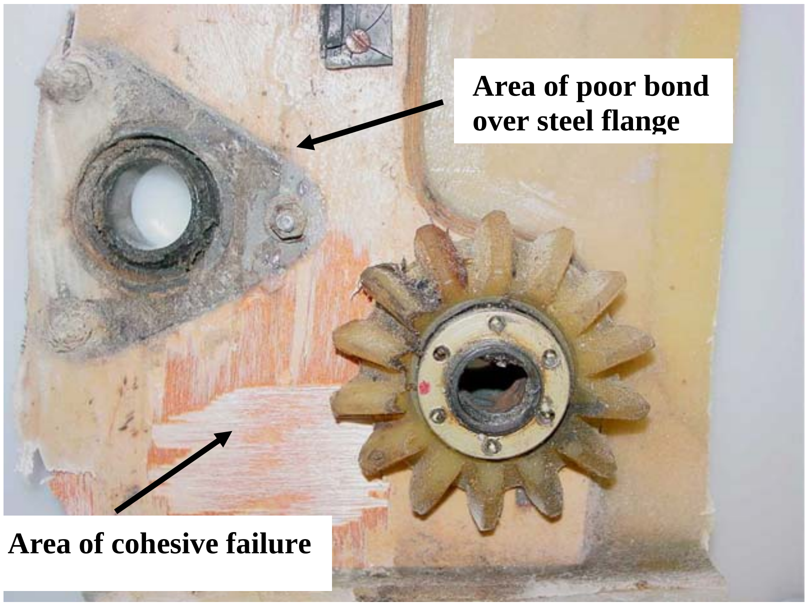


Figure 1. Details of the left hand airbrake bevel gear assembly, after being cut out of the aircraft

Below: view of inner rib after removal of web

(photos: QinetiQ)

BULLETIN CORRECTION

AAIB File:	**EW/G2004/09/13**
Aircraft Type and Registration:	Avions Pierre Robin HR100/210, G-BBCN
Date & Time (UTC):	23 September 2004 at 1433 hrs
Location:	Gloucestershire Airport, Gloucestershire
Information Source:	Aircraft Accident Report Form

AAIB Bulletin No 12/2004, page 30 refers

The last phrase of the last paragraph of the above report incorrectly stated 'there would have been a serious risk of carburettor icing'; this should have read '**there could have been a risk of induction icing.'**

The correct version is shown below:

> The surface weather conditions at the time of the accident were a temperature of around 16°C, with a dew point of 10°C, giving a relative humidity of approximately 68%. At low engine power, there could have been a risk of induction icing.

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

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

4/2003	McDonnell-Douglas MD-80, EC-FXI at Liverpool Airport on 10 May 2001	November 2003
1/2004	BAe 146, G-JEAK during descent into Birmingham Airport on 5 November 2000	February 2004
2/2004	Sikorsky S-61N, G-BBHM at Poole, Dorset on 15 July 2002	April 2004
3/2004	AS332L Super Puma, G-BKZE on-board the West Navion Drilling Ship 80 nm to the west of the Shetland Islands on 12 November 2001	June 2004
4/2004	Fokker F27 Mk 500 Friendship, G-CEXF at Jersey Airport, Channels Islands on 5 June 2001	July 2004
5/2004	Bombardier CL600-2B16 Series 604, N90AG at Birmingham International Airport on 4 January 2002	August 2004

ABBREVIATIONS COMMONLY USED IN AAIB BULLETINS

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