CONTENTS

COMMERCIAL AIR TRANSPORT

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	Airbus A320-200, I-BIKE
No & Type of Engines:	2 CFM-56 turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	25 June 2005 at 0740 hrs
Location:	On approach to Runway 09L at London Heathrow Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 98
Injuries:	Crew - None Passengers - None
Nature of Damage:	Failure of No 1 and 3 ADIRUs
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	8,300 hours (of which 1,300 were on type) Last 90 days - 130 hours Last 28 days - 50 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft had departed on a scheduled passenger flight from Milan to London Heathrow Airport, with an unserviceable No 3 Air Data Inertial Reference Unit (ADIRU). On final approach to Runway 09L at London Heathrow, in Instrument Meteorological Conditions (IMC), the Inertial Reference (IR) part of the No 1 ADIRU failed, depriving the commander (the pilot flying) of much of the information on his Primary Flight and Navigation Displays. ATC required the aircraft to go-around from a height of 200 ft on short final approach due to another aircraft still occupying the runway. The co-pilot, who had been handed control, performed the go-around and the aircraft was radar vectored for a second approach. The crew then turned off the No 1 ADIRU whilst attempting to diagnose the problem, contrary to prescribed procedures. As a result, additional data was lost from the commander's electronic instrument displays, the nosewheel steering became inoperative and it became necessary to lower the landing gear by gravity extension. The aircraft landed safely.

History of the flight

The history of the flight is derived from multiple sources, including data from both the Flight Data Recorder (FDR) and Cockpit Voice Data Recorder (CVR).

The flight departed from Milan Airport at 0547 hrs on a scheduled flight to London Heathrow Airport (LHR) with the commander as the Pilot Flying (PF). The previous day, the No 3 ADIRU was found to be unserviceable and had been turned off; the Minimum Equipment List (MEL) allowed the aircraft to depart in this condition, as both the Nos 1 and 2 ADIRUs were serviceable. During the flight, as a precautionary measure, the commander and co-pilot reviewed the Flight Manual Abnormal Procedures for the actions to be taken in the event of a second ADIRU becoming unserviceable.

Following an uneventful transit, the aircraft was given radar vectors and became fully established on the ILS approach to Runway 09L at LHR. Two stages of flap were selected and, at 1,820 ft (QNH), the landing gear was lowered. Some 16 seconds later, just as the landing gear locked down, the Inertial Reference (IR) part of the No 1 ADIRU failed and a 'NAV IR 1 FAULT' message appeared on the aircraft's Electronic Centralised Aircraft Monitor[1] (ECAM). The autopilot and autothrottle both disconnected and much of the flight instrument information on the commander's Primary Flight Display (PFD) and Navigation Display (ND) was lost, with only the ILS localiser and glideslope, airspeed and altitude indications remaining on his PFD. In addition, the aircraft's flight control laws changed from NORMAL to DIRECT law and both flight directors and the No 1 yaw damper became unavailable. Some 14 seconds after the landing gear locked down, the Enhanced Proximity Warning System (EGPWS) indicated that the terrain warning function was no longer available. The commander handed over control of the aircraft to the co-pilot, whose PFD and ND were functioning normally, and the ILS approach was continued.

At about 0724 hrs, the flap lever was set to position three. Shortly after this time the aircraft started to deviate from the glideslope and localiser. The aircraft altitude continued decreasing and, by about 300 ft radio altitude and when at an airspeed of 130 kt, the aircraft had deviated some 1.3 'dots' below the glideslope. Almost coincident with this, the CVR recorded an EGPWS "glideslope" warning (see Figure 1 Point B). The deviation below the glideslope continued to increase and a second EGPWS "glideslope" warning was recorded by the time the aircraft was at some 1.84 'dots' below the glideslope.

As the crew continued their approach, ATC advised that they would receive a late clearance to land. When the aircraft was at about 250 ft radio altitude an EGPWS "too low flap" warning was recorded on the CVR. The commander then decided to go-around in order to attempt to restore the NAV IR 1 fault condition but, before he could do so, ATC instructed the aircraft to go-around as the preceding aircraft had not yet cleared the runway. The commander acknowledged this instruction and called "GOING AROUND, REQUEST A HOLDING PATTERN OVERHEAD CHILTERN OR OCKAM TO RESOLVE A LITTLE FAILURE" but ATC were not advised of the specific nature of the failure. The thrust levers were set to the takeoff/go-around (TOGA) detent and, having descended to a minimum radio altitude of 159 ft, the aircraft then started to climb, Figure, 1 Point C. The landing gear lever was selected up, Figure 1, Point D, and the landing gear retracted normally. At this point, the EGPWS warning ceased.

The controller became concerned that the aircraft was drifting south of the runway extended centreline and

Footnote

[1] The ECAM system presents information to the pilots on the status and performance of systems on the aircraft and provides visual and aural warnings of failures and critical situations. It incorporates two electronic displays located centrally in the instrument panel. The upper, the Engine/Warning Display (E/WD), shows engine parameters, fuel state, flap/slat positions, as well as warning, caution and memo messages. The lower, the System Display (SD), shows synoptics indicating the status of the aircraft's systems and normal and emergency checklists to be actioned by the crew.

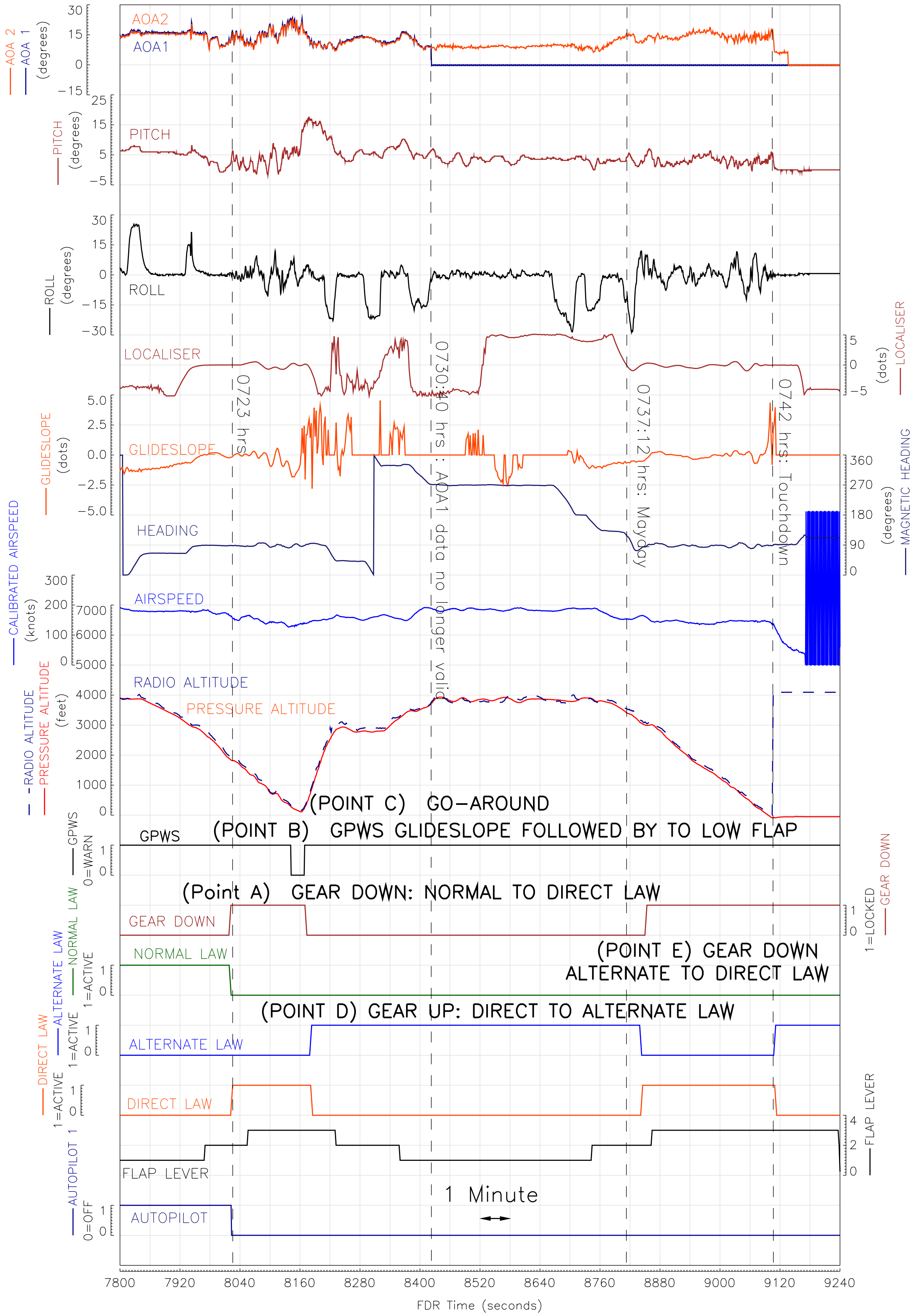

AOA2
AOA1
AOA 2
AOA 1
(degrees)
PITCH
(degrees)
ROLL
(degrees)
LOCALISER
(dots)
GLIDESLOPE
(dots)
HEADING
MAGNETIC HEADING
(degrees)
AIRSPEED
CALIBRATED AIRSPEED
(knots)
RADIO ALTITUDE
PRESSURE ALTITUDE
(feet)
0723 hrs
0730:40 hrs: AOA1 data no longer valid
0737:12 hrs: Mayday
0742 hrs: Touchdown
(POINT C) GO-AROUND
(POINT B) GPWS GLIDESLOPE FOLLOWED BY TO LOW FLAP
GPWS
0=WARN
(Point A) GEAR DOWN: NORMAL TO DIRECT LAW
GEAR DOWN
1=LOCKED
NORMAL LAW
(POINT E) GEAR DOWN
ALTERNATE TO DIRECT LAW
1=ACTIVE
(POINT D) GEAR UP: DIRECT TO ALTERNATE LAW
ALTERNATE LAW
DIRECT LAW
FLAP LEVER
1 Minute
AUTOPILOT
AUTOPILOT 1
0=OFF
7800 7920 8040 8160 8280 8400 8520 8640 8760 8880 9000 9120 9240
FDR Time (seconds)

Figure 1

advised the crew of the missed approach procedure, but did not acknowledge the commander's request to enter a hold. He then transferred the aircraft to the Intermediate Approach Controller. Following the frequency change, the commander again requested radar vectors and said "WE REQUIRE A FEW MINUTES TO RESOLVE A LITTLE…NAVIGATION FAILURE...". The controller asked for the message to be repeated, possibly due to the commander's heavily accented English, and subsequently acknowledged the request.

The co-pilot carried out the go-around and, in accordance with the prescribed procedure, turned the aircraft onto a heading of 040° and climbed to an altitude of 3,000 ft. The flaps were retracted, following which the aircraft was radar vectored downwind and instructed to climb to 4,000 ft. The Intermediate Approach Controller instructed the crew to fly at 220 kt and offered them 23 nm (track miles) to touch down. The commander accepted the distance but requested a speed of 180 kt, to give more time to address the problem. This was accepted by ATC. The crew carried out the procedures displayed on the ECAM, which stated that IR may be available from the No 1 ADIRU, if the rotary selector switch was selected to ATT (attitude), and an alignment procedure was performed. However, the weather at LHR was deteriorating with the cloud base reported by another pilot at 350 ft aal. With the IR fault on the No 1 ADIRU and the No 3 ADIRU unavailable, I-BIKE was limited to carrying out a CAT 1[1] ILS approach. The commander decided to expedite the landing, accepting the flight instrument display limitations that he had, and did not attempt the IR alignment procedure which would have delayed the aircraft's arrival.

At about 0731 hrs, ATC requested if the aircraft had a problem. The commander reported that the aircraft had had "a double inertial reference failure" but the controller replied that the implications of this were not understood. Another aircraft that had heard the message then advised the controller "THAT BASICALLY MEANS THAT THEY HAVEN'T GOT ALL THE NICE BITS OF NAV KIT…THEY ARE BASICALLY POINT AND SHOOT.....". The commander of I-BIKE then stated that they were able to perform a CAT 1 ILS approach only. At about 0734 hrs, he transmitted a PAN call requesting assistance for a radar vectored approach to Runway 09L, explaining the aircraft had suffered a navigation problem. ATC did not respond initially, due to a double transmission, but another aircraft brought it to their attention. Following this, the requested vectors were provided to position the aircraft at the agreed distance of 23 nm (track miles) to touchdown.

In attempting to address the problem with the No 1 ADIRU, the flight crew turned the No 1 ADIRU rotary switch to the OFF position. The ECAM actions did not call for this action in the event of the IR part of an ADIRU failing, but the crew recalled from their review of abnormal procedures in the Flight Manual during the transit from Milan, that there were circumstances when this was required. The commander attempted to find the relevant text in the Flight Manual but was unable to do so before ATC instructed the aircraft to turn onto base leg.

The crew's decision to deviate from the ECAM procedure, by switching off the No 1 ADIRU (with the No 3 ADIRU unavailable) caused the loss of further information from the commander's instrument displays. The landing gear normal extension system was also rendered inoperative, but it was successfully lowered using the emergency gravity (free fall) extension system.

Footnote

[1] Decision height at LHR for a CAT 1 ILS approach for this aircraft to Runway 09L was 200 ft (decision altitude 297 ft).

Another consequence of this was that the nosewheel steering system became inoperative. Accordingly, the commander advised ATC that he was not sure if the aircraft would be able to clear the runway after landing. As the aircraft was radar vectored onto an intercept heading for the localiser, the commander upgraded his PAN to a MAYDAY, transmitting "ON FINAL, MAYDAY FROM THIS MOMENT, WE CANNOT PERFORM A GO-AROUND, AH FINALS 09L"[1], in order to ensure priority. ATC switched traffic ahead of I-BIKE onto Runway 09R to provide a clear approach and, due to his reduced airspeed, also radar vectored a following aircraft to the north. At 0739 hrs, the crew advised ATC that the aircraft was fully established. Control of the aircraft was transferred to the tower controller who advised that there was traffic on the runway to vacate. The crew responded by advising that "WE HAVE AN EMERGENCY", which the controller acknowledged. Landing clearance was given for Runway 09L a short time later.

Although the tower controller was aware that I-BIKE had a navigation problem and that it may not be able to clear the runway after landing, he was not made aware that the commander had declared a MAYDAY and so did not bring the airport Rescue and Fire Fighting Service (RFFS) to a Local Standby state.

The aircraft touched down at 0742:05 hrs at an airspeed of about 134 kt and began to decelerate. Some 50 seconds later, when the ground speed was about 50 kt, the aircraft made a right turn, using rudder and asymmetrical braking, onto the adjacent taxiway. The aircraft came to a stop and the park brake was applied; the crew then requested a tug to tow the aircraft to the stand.

Footnote

[1] The normal protocol for transmitting a PAN is to call the word PAN six times, as three groups of two words, and the word MAYDAY three times as a single group.

Abnormal procedures

With an IR fault in the No 1 ADIRU and the No 3 ADIRU not available, the IR alignment procedure displayed on the ECAM may recover attitude and heading information to the commander's PFD and ND, provided the fault is limited to the loss of the ability to navigate. This procedure requires the rotary selector switch on the Air Data and Inertial Reference System (ADIRS) control panel to be set to the ATT position and aircraft heading data to be entered via the numeric keyboard on the control panel. The aircraft must be maintained level at a constant speed for 30 seconds during this procedure. If the alignment procedure is not carried out, then no changes of rotary switch selector position on the ADIRS control panel are required. By leaving the rotary control switch in the NAV position, air data is still available with airspeed and altitude, etc. being provided to the commander's PFD. Also, the normal landing gear extension and nosewheel steering systems remain available.

Weather

The synoptic situation at 0600 hrs showed an area of high pressure in the mid-Atlantic feeding a north-easterly flow over south-east England with a weak cold front over the London area.

METARS for London Heathrow covering the landing period were:

EGLL 250720Z 04006KT 350V080 2800 HZ BKN006 OVC 011 17/16 Q1018 BECMG 5000=

EGLL 250750Z 03007KT 340V060 2700 HZ SCT005 BKN007 OVC011 17/15 Q1018 BECMG 5000=

Conditions were better than CAT I minima for the approach and the nominated diversion for the flight, London Gatwick airport, was experiencing similar weather.

Engineering investigation

Aircraft maintenance history

On 24 June 2005, the aircraft suffered an IR fault in the No 3 ADIRU. An attempt was made to reset the unit, but this proved unsuccessful. The aircraft was released for service with this ADIRU selected OFF, in accordance with procedure 01-34-3-10-01 a), (562) of the operator's MEL and, accordingly, an Acceptable Deferred Defect was raised in the Aircraft Technical Log. This is a Category C item under the JAA MMEL/MEL.040 definition, and such items must be rectified within ten calendar days, excluding the day of discovery of the defect. The Technical Log entry reflected that the defect must be rectified by 4 July 2005.

A320 Air Data and Inertial Reference System, ADIRS

General description

The ADIRS supplies air data and inertial reference information to the pilots' Electronic Flight Instrument (EFIS) displays and other user systems on the aircraft, including, but not limited to, the engines, autopilot, flight control and landing gear systems.

The aircraft is equipped with three identical ADIRUs and each receives air and inertial reference data from independent sensors. The ADIRU is divided into two parts, either of which can operate independently in case of a failure of the other. The Air Data Reference (ADR) part provides airspeed, angle of attack, temperature and barometric altitude data, and the Inertial Reference (IR) part attitude, flight path vector, ground speed and positional data.

The commander's and co-pilot's EFIS displays are identical and comprise the PFD and the ND units, which show flight parameters and navigation information respectively. In normal operation, the No 1 ADIRU feeds the commander's displays and the No 2 ADIRU the co-pilot's displays. The No 3 ADIRU is a standby unit and, in the event of a partial or complete failure of either the No 1 or No 2 unit, the No 3 ADIRU may be selected to supply air data and/or inertial reference data to either the commander's or the co-pilot's displays. There is no cross-channel redundancy between the No 1 and 2 ADIRUs, No 3 ADIRU being the only alternate source of air and inertial reference data.

ADIRS operation

The ADIRS is controlled via the ADIRS control panel on the overhead panel, Figure 2. In normal operation, the rotary selector mode switches are set to the NAV position. In this configuration, the No 1 and 2 ADIRUs supply data to the commander's and co-pilot's EFIS displays respectively, with No 3 ADIRU available as a standby. Following loss of the ADR and/or IR function of either the No 1 or 2 ADIRU, rotary selector switches on the SWITCHING panel on the centre pedestal, Figure 3, enable air data and/or inertial data from the No 3 ADIRU to be selected to replace the data from the failed unit.

An IR fault in ADIRU No 1 or 2 will cause a loss of attitude and navigation information on their associated PFD and ND screens. An ADR fault will cause the loss of airspeed and altitude information on the affected display. In either case the information is restored by selecting the No 3 ADIRU.

According to the Flight Crew Operating Manual, a failure of the IR section of the ADIRU is indicated by a steady amber FAULT light on the corresponding IR push button on the ADIRS control panel, with

Figure 2

ADIRS Control Panel

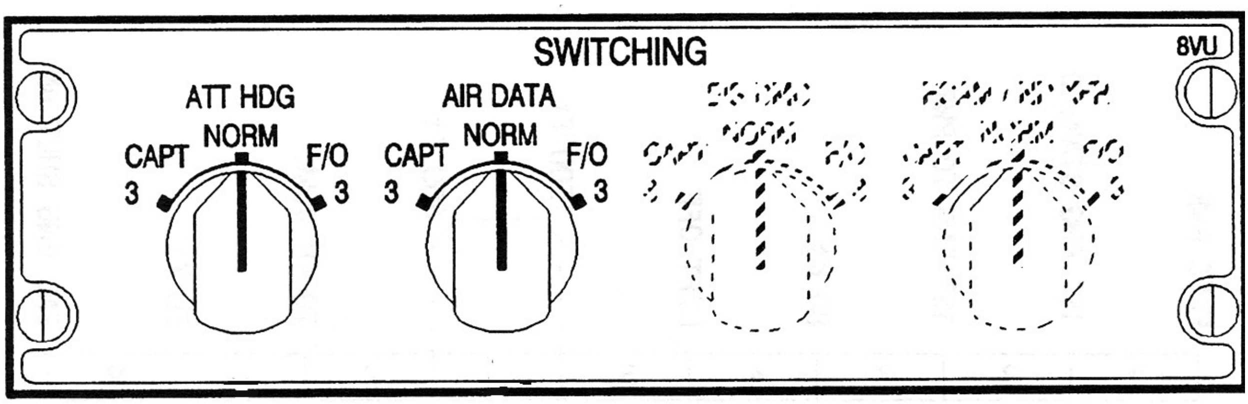


Figure 3

Switching Panel

an associated caution message on one of the ECAM displays. A flashing amber light indicates that the affected system has lost the ability to navigate, but attitude and heading information may be recovered by setting the mode rotary selector switch to the ATT position and performing an alignment procedure. An ADR failure is indicated by a steady amber FAULT light on the corresponding ADR push button and an associated ECAM caution message. In the event of an ADR failure in an ADIRU, the air data output may be switched off by pressing the appropriate ADR push button switch on the ADIRS control panel.

The landing gear control system also uses airspeed information from the No 1 and 3 ADIRUs. The Landing Gear Control and Interface Units (LGCIUs) require airspeed data for the landing gear overspeed protection function. When the airspeed exceeds 260 kt, a safety valve closes to isolate the hydraulic supply, thus inhibiting deployment of the landing gear in order to avoid structural damage. Loss of both airspeed data sources from the No 1 and 3 ADIRUs will also cause the valve to close, with the effect that the landing gear cannot be operated hydraulically and must be lowered by gravity using the emergency extension system. The nosewheel steering system requires the nose landing gear doors to be closed before hydraulic pressure can be applied to the steering actuator. Since the landing gear doors remain open after gravity extension, the nosewheel steering system is also rendered inoperative.

Enhanced Ground Proximity Warning System

The aircraft was installed with an Enhanced Ground Proximity Warning System (EGPWS). The EGPWS system provides a number of warning modes, two of which are Mode 4 and Mode 5. Mode 5 provides a "glideslope" warning if the aircraft descends more than 1.3 'dots' below the glideslope when the aircraft is below 1,000 ft radio altitude, the landing gear is down and the aircraft is on approach. Mode 4 provides a "too low flap" warning when the aircraft is below 245 ft radio altitude, the landing gear is down, the flaps are not fully extended[1], airspeed is below 159 kt and the cockpit overhead panel LANDING CONF 3 push button has not been selected to ON. The LANDING CONF 3 selection inhibits the "too low flap" warning whenever the aircraft is configured with the flaps set at position three for landing.

Centralised Fault Display System (CFDS) information

The main function of the CFDS is to acquire and store data on aircraft systems faults. The recorded faults and associated messages are labelled according to the phase of flight in which they occurred, and the time of occurrence. At the end of a flight, the CFDS generates a Post-Flight Report, containing a list of any recorded system faults, together with the corresponding ECAM fault messages, that occurred during the flight. This serves as a troubleshooting aid to maintenance personnel.

A review of the CFDS Post Flight Report following this incident showed that NAV IR 1 FAULT and F/CTL DIRECT LAW ECAM warning messages occurred at 0724 hrs UTC, approximately 18 minutes prior to touchdown. At 0726 hrs, an F/CTL ALTN LAW warning occurred. At 0730 hrs, the following ECAM warnings occurred: NAV IR 1 FAULT, NAV GPWS TERR DET FAULT, NAV ADR 1+3 FAULT, NAV GPWS FAULT, SFCS and, at 0737 hrs, an ECAM warning for F/CTL DIRECT LAW was recorded.

Footnote

[1] There are five flap positions, designated 0 (fully retracted, 1, 2, 3 and FULL (fully extended). Landings are normally conducted with the flaps fully extended, but position 3 may be used in some circumstances.

Dispatch with No 3 ADIRU inoperative

The operator's MEL, which is based on the manufacturer's Master Minimum Equipment List (MMEL), permits the aircraft to be dispatched with the IR function of either the No 2 or the No 3 ADIRUs inoperative. Dispatch is also permissible with the ADR function of either the No 2 or the No 3 ADIRU inoperative. The IR or ADR functions may not be inoperative on more than one ADIRU (MEL item 01-34-3-10-01 a) refers). If an IR fault occurs on either the No 2 or No 3 ADIRU, the MEL procedure for despatching the aircraft requires the rotary selector switch for the affected ADIRU to be selected to OFF. This has the effect of switching off the entire ADIRU and is necessary because there is no way of switching off the IR part of the ADIRU in isolation. The MEL rationale for switching off the entire ADIRU is to ensure that the faulty computer cannot interfere with the aircraft systems.

With the No 3 ADIRU unavailable, the operation of the aircraft is unaffected provided no faults arise in the remaining ADIRUs. If IR or ADR data is lost from a second ADIRU, systems degradations will occur, as the No 3 ADIRU is no longer available to replace the missing data.

Effects of the loss of No 1 and 3 ADIRU data

Various systems on the aircraft require air data and inertial reference data for their control and operation. According to the aircraft manufacturer, with the No 3 ADIRU inoperative, a subsequent No 1 ADIRU IR fault will cause the following systems to become inoperative:

- Autopilot No 1 and No 2 (and consequently Flight Director No 1 and No 2)
- Autothrust system
- Yaw damper No 1
- Enhanced functions of the EGPWS
- Loss of attitude and navigational data from the commander's PFD and ND

The flight control system 'Normal Laws' are no longer available and revert to 'Alternate Laws' with the corresponding loss of some of the flight control protections, including the 'High Speed' and 'Angle-of-Attack' protection features. The airspeed is restricted to 320 kt, due to loss of the 'High Speed' protection function. In the event of a complete failure of the No 1 ADIRU or, as in this incident, it being switched to OFF with the No 3 ADIRU already inoperative, the following additional systems will be inoperative:

- GPWS
- Rudder Travel Limit unit No 1

Analysis

Air traffic control

Following the go-around from the first approach, the aircraft commander initially wanted to enter a hold at Ockham or Chiltern in order to resolve the ADIRU problem. Either this request was not understood, possibly due to the commander's heavily accented English, or it may have been missed, because the controller was concerned by the aircraft's drift to the south of the runway centreline. However, the weather at LHR was deteriorating with the cloudbase reported by another pilot at 350 ft aal. With the IR fault on the No 1 ADIRU and the No 3 ADIRU unavailable, I-BIKE was limited to carrying out a CAT 1 ILS approach. The commander therefore changed his mind and decided to expedite the landing, accepting the flight instrument display limitations he had, and not to attempt the IR alignment procedure, which would have resulted in further delay. The subsequent PAN call was masked by a double transmission and the controller was made aware of the PAN and the limitations imposed by the 'double inertial reference failure' by another pilot. Whilst ATC did not completely understand the problem, they did not want to place additional workload on the commander whilst he was handling an abnormal situation and they ensured priority was given to the aircraft.

At a range of 11 nm from touchdown, when the commander transmitted "ON FINAL, MAYDAY FROM THIS MOMENT, WE CANNOT PERFORM A GO AROUND, AH FINALS 09L", the MAYDAY element of this call was not heard by the controller. This was probably due to a combination of the commander not announcing the MAYDAY using the expected protocol and his heavily accented English, rather than any failing within ATC. As a result, the RFFS was not brought to Local Standby for the landing aircraft which had declared an emergency. This highlights a problem occasionally faced by ATC controllers of some flight crews not adopting the accepted protocol when declaring an emergency situation, (see footnote page 7).

Aircrew

When the ADIRU 1 fault occurred, the commander handed control to the co-pilot. They agreed to carry out a go-around and take up a holding pattern in order to action the ECAM abnormal procedure as adequate fuel was available to delay the landing. The commander found monitoring the radio to be distracting, given the high level of radio traffic in the London area. This also possibly contributed to his desire for more time to resolve the ADIRU fault and prepare the aircraft for landing, and hence his request to take up a holding pattern. However, in view of the deteriorating weather situation and the fact that only a single ADIRU was functioning normally, the commander then decided against carrying out the NAV alignment procedure and delay the landing and, therefore, did not repeat his request to ATC to take up a holding pattern.

The excursion below the glidepath, late on in the initial approach, following the No 1 ADIRU fault, was co-incidental with a "too low flaps" warning from the EGPWS, as the aircraft was not configured for a normal landing, ie, FULL flap had not been selected and the LANDING CONFIG 3 button had not been pressed. This occurred with the co-pilot flying the aircraft (manually) in an unusual configuration, ie, in 'Direct Law'. Otherwise, he flew the aircraft accurately, both in 'Alternate' and 'Direct Law', to the subsequent uneventful landing.

The commander subsequently found himself in a situation where there was no clear best course of action and with little spare time in which to deal with the problem. Although the crew took action in response to the ECAM messages, they also attempted to locate the relevant pages in the Flight Manual relating to a No 1 ADIRU failure. The commander recalled a requirement to turn the ADIRU rotary selector switch to OFF, but this action was not called for on the ECAM. Unable to find the information in the time available, the crew elected to select the rotary switch to OFF, but this action unnecessarily degraded the aircraft systems further, resulting in the need to extend the landing gear by gravity extension and the loss of nosewheel steering.

EGPWS

When the EGPWS Mode 4 “too low flap” warning was recorded, the aircraft flaps were in configuration three, the airspeed was below 159 kt and the landing gear was down. The EGPWS Mode 4 warning would have been active at that time as long as the LANDING CONF 3 push button had not been selected on the flight deck to inhibit the warning. Although the operation of this push button was not recorded on the FDR, it was considered most probable that it had not been selected to ON during the first approach, as the warning was activated.

During the initial approach, the recording of both the EGPWS Mode 5 “glideslope” warning and Mode 4 “too low flap” warning indicated that air data information was still available to the EGPWS from the ADR part of the No 1 ADIRU. Had data not been available, both EGPWS warnings would have been inhibited. It was concluded, therefore, that data from the ADR section of the No1 ADIRU remained available following the failure of the IR section.

Conclusions

During this investigation, it was apparent that the operator’s training organisation train their flight crews to a high standard and that nothing in the training of the I-BIKE crew should have led them to deviate from the checklist displayed on the ECAM. The operator’s training organisation took the view that the commander had correctly elected to carry out a go-around and deal with the failure of the navigation equipment in a holding pattern. However, the reducing cloudbase, combined with being limited to a CAT 1 ILS approach, then became the main consideration of the crew to land the aircraft without unnecessary delay. The incorrect action by the crew of selecting the No 1 ADIRU to OFF, rather than following the ECAM checklist, was carried out from memory at a time of relatively high workload, and led to further loss of aircraft systems.

By not adopting the usual protocol for declaring a MAYDAY, the commander may have contributed to ATC not being fully aware that the crew had declared an emergency situation. His heavy accent may also been a factor. This resulted in the airport RFFS not being brought to a Local Standby state of readiness for the landing.

INCIDENT

Aircraft Type and Registration:	BAe 146-300, G-JEBB
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines
Year of Manufacture:	1991
Date & Time (UTC):	15 February 2006 at 1330 hrs
Location:	Approach to Birmingham International Airport
Type of Flight:	Public Transport (Non revenue)
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Ruptured hydraulic accumulator and small hole in fuselage pressure hull
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	4,500 hours (of which 3,000 were on type) Last 90 days - 82 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and metallurgical examination commissioned by the AAIB

Synopsis

During the approach a loud bang was heard by the aircrew, followed by a loss of the yellow hydraulic system. After the aircraft landed safely a hydraulic accumulator was found to have burst. The failure was subsequently attributed to a material defect in the cylinder wall of the accumulator. No one was injured in the incident. A safety action plan is being put in place by the aircraft manufacturer, in conjunction with the accumulator manufacturer, to check other accumulators which might have similar defects.

History of the flight

The aircraft was on a positioning flight to Birmingham Airport and whilst on final approach and at an altitude of between 100 to 200 ft above ground level, a loud bang was heard by the aircrew. Shortly afterwards a caption for hydraulics illuminated and the commander, who was the handling pilot, noticed an indication that the hydraulic fluid level in the yellow system was falling.

The commander believed that the aircraft had suffered a mechanical failure in either the hydraulic bay or the No 2 engine (in which the engine driven pump for the yellow hydraulic system was located). He told the co-pilot that he intended to continue with the landing since the aircraft was in landing configuration and the failure had caused only the loss of functionality for half the roll spoilers.

After an uneventful landing and with the aircraft at a safe speed the commander turned both the engine driven pump and the AC pump off to minimise the risk of further damage. There was an engineer on board and he visually checked the No 2 engine for any signs of damage or hydraulic leaks. Whilst no damage was evident to the engineer, the No 2 engine was shut down as a precautionary measure and the aircraft was taxied using three engines. As a result of the failure, the park brake was not available so the aircraft was held using toe brakes prior to the wheels being chocked.

After the shutdown checks were completed it was determined that the yellow system accumulator had burst causing immediate loss of functionality of the yellow hydraulic system. Moreover a metal pin from the accumulator had pierced the fuselage pressure hull.

The burst accumulator (see Figure 1) was removed from the aircraft and sent to the AAIB.

Hydraulic accumulator information

There are two hydraulic accumulators located under the BAe 146 fuselage floor close to the main landing gear installation and inside the pressure hull, and these are fitted so that the hydraulic system can cope with fluctuations in demand. The accumulator consists of a pressure cylinder with a piston inside. On one side of the piston is hydraulic fluid and on the other is nitrogen, nominally at 1,000 psi.

The accumulator was assembled in 2001 and was installed in the aircraft 10 months prior to the incident, during which time the aircraft had made 1,844 landings and accumulated 1,593 flying hours.

The pressure cylinders are machined from solid cylindrical steel bar stock of material specification S98 or similar and have a wall thickness of 2.8 mm. The manufacturer's job card specified fluorescent magnetic particle inspection of the cylinder in both longitudinal and circumferential directions to detect for cracks. The manufacture, surface treatment and crack detection of the cylinder were all subcontracted out by the

Figure 1

Accumulator as removed from the aircraft accumulator manufacturer to specialist organisations. However, the organisation that manufactured the cylinder has since ceased trading.

Metallurgical examination

The damaged accumulator was subject to a metallurgical examination which resulted in two inclusions being found in the cylinder wall. These inclusions were thin strands of non-metallic material that were present in the bar stock prior to machining and were located on the outer face of the cylinder wall running longitudinally. The longer inclusion (see Figure 2) was 5.7 cm long and was where the cylinder initially burst. This was immediately followed by failure of the cylinder wall at the second inclusion. Both the inclusions had reduced the wall thickness locally by approximately two thirds and the discontinuities in the cylinder wall had subsequently grown as a result of low cycle, high stress fatigue (see Figure 3).

Magnetic crack tests were carried out and revealed no other defects in the cylinder.

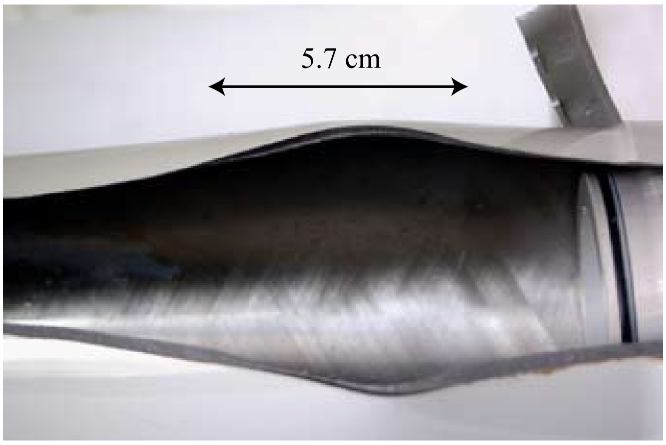


Figure 2

Photograph showing the location of the primary inclusion

Safety action

The manufacturer of the accumulator and the manufacturer of the aircraft were promptly informed of the results of the metallurgical examination. They have examined their inspection records and, at the time of writing this report, are putting in place a programme which includes non-destructive crack detection of those components considered to be at risk. They

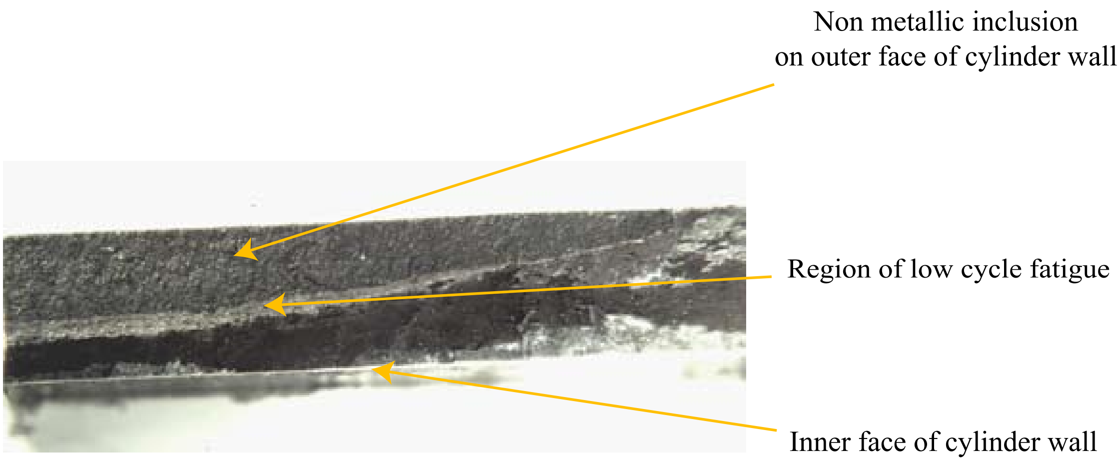


Figure 3

Photograph showing one end of the fracture face for the shorter of the two inclusions are also reviewing the inspection and manufacturing processes for the accumulators. In view of this it is not considered necessary for the AAIB to make any safety recommendations.

Comment

The failure of the hydraulic pressure accumulator was caused by a pre-existing inclusion of non-metallic material, and this defect progressed through low cycle fatigue resulting in the cylinder bursting.

This type of inclusion in the cylinder can arise if insufficient material is machined away at various stages in the production of the cylinder from the solid steel bar stock. Any defects remaining after machining should have been detected by the subsequent magnetic particle inspection and should have resulted in the cylinder component being rejected.

INCIDENT

Aircraft Type and Registration:	Boeing 737-33A, G-TOYE
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1995
Date & Time (UTC):	15 January 2006 at 0605 hrs
Location:	Birmingham Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 103
Injuries:	Crew - None Passengers - None
Nature of Damage:	Dent in radome
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	4,005 hours (of which 1,984 were on type) Last 90 days - 197 hours Last 28 days - 64 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After pushback the aircraft rolled forward and struck the tug because the tow bar had been disconnected without any brakes being applied on the aircraft.

History of the flight

The aircraft was pushed back from its parking stand and then pulled forward by the tug to be aligned with the taxiway. The flight crew had started engine No 1 and were in the process of starting engine No 2 when a member of the ground crew requested over the intercom that the flight crew set the parking brake. The commander told the ground crew "just wait one minute" whilst he continued with the start. The commander then became aware a few seconds later that the aircraft was moving forwards and the ground crewman repeated his request for the brakes to be set to park. The commander applied the brakes and set them to park but not before the aircraft had rolled forward sufficiently for the radome to hit the tug. The aircraft was then inspected by an engineer to assess the aircraft damage which was confined to a dent in the radome.

Comment

The commander believes that the ground crewman on the intercom may have misheard his instructions to wait resulting in the ground crew disconnecting the tow bar whilst there were no aircraft brakes applied.

INCIDENT

Aircraft Type and Registration:	Boeing 747-436, G-BNLG
No & Type of Engines:	4 Rolls-Royce RB211-524G turbofan engines
Year of Manufacture:	1989
Date & Time (UTC):	20 February 2005
Location:	En route from Los Angeles International Airport to London (Heathrow) International Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 18 Passengers - 352
Injuries:	Crew - None Passengers - None
Nature of Damage:	Major damage to No 2 engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	12,680 hours (of which 1,855 were on type) Last 90 days - 212 hours Last 28 days - 75 hours
Information Source:	AAIB Field Investigation

Synopsis

Immediately after the aircraft took off on a night flight from Los Angeles to London, a banging sound was heard and passengers and ATC reported seeing flames from the No 2 engine. The symptoms and resultant turbine over-temperature were consistent with an engine surge; the crew completed the appropriate checklist, which led to the engine being shut down. After assessing the situation, and in accordance with approved policy, the commander decided to continue the flight as planned rather than jettison fuel and return to Los Angeles. Having reached the east coast of the USA with no indications of further abnormality and with adequate predicted arrival fuel, the crew decided to continue to the UK. The winds and available flight levels were subsequently less favourable than anticipated and, nearing the UK, the crew decided to divert to Manchester in order to maintain the required arrival fuel reserve.

In the latter stages of the flight the crew encountered difficulties in balancing the fuel quantities in the four main tanks. They became concerned that the contents of one tank might be unusable and declared an emergency in accordance with the operator's procedures. The aircraft landed with low contents in both outboard main tanks, although the total fuel quantity was in excess of the planned reserve. The fuel system, in the configuration selected, should have continued to feed the operating engines until all tanks emptied.

The investigation determined that the engine surge had been due to excessive wear to the high-pressure compressor casing and, with the standard of fuel controller software installed, this resulted in turbine over-temperature damage. There was no evidence of fuel system malfunction and it was possible to maintain fuel tank quantities in balance by the selective use of fuel pumps. The evidence suggested that the operator should ensure that flight crews are provided with relevant instruction on 3-engined fuel handling during initial and recurrent training, and that the regulators should review the policy on flight continuation for public transport aircraft operations, following an in-flight shutdown of an engine, in order to provide clear guidance to the operators. Eight recommendations are made, six of which relate to flight data recorders.

History of the flight

Following a 48 hour period of rest, the crew reported for duty on 20 February 2005 to operate a flight from Los Angeles International Airport to London (Heathrow) International Airport. The flight crew consisted of three pilots: the commander and two first officers (designated 'primary' and 'heavy'), who had all operated an inbound flight two days previously. For the outbound flight they decided to load an additional 4 tonnes (4,000 kg) of fuel due to the forecast weather and possible air traffic flow restrictions into London; this resulted in a total ramp fuel of 119 tonnes. There were no known relevant deficiencies with the aircraft. All three pilots were on the flight deck for the initial part of the flight.

The 'primary' first officer was the handling pilot in the right seat. The takeoff, at 0524 hrs, was from Runway 24L using reduced power and Flap 20; the 'heavy' first officer was seated on the jump seat. It was raining and the surface wind was from 180° at 10 kt. The takeoff appeared normal until, just after the landing gear had been selected up, at approximately 100 ft agl, there was an audible and continuous "BUMP, BUMP, BUMP" sound from the left side of the aircraft. The handling pilot was aware of a slight yaw to the left, which was easy to control. All three flight crew members saw a reduction in the indicated No 2 EPR and an increase in the associated EGT. The EGT rise continued above the normal limits and the exceedence and corresponding digital display were annunciated in red.

At the same time ATC transmitted that flames could be seen down the left side of the aircraft. The crew agreed that it was a surge on No 2 engine and that the commander, who was the non-handling pilot, should carry out the appropriate recall actions. The commander was the only member of the flight crew who had previously experienced an airborne engine surge. With the correct engine identified, he completed the memory items from the quick reference handbook (QRH) procedure for *'ENGINE LIMIT/SURGE/STALL'*, retarding the No 2 thrust lever until the abnormal conditions ceased; this occurred at the idle position. By now, G-BNLG was climbing through approximately 1,500 ft and the crew declared a 'PAN' to ATC, who cleared the flight to continue the climb to 5,000 ft amsl. The crew also requested radar vectors to remain within the local area whilst they evaluated the situation. Once the aircraft was in the clean configuration, the commander passed the QRH to the first officer on the jump seat for him to confirm and read the checklist for *'ENGINE LIMIT/SURGE/STALL'*. Continuous ignition was selected 'ON' and the crew confirmed that the engine indications appeared normal. The commander then gently advanced the No 2 engine thrust lever and this resulted in an almost immediate audible surge noise. A subsequent attempt at a higher airspeed had the same effect. The crew discussed the situation and agreed that the best course of action was to shut down the No 2 engine. This was actioned by the commander in accordance with the QRH.

The crew then agreed that the 'heavy' first officer would go to the cabin to look out of the left side of the aircraft for signs of damage and to brief the Cabin Services Director (CSD), while the commander and the 'primary' first officer would review their options. The CSD was advised of the situation and asked to stand-by for further instructions. No damage could be seen by looking out of the aircraft, but it was dark and there was no effective illumination of the relevant area. Several passengers informed the 'heavy' first officer that they had seen flames and one passenger, who was a pilot, stated that he thought that it had been an engine surge. The 'heavy' first officer returned to the cockpit and briefed the commander accordingly. By then, the commander and 'primary' first officer had reviewed the situation. The 'Eng Out' option had been selected on the Flight Management Computer (FMC) and the crew had consulted the aircraft and company manuals. Additionally, the commander had spoken with the operator's base at Heathrow by radio and had been advised that it would be preferable to continue the flight but that the course of action was the commander's decision.

The subsequent decision to continue the flight was taken by the commander, in consultation with the other flight crew members, after consideration of the following factors:

1. The 'Eng Out' fuel prediction indicated a landing at final destination with approximately 7 tonnes, compared to the required minimum reserve of 4.5 tonnes. (4.5 tonnes represents the fuel required for 30 minutes holding at 1,500 ft, in the clean configuration.)
2. An additional engine failure was considered and, with regard to the aircraft performance, it was deemed safe to continue.
3. The initial routing was across the continental USA where there were numerous suitable diversion airfields.
4. The present situation would not justify an overweight landing, and the time to jettison fuel (approximately 70 tonnes) down to below maximum landing weight would be about 40 minutes.
5. The No 2 engine was shut down and the windmilling parameters were normal; the aircraft appeared to be in a safe condition for continued flight.
6. The company policy was to continue to destination as long as the aircraft was in a safe condition.
7. The manufacturer's QRH procedure for *ENGINE LIMIT/SURGE/STALL* did not require the crew to consider landing at the nearest suitable airfield.

The commander's decision was to continue the flight, but the crew would monitor the situation carefully. Accordingly, he advised ATC that the 'PAN' situation was cancelled and that they would continue the flight.

For the subsequent flight across the USA, the aircraft flew at FL 270 at a Mach No of 0.75. At that level and with the predicted winds entered into the FMC, the landing fuel at Heathrow was forecast to be about 10 tonnes. For the first 2 hours of the flight, the 'heavy' first officer rested in the crew bunk. When he returned, the commander took some rest before returning to the cockpit in order to make the final decision of whether to continue before the aircraft commenced the North Atlantic crossing. For the crossing, the crew had requested FL320 but ATC could only clear the aircraft at FL350 or FL290 due to opposite direction traffic. Aircraft performance precluded FL350 and, when FL290 was entered into the FMC the landing fuel at London Heathrow was indicated to be between 7 and 7.5 tonnes. The crew had agreed to plan on a minimum landing fuel of 6.5 tonnes at Heathrow.

During the Atlantic crossing, the crew continued to monitor the fuel situation. It was noted that the fuel appeared evenly distributed until the total fuel decreased below 55 tonnes. Thereafter, with the normal fuel feed being 'Tank to Engine', No 2 Tank contents remained constant until balanced by the crew. This was achieved by selective use of the Override/Jettison pumps in No 2 Tank.

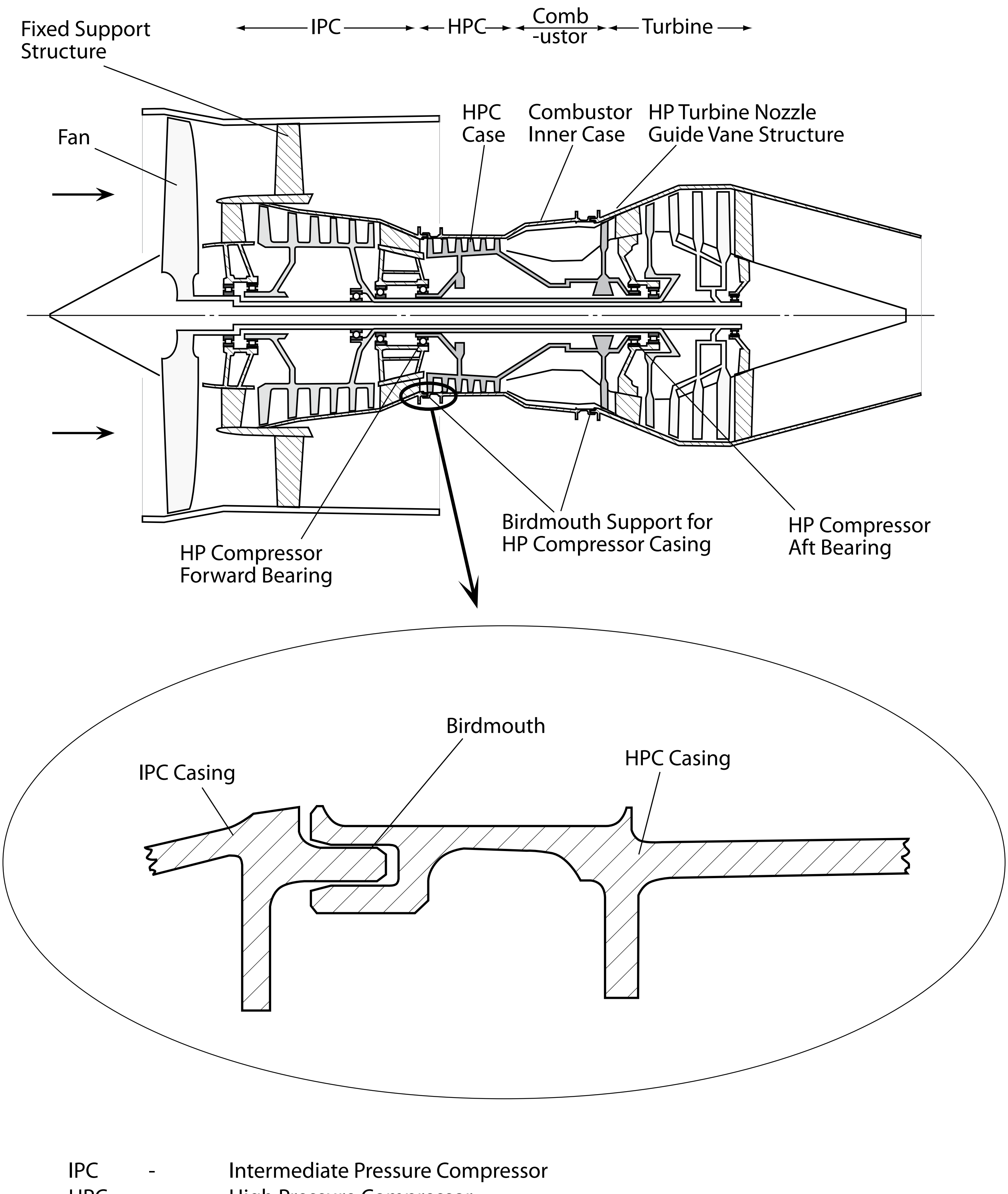
As G-BNLG approached Ireland, the total fuel indicated was about 12 tonnes, which was evenly balanced between the four main fuel tanks. By now, the aircraft was at FL350 and, due to a stronger than forecast headwind, the FMC now predicted a landing fuel at London of 6.5 tonnes. The crew discussed the situation and decided to divert to Manchester; they advised ATC accordingly. Reprogramming the FMC resulted in a predicted landing fuel at Manchester of approximately 7 tonnes.

During the descent towards Manchester, the crew became concerned that fuel did not appear to be feeding from No 2 tank, even with selective switching of the main pumps within the fuel system. With the possibility that this fuel might be unusable, which would result in the aircraft landing with less than the final reserve fuel, the commander declared a 'PAN' call to ATC. G-BNLG was cleared direct to a position 10 nm on the extended centre line for Runway 06R. Around this time, the 'FUEL QTY LOW' caution message illuminated on the Engine Indication and Crew Alerting System (EICAS) and No 4 tank indicated a quantity of 0.9 tonnes. The appropriate QRH procedure was completed, which resulted in all main fuel pumps being switched on and all cross feed valves being open. In this configuration all operative engines will be fed with fuel. The commander, concerned that the useable fuel at landing would be below the minimum reserve fuel of 4.5 tonnes, declared a 'MAYDAY' to ATC, in accordance with the operator's procedures, and assumed the role of handling pilot for the subsequent uneventful manual landing. After landing, the auxiliary power unit (APU) was started and the aircraft taxied to its allocated stand, accompanied by the AFRS. Data from the flight data recorder (FDR) indicated that the fuel on landing was approximately 5.8 tonnes.

Aircraft Description

Engine

The aircraft was powered by four RB211 engines (models 524G2 and 524G2-T); a 3-spool turbofan engine with a rated maximum sea-level static thrust of around 58,000 lb. Airflow through the engine passes in turn through a fan, an intermediate pressure compressor (IPC) and a high pressure compressor (HPC), each driven by a corresponding turbine assembly (Figure 1). The HPC is a conventional axial compressor with 6 rotor stages, each followed by a ring of fixed stator blades attached to the HPC casing. The HPC casing is bolted to the engine's combuster section inner case and the combined HPC-combuster inner case is supported between the IPC support structure and the HP nozzle guide vanes structure, in each case via a circumferential socket-spigot arrangement, known as a 'birdmouth'. The HPC spool is supported on a forward ball bearing mounted to the IPC support structure and a rear roller bearing mounted to the HP-IP turbine module casing.



IPC - Intermediate Pressure Compressor
HPC - High Pressure Compressor

Figure 1

Engine HP Compressor Support Arrangement

The fuel system on each engine was controlled by a Full Authority Fuel Controller (FAFC) which is an electronic computerised unit. The software installed on G-BNLG's No 2 engine FAFC was to Issue 15. Issue 16 software was available and being embodied on the BA fleet at each workshop visit; it had not yet been incorporated on this particular unit. At the time of this event the operator's fleet was approximately 80% embodied with Issue 16 software.

Aircraft fuel system arrangement

The B747-400 has two main fuel tanks and a reserve tank in each wing, plus a wing centre section tank (referred to as the 'centre wing tank') and a horizontal stabiliser tank (Figure 2). Fuel volumes and density are sensed by a fuel quantity indication system (FQIS) using capacitance probes in the tanks. Indications of the fuel quantities, in tonnes in individual tanks and for the whole aircraft, are displayed on a fuel system synoptic diagram on a crew-selectable page of the EICAS. The total fuel on board is always displayed on the EICAS. The tanks are also fitted with a magnetic dip-stick system to allow ground calibration of fuel quantities.

Fuel can be fed from each main tank via two main pumps, operating in parallel, or from a suction inlet in the tank. This feed can be directed to the respective engine, via a low pressure shut-off valve, and/or into a crossfeed manifold, via a crossfeed valve. In addition, each inboard main tank (Nos 2 & 3), with almost three times the capacity of each outboard main tank (Nos 1 & 4), has two override/jettison pumps, feeding into the crossfeed manifold. In order to prevent excessive fuel depletion in a jettison situation these pumps are arranged with standpipe inlets which uncover when the fuel quantity in a tank reduces to around 3.2 tonnes, causing pumping to cease. The centre tank also has two override/jettison pumps, feeding into the crossfeed manifold. The crossfeed manifold incorporates a flow-limiting valve intended to prevent unwanted crossfeed between the left and right sides of the aircraft due to normal variation in pump output pressure.

In order to induce fuel usage from an inboard tank in preference to the adjacent outboard tank when crossfeeding, a considerably higher pump output pressure in the inboard tank is required. This overcomes the

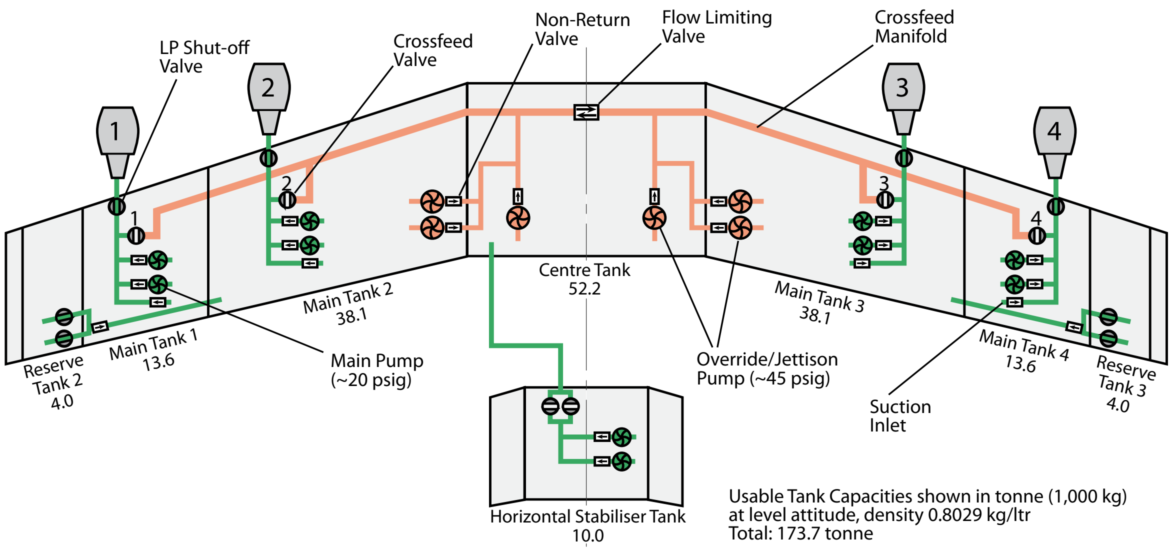


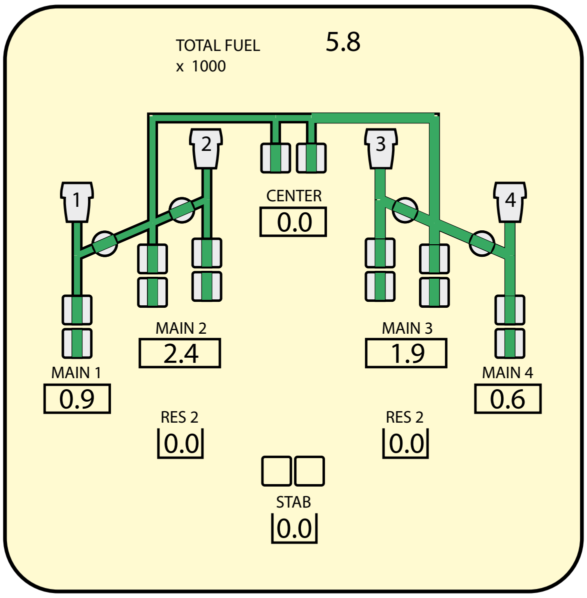
Figure 2

B747-400 Engine Fuel Feed System Schematic difference in static head between the tanks occasioned by the wing dihedral. A higher pressure is also required for such crossfeeding, because of the longer flow path and the consequent higher pipeline pressure loss when doing so. Pump outlet pressure at typical flow rates is approximately 20 psig for the main pumps and 45 psig for the override/jettison pumps. Thus the override/jettison pumps will automatically deliver the fuel feed in a situation where main pumps and override/jettison pumps are outputting to a common point.

The pumps and crossfeed valves can be controlled using push-button selector switches on an overhead fuel system panel on the flight deck. Lights in the switches illuminate to indicate a low pump outlet pressure situation or a crossfeed valve that fails to achieve the selected position. The EICAS fuel system synoptic diagram includes coloured lines signifying fuel flows (Figure 3); these are based on measured pressures, valve positions and system logic and are thus predicted, rather than sensed, flows. The flow indications are intended as secondary, rather than primary, information for the crew.

Fuel System Operation and Limitations

The control of fuel usage is largely automatic, once the system has been set before takeoff by selecting all pumps ON and all crossfeed valves OPEN. The system causes the horizontal stabiliser tank, the centre tank and the reserve tanks to empty in turn, and then for fuel to be fed from the inboard main tanks, using the override/jettison pumps to overpower the main pumps in the outboard main tanks. When the fuel quantity in an inboard main tank becomes approximately equal to that in the adjacent outboard main tank, the crew is provided with an EICAS message 'FUEL TANK/ENG'; this occurs at a total fuel load of around 55 tonnes (13.75 tonnes/tank). At this point the crew



Green line indicates predicted flow.
Fuel quantities shown are approximately those present at G-BNLG's landing.

Figure 3

Flight Deck Fuel Feed System Synoptic Display

is required to select manually Crossfeed Valves 1 and 4 Closed and Tank 2 and 3 override/jettison pumps Off, effectively causing each engine to be supplied from its respective tank.

The design intention is that no further crew action is required except in response to EICAS messages indicating the abnormal conditions of fuel tank imbalance or low fuel quantity. Imbalance is not subject to Flight Manual limitations but should generate EICAS messages to alert the crew, as follows:

1. 'FUEL IMBALANCE 1-4':
   There is a fuel imbalance of 1,360 kg between main tanks 1 and 4.
2. 'FUEL IMBALANCE 2-3':
   There is a fuel imbalance of 2,700 kg between main tanks 2 and 3.

3. 'FUEL IMBALANCE':
   This message is effective only after the 'FUEL TANK/ENG' condition and indicates that there is an imbalance of 2,700 kg between inboard main tanks (2 and 3) and outboard main tanks (1 and 4).

Some differences were noted between the Operations Manual issued by the manufacturer and that issued by the operator, relating to fuel balancing. The operator's manual expanded on the information in the manufacturer's manual providing practical advice on fuel balancing. However, the operator's manual required the use of the override/jettison pumps to correct any imbalance between main tanks; if this was not possible, the main pumps in the low quantity tank should be switched off. The manufacturer made no reference to the override/jettison pumps and required that the main pumps in the low tank be switched off in the event of an imbalance between main tanks. The rationale behind the manufacturer's procedures was that the balancing procedure was the same, regardless of whether the fuel quantities had decreased below the override/jettison pump standpipe level or not.

In the event that the fuel quantity in any main tank reduces to 0.9 tonnes an EICAS 'FUEL QTY LOW' message is given. The operator's QRH procedure for this condition required the crew, having considered the possibility of an engine fuel leak, to select manually all crossfeed valves OPEN and all main pumps ON. In this configuration all the operating engines should continue to be fed, even if one or more main tanks is emptied, until all four main tanks empty. The procedure also specified that the crew should plan to land at the nearest suitable airfield and avoid high nose-up attitudes and/or excessive longitudinal acceleration.

Auxiliary power unit

The aircraft was fitted with an APU in the rear fuselage. The APU can be used in flight to supply pneumatic and electrical power but cannot normally be started in flight. Fuel for the APU is fed from No 2 main fuel tank.

Aircraft Examination

Engine

Strip examination of G-BNLG's No 2 engine (Serial No 13367), by an engine overhaul agency, revealed significant wear of the rotor blade tips of several stages of the HPC and of the mating static abradable liner of the compressor casing. Significant frettage wear of the female part of the HPC casing forward birdmouth was evident, with a maximum gap of 0.240 inch present compared to a limit of 0.208 inch. It was concluded that this had allowed sufficient radial displacement of the front end of the casing to cause the blade and liner contact damage. A number of blades and vanes from both the IP and HP compressors had suffered damage consistent with blade contact with adjacent vanes as a result of engine surging. A Service Bulletin (SB72-D574) that modified the geometry of the casing and added a wear-resistant coating to the birdmouth had been issued. The Service Bulletin recommended accomplishment of the modification when the engine was next disassembled for refurbishment or overhaul and the operator was modifying its fleet accordingly.

The IP turbine was found to have suffered severe over-temperature damage, with substantial portions of both stator and rotor blades burnt away. This damage was consistent with the effects of over-fuelling. The downstream LP turbine section had also suffered overheat and debris damage and it was found necessary to replace all the turbine blades and nozzle guide vanes for all three turbine stages. Records indicated that the engine had accumulated 24,539 operating hours and 3,703 cycles since new; it had not been overhauled or repaired during its life.

Fuel system

Aircraft documentation indicated that G-BNLG departed Los Angeles with 119 tonnes of fuel and arrived on stand at Manchester with 4.9 tonnes, all in the main tanks. The FDR recorded a total of 5.8 tonnes on landing. The operator's engineering staff reported that, after a short period of APU ground running at Manchester, the EICAS system indicated the following fuel quantities in the main tanks:

Tank No	Fuel Quality - tonnes
1	0.5
2	2.1
3	2.0
4	0.1
Total	4.7

A series of ground checks carried out on the fuel system at Manchester showed that all pumps functioned and that no anomalies had been registered by the aircraft's Central Maintenance Computer, neither had any non-normal indications been presented to the crew on the EICAS display during flight. G-BNLG was then refuelled and, with the No 2 engine inoperative, flown to London (Heathrow) by a crew qualified to conduct planned 3-engine ferry flights. The commander of the ferry crew reported that no fuel system anomalies were detected and that crossfeeding checks during the flight showed that it was possible to feed any of the operating engines from any of the main tanks. However, he commented that, in order to get fuel to feed from an inboard main tank in preference to an outboard main tank while both were crossfeeding, it was necessary to take the 'aggressive' action of selecting both main pumps in the outboard tank 'OFF'.

Further ground checks at Heathrow revealed no anomalies. These checks consisted of dip-stick measurements of the outboard main tank contents, Aircraft Maintenance Manual fuel system checks, rig tests of the Tank 2 main pumps and testing of crossfeed operation with three engines running and the aircraft configured to simulate conditions during the incident flight. No reports of relevant fuel system anomalies have occurred during subsequent months of in-service operation.

Engine Surge

Cause of Engine Surge

It was clear from the evidence that the initial No 2 engine problem had been a surge, an abnormal condition where the airflow through a gas turbine engine becomes unstable and momentarily reverses. The cause is generally the rapid spread of a rotor blade stall condition in part of one of the engine's compressors. Blade stall occurs if the angle of incidence of the local airflow within the compressor relative to a rotor blade becomes excessive and the normal smooth flow over the blade breaks down. The angle of incidence is the resultant of the rotational speed of the blades and the flow velocity through the engine. Thus anomalies that significantly affect the flow rate at a given compressor pressure ratio can result in a stall. The stall condition can extend over a number of blades, and/or a number of compressor stages, causing a reduction in airflow, in pressure rise and in efficiency that, if sufficiently severe, can lead to a surge.

The engine is designed such that a margin from compressor stall is maintained for all steady-state and transient situations but this is reduced, and can be eliminated, if compressor rotor blade tip clearances become excessive. Information from the engine manufacturer indicated that the normal steady-state tip clearance of the HPC rotor blades was in the order of 0.020 in. In transient conditions the clearance alters due to the combined effects of varying centrifugal loading on the compressor rotor, differential thermal expansion of the compressor rotor and casing and deflections due to thermally induced loading. Because of these effects the engine will have a reduced surge margin approximately 50 seconds after take-off power is set.

The flow reversal associated with a surge can commonly occur on a low-frequency cyclical basis, up to 7 times per second. The symptoms can include a loud bang, or series of bangs, audible to the passengers and crew, flames at the engine inlet and exhaust and sudden loss of engine thrust. This may be followed by an engine rundown or by a restoration of stable flow through the engine, possibly with areas of compressor stall still present. Compressor damage can be caused during the surge and may assist its continuation.

HPC Birdmouth wear surge

Rotor blade tip clearance can be affected by wear of the HPC casing birdmouth feature. Excessive wear allows the forward end of the HPC casing to displace radially downwards, thereby increasing blade tip clearances over the lower half of the compressor and causing the rotor blades to contact the liner over the upper part and erode, further increasing the lower clearances. Experience has shown that where this has led to a compressor stall and engine surge the HPC tip clearance has increased to around 0.020-0.040 inch, with the engine typically having accumulated in the order of 3,500 cycles. Commonly, where the clearances have become excessive, a stall will occur when power is increased in reverse thrust. Information suggested that this may have been used as an indicator that repair was required. Two previous cases of RB211 in flight shut downs (IFSDs) due to surge resulting from HPC birdmouth wear had been reported, on RB211-524G-T and 524H-T type engines.

Engine over-fuelling

The software installed in G-BNLG's No 2 engine FAFC was at Issue 15. A Rolls Royce Service Bulletin (SB) No RB.211-73-D435, issued on 6 July 2001, amended the software to Issue 16, with the stated objective of 'upgrading the software standard and maintaining reliability'.

The reason for the change was to rectify problems that had been experienced with Issue15. One had resulted from a change of logic introduced at Issue14 (and included in Issue15) in order to address a control problem found in cases of fracture of the burner pressure (P30) sensing line. Fuel flow was computed as a function of P30 and fracture of the P30 line originally caused the fuel flow to decrease and the engine to flame-out. In order to prevent this, a P30 pipe break logic was introduced at Issue14 whereby, in the event of an anomalous P30 decrease, the FAFC used a synthesised P30 based on HP rotor speed N3. However, service experience showed that this logic could be erroneously activated during a surge and locked-in stall event, leading to over-temperature damage to the turbine blades and vanes.

The justification evidence for the SB included:

> *"The following events have been reported in service: (a) During Take-off rotation engine surged and locked in stall due to HP compressor damage. The stall triggered the FAFC P30 pipe break logic and increased fuel flow leading to high TGT [turbine gas temperature] and turbine damage."*

The Issue16 software aimed to overcome this and other problems. Compliance with the SB was specified as: "RECOMMENDED (1B). Rolls-Royce recommends that this Service Bulletin be accomplished on an expedited basis." The operator noted that modification of their fleet, on this basis, would take between 4 and 5 years. At the time of the incident approximately 80% of the fleet had been modified; the remainder of the fleet has been modified subsequently.

Possible consequences of an engine failure

Engine surge effects

During the investigation, detailed information on the possible adverse structural and systems consequences on the aircraft and engines of an engine surge was sought from the aircraft and engine manufacturers. Their experience indicated that a surge that did not self-recover was likely to cause damage to the engine. This could include contact damage between compressor rotor and stator blades due to forward displacement of the rotor, leading to bent or cracked blades, detachment of parts of the compressor liner and possibly overload damage to engine bearings or bearing mounting structure. With some standards of fuel control system, turbine over-temperature damage could also occur.

Testing had shown that the loads on the engine due to a surge were relatively low compared to the design case of detachment of a fan blade; significant damage to the engine structure or its mounts would not be expected. The experience gave no indications that engine rotor blade rubbing had caused a fire hazard or that there had been a significantly increased overall probability of an engine internal fire or an engine bay fire following a surge. Neither were there signs, for aircraft configured similarly to the B747, that the operation of other engines had been affected, either from the surging engine or because of intake flow distortion caused by the surge or by the resultant aircraft yaw.

Clearly a surge would result in a loss of thrust and in thrust asymmetry. However, the engine manufacturer, in conjunction with the CAA, had conducted a risk assessment, which had also considered the risk of the same event occurring at the same time, on the same aircraft in more than one engine. The conclusion reached was that an engine surge is not hazardous. Following any subsequent shutdown of the engine, the output of bleed air, electrical and hydraulic power from the engine would be affected in certain flight conditions. In order to meet certification requirements for multi-engined public transport aircraft, the loss of an engine at the most adverse point is a design case that is catered for by redundancy. The B747 has an appreciable level of systems redundancy and no evidence was found to suggest that the aircraft systems would be affected by the loss of an engine. The principal effects on the aircraft would be in terms of performance penalties, with altitude capability reduced by around 5,000-8,000 ft and fuel consumption increased by around 8% at normal cruise speed.

Effects of extended continued flight

Detailed information on the possible adverse consequences of a long period of flight with a damaged engine that had been shutdown was sought during the investigation. The engine manufacturer noted that engine certification regulations generally did not require a prolonged windmilling to be demonstrated and this was the case for the RB211-524. However, the qualification testing for the type had included 3 hours of engine windmilling operation, related to the 180 minutes Extended Twin Operations (ETOPS) clearance, with no bearing damage expected. In accordance with this, the manufacturer's Maintenance Manual permits an engine to be ferried, whilst windmilling, with no restriction except with relation to FAFC low temperature limits. In response to operator inquiries about the effects of windmilling after the loss of engine oil, the manufacturer had issued a Notice To Operators (NTO) 421 on 25 July 1991. This concluded that:

> *'windmilling the engine for lengthy periods without engine oil does no harm to the bearings within that engine. In engine terms therefore, a flight may continue after in-flight shut down for oil loss. Should an Operator nevertheless wish a flight to return or divert in such circumstances, this remains an airline decision based upon commercial/operational considerations.'*

While these observations relate to an undamaged engine, the manufacturer did not foresee further major damage resulting from windmilling an engine with damage similar to that sustained by G-BNLG's No 2 engine for a period of 12 hours or more.

The possibility of engine seizure was considered, although this is reportedly a rare occurrence. The aircraft manufacturer noted that seizure at full power had been a B747 design case and that, in the unlikely event that windmilling caused additional engine damage that led to a seizure, no hazardous effects would be expected. A seized engine would be easily identifiable by the flight crew; the relevant QRH procedure, 'Severe Engine Damage', requires a landing at the nearest suitable airfield.

Similarly, it was considered that the vibrational stresses associated with a windmilling engine that had been damaged would be relatively low compared to those generated in other design cases, such as high power operation with an IPC rotor blade detached. The engine manufacturer did not anticipate hazardous effects from prolonged windmilling of an engine that had been damaged during a surge event and then shutdown.

As a 4-engined aircraft the B747 is designed and certificated to tolerate the loss of a second engine following an initial IFSD, without losing essential systems or necessary performance capabilities. The likely effects on systems would include the need to shed non-essential electrical loads, such as galleys, and to limit bleed air supplies in order to maintain adequate performance from the operating engines. There would also be a loss of the auto-land capability with two engines inoperative on one side of the aircraft. Aircraft performance implications would include a substantial further loss of altitude capability, but it is intended that route planning after the first IFSD would cater for this eventuality. The probability of the loss of a third engine, during the diversion that would subsequently follow the second engine loss, is considered below.

Loss of engine power

Modern public-transport aircraft design has included target maximum rates for engine failure and IFSD in order to achieve an acceptably low risk of a potentially catastrophic loss of aircraft propulsion. For design and certification a risk level of "Extremely Improbable", or 1×10^{-9} per flight hour, is generally used.

Assessments have been particularly focused on ETOPS and on the allowable flight time of the planned route from the destination or a suitable diversion airfield. In this case the intention is, following the loss of an engine, to maintain an acceptable risk of failure of the second engine from an unrelated cause during the diversion. Probability calculations allow for variation in IFSD rates with the level of engine power set (lower rate than average for cruise power and higher for maximum continuous power). The current internationally accepted guideline in order to maintain 180 minutes ETOPS status is in the order of 0.02 IFSDs per 1,000 engine flight hours.

Similar assessments have been extended to 3-engined and 4-engined aircraft. A particular case for a 4-engined aircraft is where, after an initial engine failure and IFSD, the flight is continued until a second engine failure, at which point a diversion and landing is carried out. For comparison, information from the aircraft manufacturer indicated that the average IFSD rates required to achieve an Extremely Improbable risk level for catastrophic loss of propulsion were as follows. These were based for the purpose of the assessment on a planned flight time of 20 hours and a maximum diversion time of 10 hours:

Number of Engines	Action After Initial IFSD	IFSD Rate -ISFDs/1,000 Engine Hours
4	Diversion	0.11
4	Continuation until 2nd IFSD then diversion	0.09

Information from the engine manufacturers indicated that the average IFSD rate achieved in revenue service with the type of engines fitted to G-BNLG for the 12 months up to June 2005 had been 0.0073/1,000 engine flight hours.

Operational Policy

Flight Continuation

The aircraft manufacturer did not provide guidance as to the acceptable period of continued flight following an IFSD. The crew was subject to the operator's written policy for flight continuation which was that, once certain considerations have been satisfied, the flight should continue to destination or to an operator-served destination as close as possible to it. This policy had been approved by the UK CAA. The following factors were to be reviewed before making the decision to continue:

> 1. *The circumstances leading to the engine failure should be carefully considered to ensure that the aircraft is in a safe condition for extended onward flight.*
> 2. *The possibility of a second engine failure should be considered. This would require evaluation of performance considerations, diversion requirements and range and endurance on two engines.*

The USA Federal Aviation Regulations (FAR Part 121.565) requires a landing at the nearest suitable airport following an engine failure or IFSD, except for an aircraft with three or more engines. In this case, the commander 'may proceed to an airport he selects if he decides that this is as safe as landing at the nearest suitable airport', having considered a number of factors. These included the nature of the malfunction and possible mechanical difficulties, fuel requirements, weather, terrain and familiarity with the chosen airport. The commander is required to keep ATC informed and the operator is required to inform subsequently their airworthiness authority of the event.

As part of this investigation a review was also made of other UK and overseas operating companies to determine the guidance given to their crews in the event of an engine failure on a 4-engined aircraft. One operator required that the aircraft land at the nearest suitable airport. Another had no policy and left it as a commander's decision. One operator required the aircraft to return to the airfield of departure if the engine failure occurred prior to reaching cruise altitude and the conditions at that airfield were suitable; otherwise, the commander could continue to an airfield of his selection. Three other operators had policies similar to that of G-BNLG's operator. All of the continuation policies emphasised that any continuation was dependent on the aircraft being in '*a safe condition for flight'*.

Three-engine operations and fuel management

Following the incident involving G-BNLG, the operator issued Operational Safety Notice (OSN) 06/05 on 23 February 2005 on the subject of 'Three Engine Operations and Fuel Management'. This OSN acknowledged the differences in fuel management following an IFSD and provided guidance to crews. Thereafter, the operator issued a Flight Crew Notice (FCN) 20/05 on 7 June 2005, which introduced the use of the three-engine ferry procedure of anticipating a fuel imbalance. However, on 5 September 2005, after further discussion with the airframe manufacturer, the operator withdrew this FCN and instructed all crews to follow the manufacturer's standard fuel handling procedures.

Other incidents

Since April 2001 this operator has recorded 15 incidents with the B747 where an engine has been shutdown and the flight continued. Over the same period, two incidents involving an IFSD each resulted in a diversion. One of these involved a fuel leak and the other involved an engine reverser unlocked indication.

The engine manufacturer provided statistics showing that, from 1989 to May 2005, there had been 389 surge events from all causes for the RB211 524G2 and 524G2-T engines. The worldwide fleet size was 603 with a total engine operating time of 26.4 x 10^6 hours. Of the 389 surge events, 57 resulted in an abandoned takeoff and 65 resulted in an IFSD; of these 54 were subsequently removed due to damage. The manufacturer considered that prolonged windmilling may have caused additional damage in two of the cases, both LP compressor fan blade failures, but in both cases a diversion had been carried out due to significant vibration.

Flight Recorders

General

The aircraft was equipped with a 25 hour duration flight data recorder (FDR) and a thirty minute cockpit voice recorder (CVR). The CVR did not assist in this investigation as the approach and landing phases had both been overwritten prior to electrical power being isolated from the CVR. The aircraft was also equipped with a data management unit (DMU[1]) which recorded additional flight data on to an optical quick access recorder (OQAR[2]).

Following the replay of the FDR, it was found that just over three hours of data had not been recorded by the FDR, which included the first hour and fourteen minutes of the incident flight. The QAR data was successfully replayed and provided data for the entire flight.

The FDR did not record individual fuel tank quantities; however it did record the total fuel quantity. Individual fuel tank quantities were provided by the QAR data, as was the sequence of events during the take-off phase, when FDR data was not recovered.

Data recorded during the flight

The aircraft took off at 0524 hrs with a total fuel quantity of 119.2 tonnes. Nine seconds after takeoff, at 296 ft radio height, the No 2 engine N1 shaft speed reduced from 102%, coincident with an increase in the EGT. Four seconds later the position of the No 2 engine throttle reduced. However, the EGT continued

Footnotes

1 Teledyne Controls DMU. The DMU was a non-mandatory acquisition unit that was programmed by the operator. One of its functions was to record flight data onto a quick access recorder for the purpose of supporting a flight data monitoring (FDM) program.

2 Penny and Giles Aerospace QAR. A non-crash protected recorder that utilised a removable magneto-optical disk for the purpose of recording data.

to increase until it peaked at 1,172° C. As the throttle reached the idle thrust position, the N1 shaft speed decayed to approximately 35% and the EGT then reduced. The aircraft continued the climb to 5,000 ft. Over the next two minutes the No 2 throttle position increased and subsequently reduced for two short durations; the No 2 engine was then shutdown at 0529 hrs. At 0541 hrs the aircraft commenced a climb to FL 270, which it reached at 0606 hrs with a total fuel quantity of 106.7 tonnes.

The main tank fuel quantities prior to the top of descent until the landing are depicted in Figure 4. At 1513 hrs (Figure 4, point A) whilst at FL350, the total fuel quantity was 11 tonnes. The stabiliser, and both reserve fuel tank quantities were at zero with the centre tank at 0.2 tonnes and the main fuel tank quantities for No 1 to No 4 tanks were: 2.6 tonnes, 3.2 tonnes, 3.1 tonnes and 1.9 tonnes respectively. At 1532 hrs (Figure 4, point B), with a total fuel quantity of 8.1 tonnes, a descent to FL290 was initiated; this altitude was maintained until 1537 hrs when the final descent was commenced.

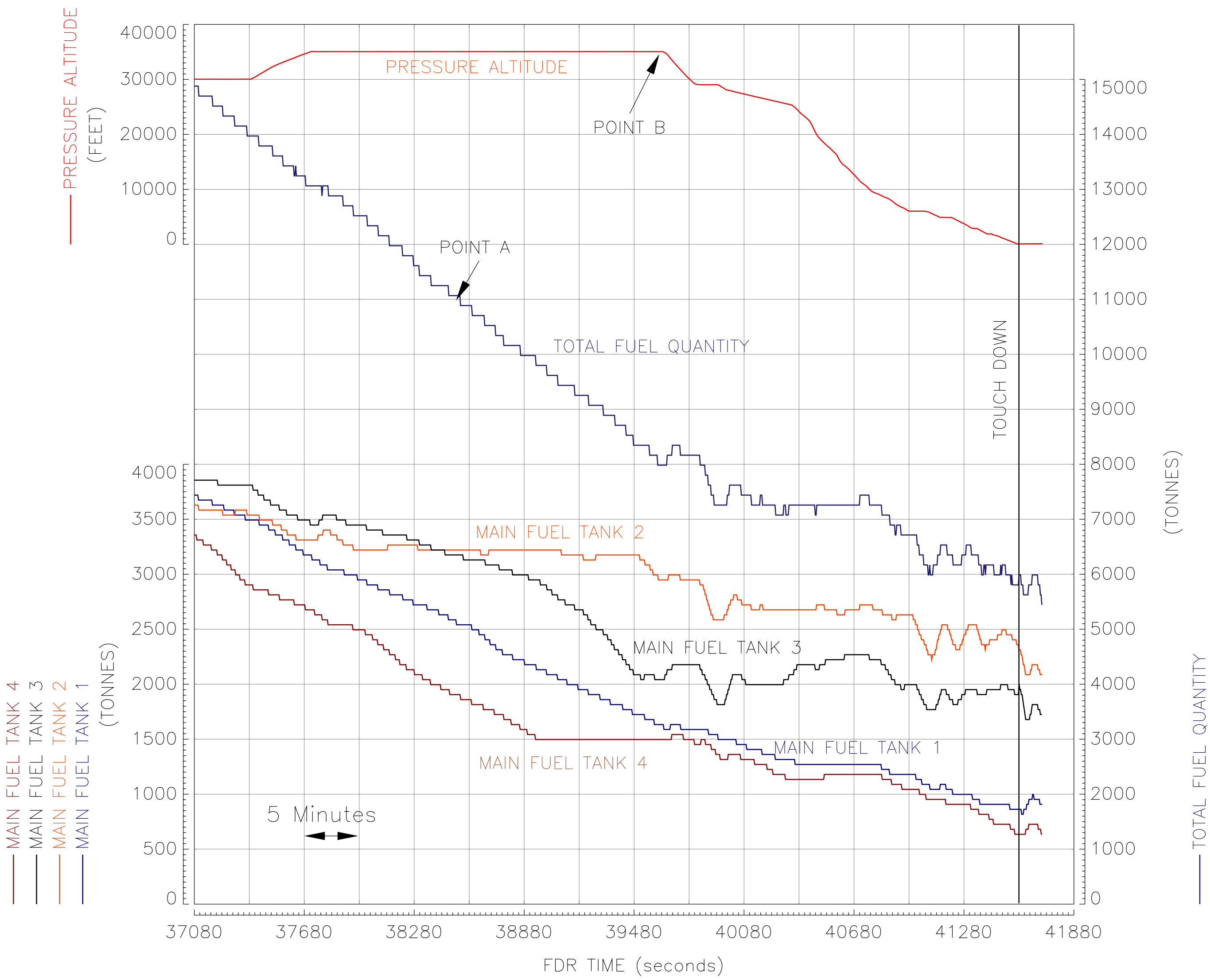


Figure 4

Salient FDR Parameters
(Incident to G-BLNG on 20 February 2005)

Touchdown occurred at 1604 hrs when the total fuel quantity was 5.8 tonnes. The fuel distribution across the No 1 to No 4 main fuel tanks was: 0.9 tonnes, 2.4 tonnes, 1.9 tonnes and 0.6 tonnes respectively. The FDR stopped recording at 1617 hrs when the aircraft was shutdown.

FDR data recovery

Recording overview

The data was recorded onto eight tracks of a magnetic tape. Each track was no less than three hours and eight minutes in duration, ensuring a minimum of 25 hours was recorded. The tracks were written sequentially; at the end of writing one track the FDR would automatically change direction of the tape and write data onto the next track. Odd numbered tracks, 1, 3, 5 and 7, were written to in one direction and even tracks, 0, 2, 4 and 6, the other.

The FDR utilised four heads, two erase and two for recording and replaying data. The heads were paired; one erase and one record and replay. One pair recorded odd and the other even numbered tracks. The erase head is physically positioned upstream of the record and replay head; during the recording process the track to be recorded on was erased prior to new data being recorded on it. Tracks should never have been erased simultaneously in normal operation.

Workshop test findings

The FDR was initially taken for testing to a Honeywell approved repair agent. The FDR was disassembled and the incident tape was retained by the AAIB. A test tape was installed and preliminary tests confirmed that the FDR was capable of writing data to all tracks.

The FDR was then taken to the operator's avionics repair facility. The operator had two test rigs, a Honeywell Acceptance Test Unit[1] (ATU) and a Honeywell FDR functional tester. The ATU provided a predominantly automated test of the unit, whereas the functional tester relied upon a predominantly manually operated test of the unit. The operator confirmed that the ATU was the preferred means of performing initial tests on an unserviceable unit and that it was also the preferred system when carrying out the final release to service test. The operator advised that the functional tester had been used rarely since the introduction of the ATU, which had been in use since about 1995. The component maintenance manual (CMM) also provided details of two alternative methods of testing that used automatic test equipment.

The FDR was first tested using the ATU which reported no faults with the unit. The FDR was then connected to the functional tester and the unit was configured to record test data onto tracks 4 through 7. When the tracks were replayed, data was recovered from all tracks, except for track 6, which had no data recorded on it. Additional tests were performed confirming that when data was being written to track 7 the data on track 6 was being simultaneously erased.

The fault was traced to the distribution board. The distribution board forms part of the crash protected tape transport assembly. Part of its function is to provide an interconnecting point between the four heads and the FDR's circuitry that was external to the crash protected assembly. A short circuit, between terminals E48 and E49, was found on the underside of the distribution board (see Figure 5). The short circuit was made by a terminal attachment wire, from terminal number E48, becoming

Footnote

[1] Honeywell ATU: A PC-based system that performed tests under software control that enabled FDR's to be released to service. ATU part number 964-0434-042, utilising test software part number 998-1513-513.

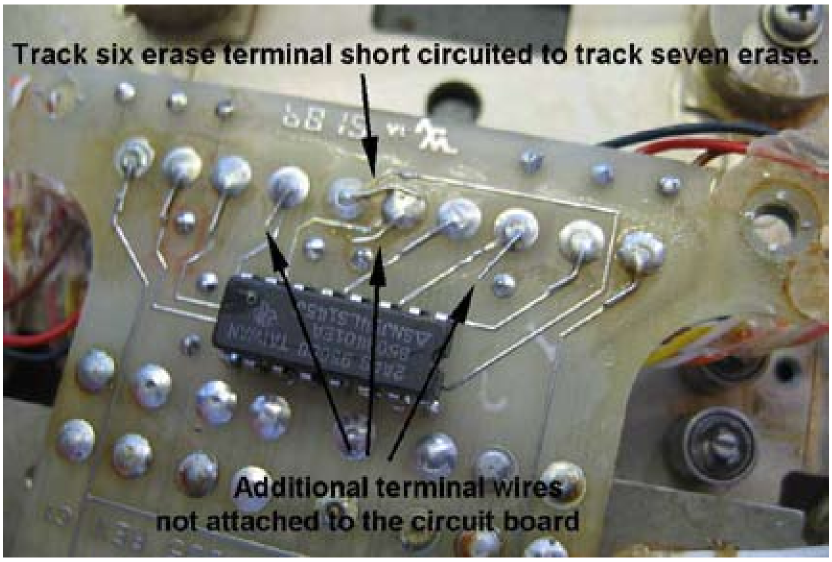


Figure 5 (left)

Faulty distribution board

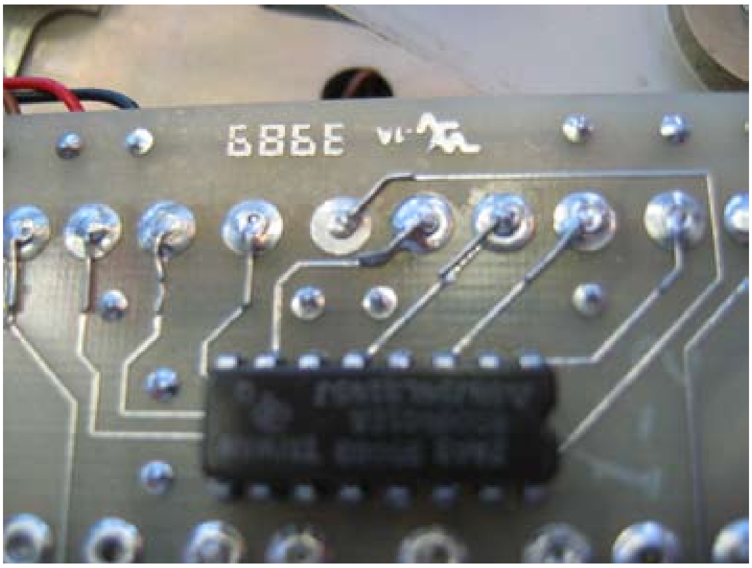


Figure 6 (right)

Correctly configured distribution board

detached from its correct position and becoming soldered to the adjacent terminal, E49. It was also noted that other attachment wires were in close proximity to adjacent circuitry. Figure 6 shows the attachment wires in the correct positions.

The result of the short circuit was that when track 7 had been recording, data previously recorded on track 6 would have been erased.

Workshop history

The workshop history of the unit was checked and it was found that all four heads had been replaced in September 2002. The operator's annual FDR replay records were inspected and it was found that the erasure fault had not been present prior to the replacement of the heads. Therefore it is considered most likely to have been introduced as a result of this maintenance work. The short circuit was not detectable until the board had been physically removed from the transport assembly. The operator advised that the board would not typically be removed when the heads were replaced as access to the solder terminals was adequate. The history also indicated that after the heads had been changed the unit had been to the workshop on three further occasions and released to service prior to the incident.

Built In Test Equipment (BITE)

When it was initially discovered that data was missing from the FDR, the aircraft technical records were checked to see if an FDR fault had been reported prior to, or during, the incident flight. No report had been made. The aircraft's Central Maintenance Computer records were checked and it had not received a fault message from the FDR systems BITE. During the workshop tests, the BITE did not indicate the presence of the fault.

FDR annual readouts

The operator, in accordance with the regulation, had performed annual readouts of the FDR. The last readout had been performed in January 2005. The operator had also retained two additional readouts, from April 2004 and August 2002. The data from August 2002 was inspected. No data was missing, although, data was found to be missing from the April 2004 and January 2005 readouts. The duration was consistent with the loss of one track in both readouts.

Subsequent FDR faults

Following the discovery of the short circuit fault, the operator carried out a review of its FDR annual readouts. The review identified an FDR of the same type which had data missing that was consistent with the loss of one track. The operator advised that the FDR passed the ATU tests but failed the functional tester release to service test. The FDR was disassembled at the operator's avionics repair facility and a short circuit on the underside of the distribution board was found between terminals E47 and E49. The result of the short circuit was that when track 6 had been recording, data previously recorded on track 5 would have been erased.

Operators FDR testing procedures

Following the discovery of the short circuit fault, the operator's avionics repair facility introduced a change to its testing procedures for the series 980-4100 model of FDR. The change required that a recording test be performed, using the functional tester, that would identify a failure in the erase function.

Analysis

Initial crew actions

The abnormal engine behaviour indicated to the crew shortly after takeoff and reported by ATC and passengers was symptomatic of an engine surge. The crew dealt with the situation by prioritising control of the aircraft, declaring an emergency and remaining close to the airfield while evaluating the situation. The check of engine behaviour on advancing the thrust lever and the subsequent IFSD were in accordance with the QRH.

Engine failure

It was clear from the evidence found during the investigation that the initial No 2 engine problem had been a surge. The degree of wear found to the front of the HPC casing birdmouth locating ring allowed radial displacement of the front of the HPC casing that would have increased the HPC rotor blade tip clearance and thus eroded the normal compressor stall margin. The further increase in clearance, that was a consequence of the loading and thermal effects when engine power was advanced, was predicted to peak around 50 seconds after setting take-off power. The surge that occurred just after G-BNLG took off was consistent with the effects of a compressor stall induced by the increase in HPC tip clearance from these combined effects.

This was the third case globally of an IFSD due to 'Birdmouth Wear Surge' and the first experienced by this operator. Birdmouth wear only affects some variants of the RB211 engine. While such a surge should not directly cause a hazard, the associated sudden loss of thrust and possible major engine damage made it an undesirable event, particularly since the engine manufacturer indicated that there was a propensity for the surge to occur close to the aircraft take-off point. However, the risk assessment carried out by the engine manufacturer, in conjunction with the CAA, prior to the publication of the Service Bulletin, had concluded that an engine surge is not hazardous. The modification action to rectify this problem, recommended by the engine manufacturer, had not yet been taken on this unit because neither the engine nor the module had visited an engine overhaul facility since new.

Engine fuel control

The major turbine damage sustained by the No 2 engine due to over-fuelling during the surge was a likely consequence of the FAFC behaviour when operating with the Issue 15 software used with this engine. The problem could be prevented by upgrading to Issue 16, and this had been recommended by the engine manufacturer "on an expedited basis." At the time of the incident approximately 80% of the operator's fleet had been modified, but this particular unit had not. This modification has now been incorporated across the entire RB211-524G/H-T fleet.

Flight continuation

Once the engine had been shutdown, the crew had to decide between the options of continuing to the original destination or diverting to a suitable alternate airfield, which could include the departure airfield. In the absence of any indications of damage, other than possibly to the shutdown engine, the commander assessed that an immediate, overweight landing was not required.

A decision to return to Los Angeles would have required approximately 70 tonnes of fuel to be jettisoned to reduce the aircraft's weight to below the normal maximum landing weight. As this would have taken around 40 minutes the commander decided to continue the flight and monitor the situation, as numerous suitable diversion airfields would be available near the route. The crew confirmed that the aircraft had sufficient fuel and performance to continue the flight safely, even considering the possibility of a further engine failure. They judged that the engine had not suffered damage likely to cause a seizure or other further significant damage. In addition, the manufacturer's QRH procedure for ENGINE LIMIT/SURGE/STALL did not require the crew to consider landing at the nearest suitable airfield.

In the continuing absence of indications of other abnormalities, the final decision to continue to their destination was in accordance with the operator's policy of continuing the flight provided the indications suggested that "the aircraft is in a safe condition for extended onward flight".

Systems operation should not be affected significantly following an IFSD; the level of redundancy would be reduced but the aircraft was designed and certificated to tolerate the loss of a second engine without losing essential systems. Previous experiences of the effects of engine surge suggest that it was likely that damage would be confined to the affected engine. Furthermore, the manufacturers did not foresee any problems with the extended windmilling of a damaged engine and previous cases had not resulted in significant additional damage.

A consideration, in relation to an extended continuation after an IFSD, would be the possibility of further engine failures. An indication of the relative risk for a 4-engined aircraft of continuation, compared to a diversion, was given by an assessment of the average IFSD rate required to achieve an equivalent Extremely Improbable risk of subsequent potentially catastrophic loss of propulsion in the two cases. This indicated a marginally higher rate for the continuation, but the calculated IFSD rate in both cases exceeded the rate that had recently been experienced in-service for G-BNLG's engine type. The crew's evaluation of the planned route showed that the further aircraft performance degradation resulting from a second engine loss would not be critical.

Thus, no evidence was found to show that the flight continuation posed a significant increase in risk, and the investigation established that the aircraft landed with more than the required minimum fuel reserves. However, there were indications of deficiencies in the training regarding fuel management provided to the flight crew. The three qualified pilots were not confident that all the fuel was available and their difficulties with fuel management indicated that their knowledge of the fuel system with three engines operating was insufficient. The fuel balancing procedures used by the operator, while suitable for normal operations, was a factor in the diversion involving G-BNLG. Following the incident, the operator provided guidance to crews that was more extensive, whilst progressing discussions with the airframe manufacturer. This has resulted in the operator reverting to the fuel handling procedures recommended by the manufacturer.

The operator's continuation policy had been approved by the CAA and was similar to that used by other overseas airlines operating 4-engined aircraft. The investigation noted, however, that there was a variation in operators' policies varying from "land at the nearest suitable airfield" to no policy at all. With the introduction of public transport flights of up to 16 hours duration it is considered that clear guidance should be provided to operators on the possible consequences of continued operation following an IFSD, particularly when this occurs early in the flight. It is therefore recommended that the CAA and the FAA, in conjunction with other relevant agencies, should review the policy on flight continuation for public transport aircraft operations, following an in-flight shutdown of an engine, in order to provide clear guidance to the operators.

Aircraft fuel management

There had not been any malfunction of G-BNLG's fuel system. Following the point at which the main fuel tank contents had equalised, a balanced distribution between the tanks had been achieved over most of the subsequent flight by periodic use of the override/jettison pumps in Tank 2, in accordance with the operator's procedures. These pumps, with their higher output pressure, would override the main pumps in the outboard tanks and induce preferential engine feed from the inboard tank.

This facility was lost when fuel levels decreased below the inlet level for the override/jettison pumps and this was the point at which the distribution problems began. Thereafter, it would have been possible to induce preferential engine feed from an inboard tank by keeping both its main pumps running and shutting off both main pumps in the adjacent outboard tank, as shown during testing after the incident. However, the effectiveness of this procedure would not be readily apparent during descent, because of relatively low fuel consumption. Shutting off only one pump in the outboard tank was insufficient and an engine would tend to continue to feed from the outboard tank in this configuration.

Although the fuel system was fully described in the aircraft manuals, the operator's fuel balancing procedures were different from that of the manufacturer.

The crew had been using the override/jettison pumps to maintain fuel balance but these became ineffective towards the end of the flight. Thereafter, there was a reluctance to turn both main pumps off in a tank and a lack of confidence that this would be effective. There was increasing concern that they would not be able to keep the main tanks balanced and that some of the fuel might be unavailable.

A better understanding of the fuel system should have reassured the crew that fuel should have been available to all engines even with one tank empty. Nevertheless, the awareness of the apparent problem came at a time when the crew had made the decision to divert, had started the descent to Manchester and was therefore busy. If the crew had been in the habit of utilising the manufacturer's procedures for balancing fuel by only using the main pumps, it is possible that they would have become more confident with the procedure. Although the problem had not previously been encountered by other company pilots, the potential difficulties might have been foreseen by the operator. After the incident, the operator reverted to the manufacturer's fuel handling procedures.

The operator has a training programme for pilots who are qualified to carry out planned 3-engined ferry flights, the emphasis of which rightly concentrates on the takeoff. Additionally, all flight crews are subject to regular simulator evaluation of 3-engine handling. However, this later training is necessarily limited in time and crews are not normally subject to an extended period of 3-engine flight with the associated fuel balancing requirements. It is therefore recommended that the operator include relevant instruction on 3-engined fuel handling during initial and recurrent training.

Safety Recommendations

The following recommendations are made:

Safety Recommendation 2006-018

It is recommended that the Civil Aviation Authority and the Federal Aviation Administration, in conjunction with other relevant agencies, should review the policy on flight continuation for public transport aircraft operations, following an in-flight shutdown of an engine, in order to provide clear guidance to the operators.

Safety Recommendation 2006-019

It is recommended that British Airways include relevant instruction on 3-engined fuel handling during initial and recurrent training.

Response to Safety Recommendation 2006-019

British Airways has accepted this recommendation and has taken the following action:

The revised fuel management procedures have been incorporated into the relevant manuals and training courses. All Boeing 747-400 flight crew have received additional engine-out fuel management training as part of their regular simulator training. Three-engine fuel management, including low fuel quantity procedures, have been added to the recurrent training cycle.

Recommendations relating to the FDR

Reliable FDRs are an essential component of effective accident investigation and in order to address the anomalies found with the model of flight recorder fitted to G-BNLG the following recommendations are made:

Safety Recommendation 2006-022

It is recommended that the Federal Aviation Administration should require that Honeywell modify the appropriate Return to Service test procedures, to ensure the detection of a fault which prevents a series 980-4100 model of flight recorder from retaining the appropriate minimum duration of recorded data proscribed by regulation.

Safety Recommendation 2006-023

It is recommended that the Federal Aviation Administration should require that Honeywell modify the design and operation of its automated equipment used for testing the series 980-4100 model of flight data recorder, to ensure the detection of a fault which prevents such a model of flight recorder from retaining the appropriate minimum duration of recorded data proscribed by regulation.

Safety Recommendation 2006-024

It is recommended that the Federal Aviation Administration should require that Honeywell alert all users of Acceptance Test Unit part number 964-0434-042, utilising test software part number 998-1513-513, to make them aware that the equipment will not detect a short circuit fault between one or more tracks on the distribution board of the series 980-4100 model of flight data recorder.

Safety Recommendation 2006-025

It is recommended that the Federal Aviation Administration should require Honeywell to amend the Maintenance Manual for the series 980-4011 model of flight data recorder to include a specific inspection of the underside of the distribution board for the presence of short circuits and detached wiring following the replacement of components.

Safety Recommendation 2006-026

It is recommended that the United Kingdom Civil Aviation Authority should require that operators of United Kingdom registered aircraft, installed with the series 980-4100 model of flight data recorder, review the annual flight recorder readout records for those aircraft in order to determine compliance with the applicable requirements for duration of recording.

In order to ensure the detection of failures within any mandatory flight recorder installation, which prevent the minimum required duration of recording being retained, the following safety recommendation is made:

Safety Recommendation 2006-027

It is recommended that the Federal Aviation Administration, European Aviation Safety Agency and the United Kingdom Civil Aviation Authority should require that, as part of any flight recorder readout procedure mandated by regulation, an assessment is conducted to ensure that the quantity and quality of all data recovered from the FDR is correct for the data rate of the system and the recorder part number concerned.

INCIDENT

Aircraft Type and Registration:	Boeing 747-41R, G-VWOW
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	3 November 2005 at 0714 hrs
Location:	Runway 27R London (Heathrow) Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 20 Passengers - 348
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to lower side of engine pod
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	9,470 hours (of which 2,740 were on type) Last 90 days - 221 hours Last 28 days - 81 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft flew an approach to Runway 27R at London (Heathrow) Airport, whilst subjected to a crosswind component of approximately 30 kt from the left. A roll to the left immediately after touchdown was not detected by the handling pilot who was concentrating on selecting reverse thrust on the engines. This roll resulted in the left hand (No 1) engine striking the ground. It subsequently transpired that the crosswind component had reduced from 32 kt to 8 kt in the last 25 ft of descent prior to touchdown.

History of flight

The aircraft was flying a scheduled public transport flight from New York's John F Kennedy Airport to London (Heathrow) Airport (LHR). Prior to departure the flight crew had studied the weather forecast information, and in particular the landing conditions at LHR. The forecast indicated that LHR would be subject to a strong southerly wind with a high probability of heavy rain showers. During the cruise the flight crew updated themselves on the LHR forecast and actual weather utilising the ARINC Communication Addressing and Reporting System (ACARS). When preparing for their approach, the crew received the LHR ATIS which advised that the nominated landing runway was Runway 27L, the surface wind was 200°/12 kt and that windshear and severe turbulence could be expected on the approach. The commander, who was the handling pilot, briefed the first officer (FO) on the approach and mentioned that they could be landing on either 27L or 27R as both runways were commonly used for landing at their estimated time of arrival of 0710 hrs. He also commented that they were likely to encounter a significant crosswind on landing.

Whilst in the hold at the Ockham VOR, the Heathrow Director advised the flight crew that they would be landing on Runway 27R. During the subsequent ILS approach the FO appraised the commander of the crosswind and headwind components, read directly from the Flight Management Computer. ATC cleared the aircraft to land when it was at 1,400 ft and gave a surface wind of 210° at 18 kt; this was the wind automatically averaged over a 2 minute period. The autopilot and autothrust were disengaged at 1,350 ft, at which time the crosswind component was 28 kt from the left. The crew experienced windshear at this point, with a variation in IAS of ±25 kt. The touchdown appeared normal to the flight crew and the speedbrakes deployed automatically, followed by the commander's selection of reverse thrust on all engines. The commander reported that he found operation of the thrust levers slightly awkward as he was relatively inexperienced in operating from the left hand seat. Neither of the pilots was aware of any engine to ground contact.

As the aircraft landed, the flight crew of another aircraft on the ground observed the landing aircraft's left side outer engine contact the runway, and reported this to the ATC ground controller. When the aircraft had decelerated to approximately 60 kt during the landing roll, the ATC tower controller transmitted "WHEN YOU LANDED YOU IMPACTED YOUR LEFT HAND I THINK IT'S THE NUMBER ONE ENGINE COWLING ON THE RUNWAY". The aircraft was then inspected by the AFRS before taxiing to a remote stand where the passengers disembarked without further incident.

Aircraft examination

Examination of the aircraft showed an area of scraping on the underside of the No 1 engine nacelle. The nacelle is made up of a fixed inlet cowl at the front and a fixed C-Duct cowl at the rear, with twin fan cowl doors in between. A sump for waste fluids from the engine, located in the bottom of the nacelle at the aft end of the fan cowl doors, has an overboard drain mast that protrudes below the doors. The damage consisted of longitudinal scraping of the aft part of the inlet cowl, the lower edges of the fan cowl doors and the forward part of the C-Duct cowl, together with slight local deformation of a bulkhead at the aft end of the inlet cowl. In addition, the drain mast on the bottom of the sump had been partly abraded away, and the sump, together with some of the associated pipelines, had suffered local deformation. The engine was not damaged and no fluid release occurred. Inspections to identify runway scrape marks were necessarily brief, as it was not considered appropriate to impose major delays on runway operations; no marks were located.

Tyre pressures and landing gear shock strut pressures and extensions were checked and the deployment sequence of speedbrakes, with and without roll control inputs present, was checked using video of the sequence with the aircraft stationary on the ground. No anomalies were found.

At the time of the examination, with the aircraft lightly loaded (no payload, 18,100 kg of fuel) and supported on its landing gear, the ground clearance of the outboard nacelles averaged 75 inches (1.9 m). Information from the 747-400 Flight Crew Training Manual indicated that, with the engine type fitted to G-VWOW, nacelle ground contact would occur with the combination of aircraft pitch and roll angles shown in Figure 1. The graph related to a situation with relevant main landing gears in ground contact, with shock struts compressed, and the aircraft pitched about the body gear and rolled about a wing gear. It applied to a 'Normal Landing' situation and it was clear that changes in wing bending due to factors such as inertial loading and lift reduction on spoiler deployment could lead to significant variation in the roll angle at which nacelle ground contact would occur. The nacelle profile differs somewhat for the two other engine types that can be fitted to the B747-400 and it was noted that with one of these types the roll angle required for outboard nacelle ground contact at a given pitch angle can be up to 1° lower than shown in Figure 1.

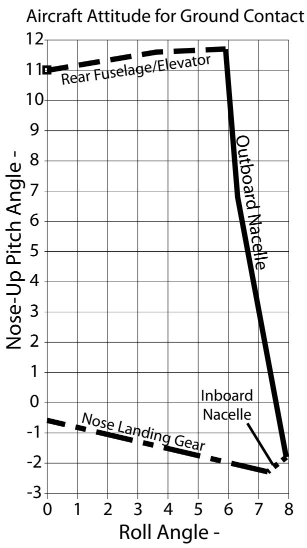


Figure 1

Meteorology

An aftercast from the Meteorological Office stated that a low pressure system centred over Ireland was feeding a fresh to strong unstable south-westerly flow over south-east England. This was reflected in the LHR 0001 hrs TAF which forecast that the surface wind between 0600 hrs and 0900 hrs would become 190° at 22 kt gusting to 35 kt, with the possibility of heavy rain showers and cumulo-nimbus clouds. A meteorological report taken at LHR 6 minutes after the incident measured the surface wind as 210° at 23 kt gusting to 36 kt.

During the final approach, the first officer was reading out wind data derived from the aircraft's inertial system which indicated a rapid reduction in crosswind component as the aircraft entered the flare. Data from the aircraft's Quick Access Recorder indicated a 32 kt crosswind component at a height of 24 ft agl reducing rapidly to an 8 kt crosswind component at mainwheel touchdown.

Air Traffic Control

In order to minimise disturbance to local communities, LHR operates a system of alternating the landing runways on a daily basis as laid down in the Manual of Air Traffic Services (MATS) part 2. Following the normal sequence of alternation, the landing runway in use on the morning of this incident was Runway 27R. It is widely accepted however, that significantly more turbulence is experienced, on the final approach to Runway 27R (with a southerly wind) than on Runway 27L. The UK Aeronautical Information Publication (AIP) contains the following warning for LHR:

> *Pilots are warned, when landing on Runway 27R in strong southerly/south westerly winds, of the possibility of building-induced turbulence and large windshear effects.*

At 0602 hrs, in response to several requests from landing aircraft, the Operations Duty Manager at LHR approved the use of Runway 27L as the landing runway. Arrival aircraft crews listening out on the LHR Director frequencies after this time would not have been aware of the reasons behind the runway selection, and this was the case for the incident aircraft crew.

At 0529 hrs, the LHR Visual Control Room supervisor had approved Tactically Enhanced Arrival Measures (TEAM) operations. These measures can be implemented during periods of significant airborne delays and involve landing aircraft on the departure runway in addition to the nominated landing runway in order to reduce these delays. The aircraft involved in this incident landed on Runway 27R (which had become the departure runway after the change in the nominated landing runway) under TEAM operations.

Flight Data Recording

Data from the Flight Data Recorder (FDR) and Quick Access Recorder (QAR) were successfully recovered. A time history of relevant FDR parameters for the final approach and landing roll is shown in Figure 2. It can be seen that, up to about 6 seconds before touchdown, the recorded wind direction was generally from the south (actual direction about 200°), with a windspeed that varied from about 15 to 30 kt. Right rudder pedal was applied about 6 seconds before touchdown. The recorded QAR windspeed reduced to about 8 kt just before touchdown. These wind parameters were derived from inertial navigation system data. The aircraft appears to have touched down with a small amount of left bank (about 2°) at about 147 kt. After touchdown, there was a rocking motion in roll with a period of about 4 seconds. The bank angle was generally about 2° to the left with an amplitude of about ±2°. After touchdown, left (into wind) control wheel was applied. About 5 seconds after touchdown, the bank angle reached a value of about 5.6° to the left. This coincided with the selection of the thrust reversers. It can also be seen that the control wheel was reduced to the neutral position when this bank angle was achieved, and that the bank angle returned to about zero. Thereafter, into wind (left) control wheel was applied for the remainder of the landing roll.

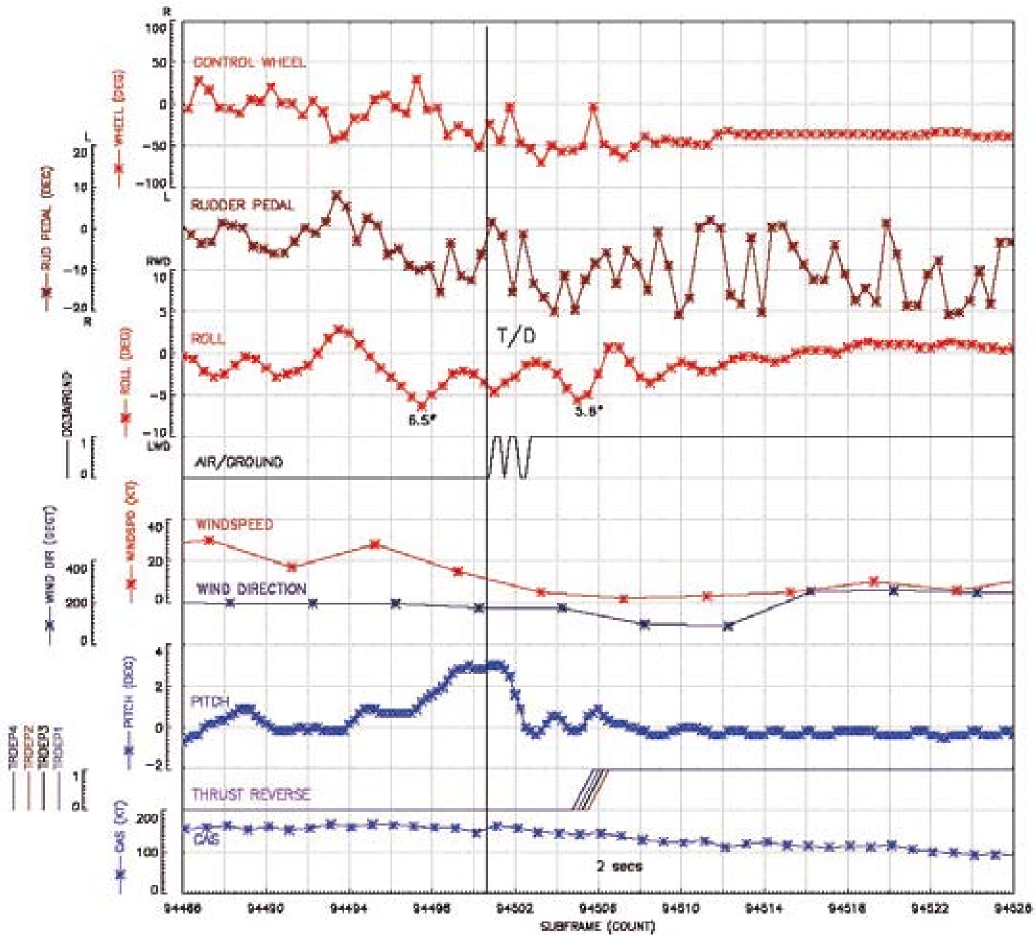


Figure 2

Relevant Flight Data Parameters

Crosswind landing technique

The Boeing 747-400 Flight Crew Training Manual presents three different crosswind landing techniques one of which is the 'de-crab during flare'. This technique is taught on this operator's conversion and command courses and is described in the Flight Crew Training Manual as follows:

> *The objective of this technique is to maintain wings level throughout the approach, flare and touchdown. On final approach, a crab angle is established with wings level to maintain the desired track. Just prior to touchdown while flaring the airplane, downwind rudder is applied to eliminate the crab and align the airplane with the runway centreline.*
>
> *As rudder is applied, the upwind wing sweeps forward developing roll. Hold wings level with simultaneous application of aileron control into wind. The touchdown is made with cross controls and both gear touching down simultaneously. Throughout the touchdown phase upwind aileron application is utilised to keep the wings level.*

This was the technique that the commander was seeking to employ during this incident. The operator uses the manufacturer's maximum crosswind guideline of 32 kt in wet conditions but impose a 20 kt crosswind limit under any conditions when the first officer is the handling pilot. The commander had flown 176 hours in command of this type of aircraft and had not landed with a crosswind greater than 20 kt. During the operator's command course, it is a requirement for the commander under training to show proficiency in crosswind takeoff and landing. The command course simulator syllabus also notes that:

> *'a combination of left and right hand circuits in day and night and including strong crosswinds should be flown'.*

After touchdown the speedbrakes, which are normally pre-armed, deploy to reduce the lift on the wings and thereby improve braking effectiveness. The Flight Crew Training Manual states:

> *'after touchdown, with the thrust levers at idle, rapidly raise the reverse thrust levers up and aft to the interlock position, then apply reverse thrust as required'.*

Discussion

Having received the weather forecast and airfield ATIS, the flight crew were expecting a significant crosswind component from the left during the approach and landing at LHR. The FO's readouts of the crosswind during the approach confirmed what the commander was expecting and experiencing. However, approximately six seconds prior to touchdown, as the commander commenced the 'de-crab during flare' procedure, the crosswind component reduced significantly. This occurred rapidly during a high workload period and is unlikely to have been fully assimilated by the commander. His initial input of left control wheel, in order to keep the wings level during the de-crab manoeuvre, led to a bank angle of approximately 6° to the left, possibly as a result of overcompensating for the expected crosswind. Although this was corrected prior to mainwheel touchdown, the bank angle was not stabilised and the aircraft continued to oscillate in roll, predominantly to the left, after the mainwheels had touched down. Left control wheel input was applied through the touchdown phase as would be expected with a crosswind from the left, and as recommended in the manufacturer's flight crew training manual. A small additional left control wheel input, coincident with speedbrake deployment, preceded a further roll excursion to the left. The pitch/roll angle combination recorded by the FDR did not reach the predicted attitude limits for nacelle ground contact but these would be affected by changes in wing bending. It was likely that this further roll excursion led to the engine pod contacting the ground. The commander commented that he did not detect this roll developing as he was concentrating on attempting to raise the thrust levers rapidly, as per the flight crew training manual, and he found some difficulty in doing so. It was also relatively dark outside and, together with rain on the windshield, this may have masked his perception of the changing attitude. He was also relatively inexperienced in the left hand seat on this aircraft, and the view over the reverse slope of the flightdeck coaming, compared to that from the right hand seat, may have hampered early recognition of an abnormal bank angle.

The investigation also considered the decision by ATC to direct this aircraft to land on Runway 27R. Earlier that morning a decision had been taken to change the landing runway from 27R to 27L in response to requests by aircraft commanders. Whilst a change of landing runway from 27R to 27L would be unlikely to have any effect on reducing the crosswind component, such a change would significantly reduce flight crew workload during a critical stage of the approach because it would reduce the turbulence encountered. Aircraft on the LHR Director frequencies at the time of this change were asked which landing runway they would prefer and most stated 27L. By the time that the incident flight crew were established with LHR Director, aircraft were no longer being given the option of which runway to use for landing; both 27L and 27R were being used for the landing runway as directed by ATC. This would appear to be inconsistent, since if a choice of landing runway is offered at the time of the decision to change the primary landing runway, then this option should be maintained until there is a significant change in circumstances.

Follow up action

The Operator

In response to this incident, the aircraft operator issued Notice to Aircrew 88/05. This notice re-confirmed the manufacturer's crosswind landing technique described earlier and also added:

> *'Reverse thrust should only be selected when the aircraft is firmly on the ground. Aileron control must not be compromised during reverse selection.'*

The aircraft operator has also included discussion, training and practice of crosswind landing techniques during the next recurrent simulator checks of all its Boeing 747-400 pilots.

Air Traffic Control

London Heathrow ATC Operations issued a Supplementary Instruction (SI 007/06) to MATS part 2 on 17 February 2006 which became effective immediately. This SI restricts the use of Tactically Enhanced Arrival Measures (TEAM) when wind conditions are likely to cause turbulence during final approach to Runway 27R except when there is an urgent operational requirement.

INCIDENT

Aircraft Type and Registration:	Boeing 767-200, N653US
No & Type of Engines:	2 GE CF6-80 turbofan engines
Year of Manufacture:	1990
Date & Time (UTC):	6 November 2005 at 0745 hrs
Location:	Final approach to Runway 26L, London (Gatwick) Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew -10 Passengers - 197
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Flying Experience:	22,334 hours (of which 4,048 were on type) Last 90 days - 198 hours Last 28 days - 38 hours
Information Source:	ATC report, operator's report, pilot's statements and flight data recorder

Synopsis

The aircraft landing gear selection was delayed until the aircraft was at 500 ft agl, and the final landing flap was not fully deployed until a few seconds before touchdown. At 500 ft agl ATC asked the crew to confirm that the landing gear was down and requested that the aircraft should carry out a go-around if it was not.

History of flight

The aircraft was at the end of a scheduled flight from Philadelphia, USA, to London (Gatwick) Airport. The descent was conducted with the autopilot and autothrust engaged with the commander, acting as the handling pilot, in the left seat. The crew were given radar vectors by ATC to intercept the final approach course for the Runway 26L ILS approach. As the aircraft descended through 750 ft agl the autopilot and then the autothrust were disconnected. The first officer (FO) selected the landing gear down at around 500 ft agl and once it was locked down, landing flap (flap 30º) was selected.

The tower controller saw the aircraft on short final approach and noticed that the landing gear was not down. He contacted the aircraft to advise the crew and gave an instruction that if the gear was not down they should go around. The crew replied that the gear was down and the controller then issued a landing clearance. The flap reached 30º shortly before touchdown and an uneventful landing was carried out.

Recorded flight data

A recording of the transmissions between the ATC tower controller and the aircraft was available for the investigation. The cockpit voice recorder information was not recovered, since it would have been overwritten during subsequent flights.

The flight data recorder was downloaded by the operator and data for the flight was recovered. A plot of selected parameters is included at Figure 1 and an expanded plot incorporating ATC recordings is provided at Figure 2. The significant parameters in the sequence of events are listed below:

— Flap 20 selected at 2,900 ft amsl

— Localiser established at 2,000 ft amsl

— Glideslope established and followed from 2,000 ft amsl

— At 740 ft agl autopilot disconnected

— At 711 ft agl autothrust disconnected

— At approximately 500 ft agl, gear lever moved down (this occurred between 2 and 4 seconds before ATC queried the gear position)

— At 420 ft agl, whilst gear doors were open and gear position disagreed with gear lever position, N653US crew responded to ATC confirming three greens

— At 229 ft agl, GPWS alert began

— Between 225 ft agl and 175 ft agl crew confirmed three gear down and locked. During this transmission the gear doors closed and gear position agreed with lever position (gear down)

— At 170 ft agl, flaps began to extend past 20º

— 5 seconds later at 90 ft agl flaps moved through 25º and GPWS alert stopped

— 7 seconds later, at 16 ft agl, flaps reached 29.7 deg (stopped)

— 9 seconds later, aircraft touched down

The recorded flight data indicated that there was a GPWS mode 4b alert active for a period of eleven seconds.

Meteorological conditions

The METAR at Gatwick, issued 25 minutes before the aircraft landed, contained the following information:

> *Surface wind from 190º at 11 kt, varying between 150 and 240º, visibility 10 km or greater, light rain, scattered cloud at 900 ft, and at 1,400 ft, broken cloud at 2,000 ft, temperature 13ºC, dewpoint 11ºC and pressure 1016 mb.*

Crew reports

There were three crew members on the flight deck for the descent and approach. The commander was the pilot flying (PF), the FO was the pilot not flying (PNF) seated in the right seat, and the in-flight relief officer (IRO) occupied the jump seat. The pilots were each interviewed by the operator two weeks after the event.

The commander recollected having briefed the crew for a visual approach to Runway 26. He recalled that he had disconnected the autopilot and flown manually from around 10,000 ft. He remembered that at some stage ATC had asked for speed control on approach. Then, descending through 1,000 ft with the flap set at 20º he had called "GEAR DOWN AND LANDING CHECKLIST", but the FO had apparently missed the call. He then called for flap 30º but the FO pointed out to him that the gear was not down. The commander

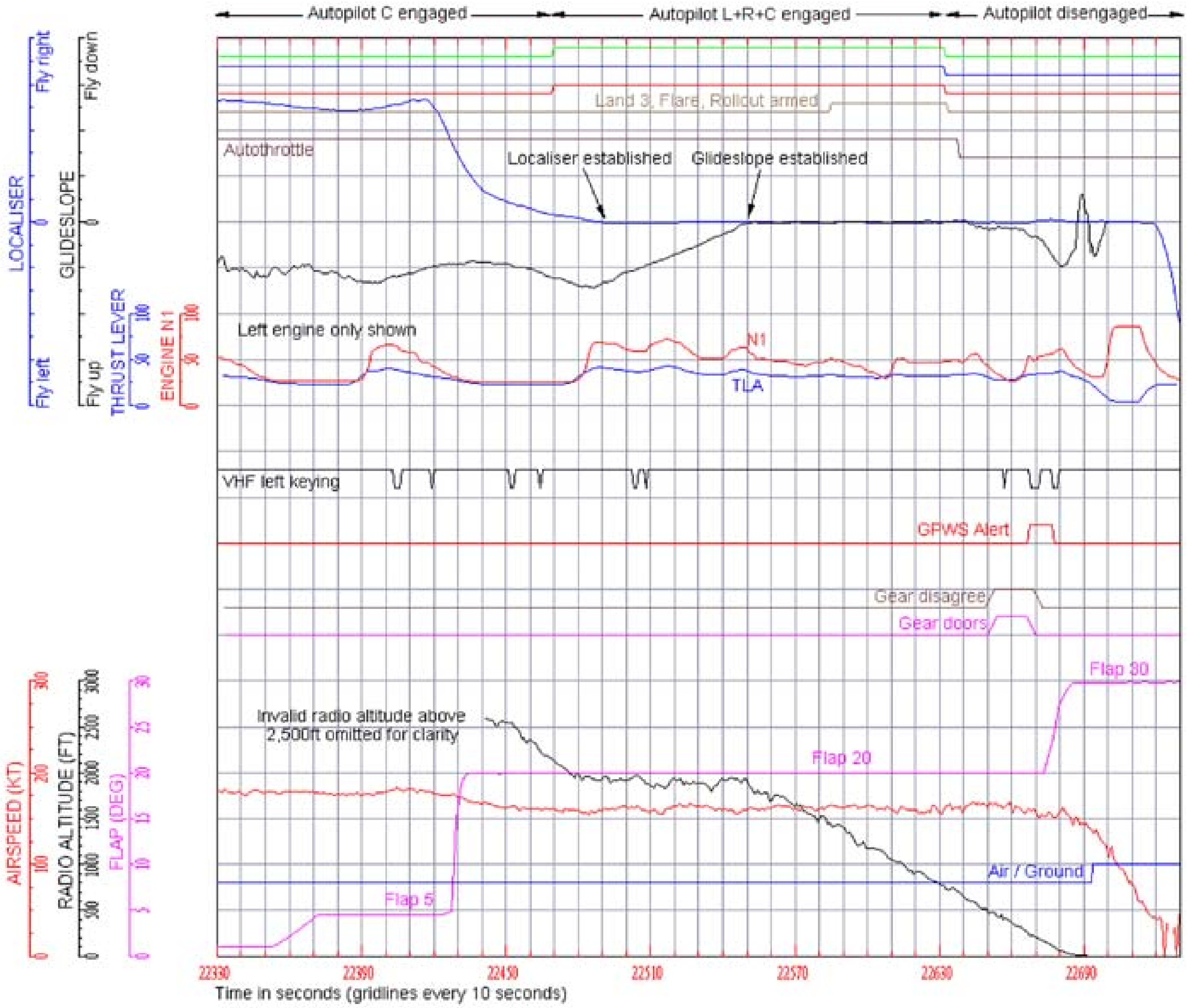


Figure 1

Selected parameters

asked again for the gear down and landing checklist. He remembered that ATC had contacted the aircraft during the approach and advised that there was no landing gear. He did not recollect hearing any warnings from the GPWS.

The FO remembered that as soon as he had put the gear handle down the tower had called to question the gear position. At that point two of the three green lights were on. When all three were green he confirmed to the tower that the gear was down. He believed that this had all been completed by 500 ft agl. He remembered that the tower had advised that if the gear was not down the aircraft should go-around. The FO thought that there may have been a momentary gear warning from the GPWS.

The IRO had been making an operational radio call to the ground handling agent during the first part of the approach. When he turned his attention back to the

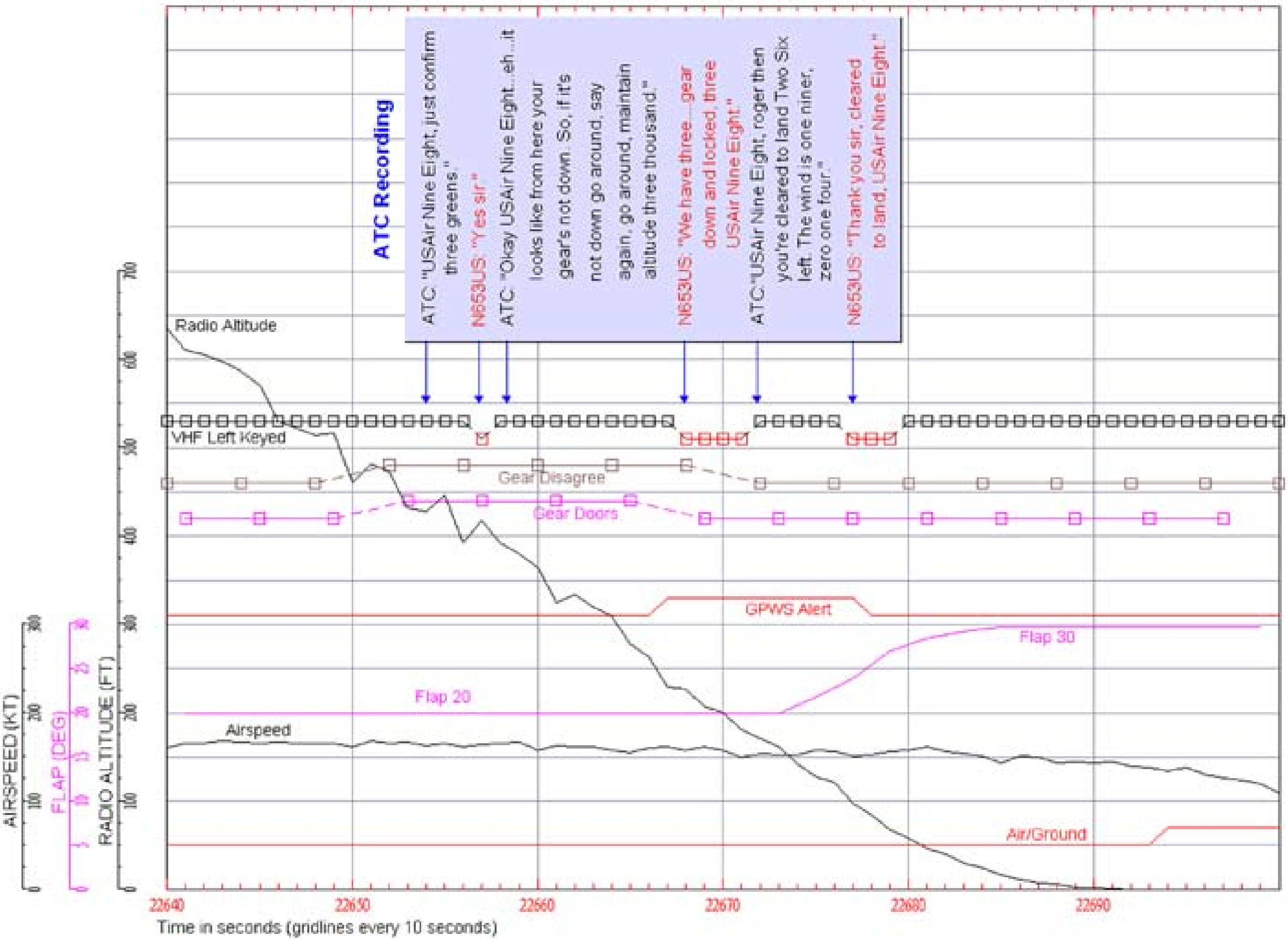


Figure 2

Expanded plot incorporating ATC recordings

approach he believed that the aircraft was intercepting the glideslope at around 1,000 ft. He thought he heard a 'TOO LOW FLAPS' and a 'TOO LOW GEAR' alert from the GPWS.

Operator information

The Flight Operations Manual (FOM) contains criteria to be observed for a stabilised approach and pilots are required to carry out a missed approach if these are not met. The FOM criteria were as follows:

> *'Flight parameters. Below 1,000 feet AFE[1], the aircraft is*
>
> — *on a proper flightpath (visual or electronic) with only small changes in pitch and heading required to maintain that path,*
>
> — *at a speed no less than Vref and not greater than Vref + 20 allowing for transitory conditions, with engines spooled up,*
>
> — *in trim, and*
>
> — *in an approved landing configuration.*

Footnote

[1] Above field elevation

at or below 1,000 ft. AFE	*IMC*	*the first pilot recognizing unstable condition calls "unstabilized" and the PF performs the go around.*
	VMC	*compliance with the flight parameters shown above (not rate of descent) may be delayed until 500 ft. AFE as long as the deviation is verbalized (e.g., "slightly high correcting", etc.).*

Analysis

A significant period of time elapsed before the crew were interviewed about the event, so it is understandable that their recollections were not accurate. The commander's recollection of events differed from what was recorded on the ATC tapes and the flight data recorder, in particular his recollections of his non-use of the autopilot and the stage by which the aircraft was fully configured for landing.

The approach until the point of glideslope intercept had apparently been normal and was flown with the autopilot and autothrust engaged. The company procedures required the aircraft to be configured for landing by 1,000 ft aal (or 500 ft agl in VMC and with a verbal recognition of the aircraft status), normal practice would be to select the gear down at or soon after the glideslope intercept at 2,000 ft amsl. There was no evidence of any external distraction or operational reason why this action was not completed at that time, and why the commander delayed his request for the gear until 1,000 ft was not explained. By asking for a selection at 1,000 ft, relatively late on the approach, there was little opportunity for any error/inaction to be corrected. The commander disconnected the autopilot at 740 ft agl to fly the aircraft manually which may then have distracted him from noticing that the gear was not down. The aircraft was not stabilised by 500 ft and at this point one of the crew should have called for a go-around. Once the gear was down, 30º landing flap was selected but, because of the time it takes to travel, it was not fully deployed until the aircraft was just above the ground. One purpose of a stabilised approach is that all the pre-landing actions are completed in good time thereby allowing crew members to focus on the landing task. This was not achieved on this occasion.

On the Boeing 767 aircraft the GPWS Mode 4a and 4b 'gear not down' discrete is based on the position of the landing gear lever. The landing gear lever was selected down as the aircraft descended through 500 ft Radio Altitude[1] (RA), thus the 'TOO LOW GEAR' part of the mode became inactive, regardless of the actual gear position. The flight data recorder showed that a GPWS Mode 4b alert was active for a period of eleven seconds, between 229 ft and 90 ft agl. During this time the aircraft was within the Mode 4b envelope but, because it was close to the internal boundaries related to airspeed, the exact audio callouts made in the flight deck were not definitely determined. The Mode 4b alerts would have been either one or both of "TOO LOW FLAP" and "TOO LOW TERRAIN".

It is of interest to compare the different recollections of each crew member with respect to the GPWS alerts. Typically a crew member who is busy and occupied with flying or other tasks may not necessarily hear an alert, but one who is not so absorbed will do so. In this instance there was a gradient from the commander, who

Footnote

[1] 500 ft RA is the height below which the Mode 4a 'TOO LOW GEAR' alert would activate

was particularly busy as he had just disconnected the autopilot, and who did not hear any alert, through to the IRO, the observing pilot, who heard two distinct calls. This demonstrates how important it is that that all crew members should respond to an alert and not to assume that it has been heard by another pilot.

The aircraft was configured for landing at a late stage of the approach, outside the operator's stabilised approach criteria, and this resulted in the final landing configuration being achieved only seconds before touchdown. The tower controller became concerned about the safety of the aircraft when the crew confirmed that the gear was down but he could see that it was not. He suggested that they should carry out a go-around if it was not down. He had made contact with the aircraft in time for corrective action to be taken, although in fact his intervention was unnecessary as the crew had already initiated the gear extension.

The reason for the late configuration of the aircraft was not determined but the safety net of stabilised approach criteria requiring a mandatory go-around was not effective. A GPWS alert was similarly ineffective in that it was either not heard or not responded to by crew members. Furthermore the crew could have been alerted by the concern demonstrated by the controller and his suggestion that the aircraft should go-around. Although a safe landing was made, established safety margins were compromised.

ACCIDENT

Aircraft Type and Registration:	Boeing 757-225, TF-ARD
No & Type of Engines:	2 Rolls Royce RB211-535E4 turbofan engines
Year of Manufacture:	1985
Date & Time (UTC):	20 August 2005 at 1210 hrs
Location:	Palma, Majorca
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 9 Passengers - 229
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the radome, landing lights and co-pilot's windscreen
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	8,000 hours (of which 4,000 were on type) Last 90 days - 130 hours Last 28 days - 60 hours
Information Source:	AAIB Field Investigation

Synopsis

Shortly after departure from Palma Airport, the aircraft entered a small but intense area of hail associated with a cumulo-nimbus cloud which was not identified on the aircraft's weather radar. Although the encounter caused damage to the aircraft's radome, landing lights and co-pilot's windscreen, the flight continued to its destination, London Gatwick, without incident.

History of the flight

The aircraft had departed London Gatwick airport at 0834 hrs that morning for a scheduled flight to Palma Airport, Majorca before returning to Gatwick. The flight was uneventful and the aircraft landed at Palma in good weather at 1020 hrs.

Following the turnaround, the co-pilot was to be the Pilot Flying (PF) for the return trip. Whilst the aircraft was on the ground, the weather deteriorated and a thunderstorm with heavy rain drifted over the airport. Departures were delayed and the Standard Instrument Departure (SID) for Runway 06R, the departure runway, had been cancelled with aircraft now being cleared to maintain runway heading to assigned altitudes to avoid the worst of the weather. TF-ARD was 'pushed back' at 1150 hrs, followed by an extended time to taxi to the holding point for Runway 06R because other aircraft departures were being delayed due to the thunderstorm. By the time the aircraft received its departure clearance, which was to maintain runway heading to 3,000 ft, the rain had stopped and other aircraft were departing with normal timed spacing. When the aircraft was lined up on Runway 06R, the checklist was completed and the weather radar was selected to ON. In accordance with Standard Operating Procedures (SOPs), the commander, as the Pilot Not Flying (PNF), had his Navigation Display (ND) set to Weather with a range of 20 nm selected and the radar beam tilted 5° up. The co-pilot had Terrain selected on his ND. The only weather returns displayed on the screen were green with no active cells showing.

The aircraft which departed ahead of TF-ARD was an A321, with the same departure clearance. The commander of that aircraft was the PF and also had his weather radar selected ON and set to 20 nm range. He recalled that, shortly after takeoff, there was an isolated, small, weather return at about 5 nm which he made a 10° turn to the right to avoid. He did not consider it very active but, in view of the recent weather, thought it prudent to take the avoiding action. When abeam that cell, another much larger and active cell was displayed at about 15 nm ahead, and he made a 50° avoiding left turn. This aircraft did not encounter any heavy rain, hail or severe turbulence during the departure or the climb to cruising level.

Having received take-off clearance, the co-pilot of TF-ARD carried out the takeoff and climbed on runway heading, in accordance with the departure clearance. The aircraft was in Instrument Meteorological Conditions (IMC) with no significant weather being displayed on the weather radar and, initially, no rain or turbulence was encountered. From the crew's recollection, at about 3,000 ft the aircraft encountered heavy hail which, although very short in duration, produced an extremely loud sound on the flight deck. The autopilot remained engaged and the PF continued the departure. The weather radar failed and the aircraft continued the climb in IMC without encountering further precipitation. The crew were aware that the aircraft had been damaged, as the co-pilot's windscreen was cracked but, on feeling the inside surface of the screen, the co-pilot confirmed that only the outer layer had suffered damage. With no weather radar and the windscreen damage not preventing further climb, the crew elected to continue to their destination rather than returning to Palma and risk encountering further severe weather.

During the flight to Gatwick the commander asked the cabin crew to inspect the engine nacelles and wing leading edges for evidence of damage, but none was apparent. Also, the flight crew could not hear any unusual noises on the flight deck that might have suggested severe damage to the radome, and there appeared to be no increase in the rate of fuel consumption. The aircraft made a normal landing at Gatwick, with the co-pilot as the PF, as he had adequate visibility through his damaged windscreen. The aircraft was taxied to a remote stand where the passengers were disembarked.

Weather

The synoptic situation at 1200 hrs showed an active cold front over Majorca, lying from Northern Italy to the Eastern Spanish coast, moving slowly southeast. Satellite pictures indicated a line of thick frontal cloud over Majorca which extended north-eastwards to the southern coast of France. A cumulo-nimbus cell was situated over the southwest of the island of Majorca in the vicinity of Palma Airport.

The Palma Airport Terminal Area Forecast (TAF) and Meteorological Actual Reports (METARs) covering the period of the flight were:

TAF

LEPA 200800Z 201019 33010KT 9999 FEW015 BKN050 TEMPO 1019 05008KT TEMPO 1019 5000 TSRA SCT020CB PROB30 TEMPO 1019 3000 TSGR

METAR

LEPA 201200Z 33008KT 1400 R24/P1500 TSRA FEW009 SCT020CB BKN035 20/18 Q1019 NOSIG

LEPA 201230Z 01006KT 320V060 6000 RA FEW008 FEW020CB BKN040 21/19 BECMG NSW

Aircraft Damage

Inspection of the aircraft confirmed that the outer layer of the co-pilot's windscreen had been cracked, both of the wing root landing light lenses had been shattered and that the radome had been severely damaged, with several large areas of material missing from its most forward region, Figure 1. Due to the length of flight, it could not be determined if the tears in the radome had been caused directly as a result of the hail encounter, or as a result of the aerodynamic loads imposed as the aircraft continued to Gatwick.

The radome is a fibreglass honeycomb structure, comprised of inner and outer skins, bonded to a honeycomb material between the skins, which provides structural rigidity. The outer skin had disbonded from the honeycomb layer over a circular area of some 60 cm radius, and aerodynamic loads had caused it to be deformed inward, which had prevented movement of the weather radar antennae. The antennae itself appeared to have been undamaged. The radome hinges, latches and fuselage location points were undamaged and the radome itself remained securely located.

The Boeing 757 windscreens are built up from several layers of toughened glass, interspersed with layers of a softer material intended to prevent complete shattering of the screen. The glass outer layer is non-structural and hence, if cracked or crazed due to, for example, impact damage, the overall strength of the screen is not compromised. The other glass layers provide the structural element of the windscreen. The outer pane of the first officer's windscreen was crazed; examination showed evidence of eight crack initiation points and in excess of 32 further impact points. Damage was limited to the outer ply and hence did not cause a reduction in the structural integrity of the windscreen. The commander's windscreen was not cracked and showed no evidence of impact points.

Three cabin window outer panes, adjacent to seats 19A, 23F and 24F were damaged. These windows consist of three panes, an inner non structural 'scratch' panel and a middle and outer structural pane. The outer pane is designed to be capable of carrying the maximum design fuselage pressure differential and the middle pane is designed to be capable of carrying 1.5 times

Figure 1
Damage to radome

the same pressure. This ensures that, in the event of either the middle or outer pane failing, the cabin would remain fully pressurised. The damage was restricted to the outer panes and consisted of a single gouge on windows 19A and 23F and two gouges on window 24F, all approximately four and five centimetres in length and two millimetres in depth. There was no evidence that the panes had cracked. The appearance of the gouges indicated that they had been caused by sharp edged objects, rather than by hail impact, and it is highly likely that these windows were struck by pieces of the shattered landing light lenses.

A further detailed examination of the airframe and engines revealed several small impact points on the fuselage, immediately aft of the radome, and on the leading edges of both wings and the horizontal and vertical stabilisers. All of the damage was within the limits specified in the aircraft's Maintenance Manual and did not require rectification action. The weather radar was functioned and found to be serviceable.

The radome, landing lights, passenger windows and the co-pilot's windscreen were replaced and the aircraft returned to service.

Flight Recorders

The aircraft was fitted with a 25 hour Flight Data Recorder (FDR)[1] and a Cockpit Voice Recorder (CVR)[2] of 30 minutes duration. The CVR recordings made at the time of the incident were overwritten with more recent information when the aircraft was on the ground after landing.

Examination of the data from the FDR for the flight showed nothing abnormal during the departure from Palma. The recorded vertical and longitudinal accelerations showed no change from their nominal values during the period of the incident. However, it was noted that the four samples per second sample rate for normal acceleration was only half that specified by JAR Ops Requirements. This matter is being investigated by the Icelandic AAIB.

Analysis

Given the weather conditions for the departure, the crew ensured that the weather radar was being used in accordance with the Standard Operating Procedures (SOPs). The FDR data did not show clearly where the hail encounter had occurred but the A321 commander and the B757 crew's recollection was that they both encountered the hail at an altitude of about 3,000 ft. This suggests that the small weather radar return observed by the A321 commander may have been the area of hail encountered by the B757. It is considered that the B757 probably did not fly through the larger, active storm cell, which the A321 commander turned to avoid. It is also possible that the hail was falling from the anvil of a cumulo-nimbus cloud, separated by some distance from the main cell. However, whilst the damage was relatively severe, the aircraft remained in a safe condition and was able to return to Gatwick. As noted by the cabin crew, there was no observable damage to the engine intakes or flying surfaces that could be seen in flight, and only the outer, non-structural, layer of the co-pilot's windscreen was cracked.

A major limitation of the aircraft weather radar systems is that ice crystals or hail may only produce small, or no, returns. This was a feature in a previous event reported by the AAIB (G-MIDJ, AAIB Bulletin 6/2004). Only rain or soft hail is detected and the intensity is displayed

Footnotes

[1] Honeywell Universal Flight Data Recorder UFDR: *Part Number 980-4100-DXUN, Serial Number 9763.*

[2] L-3 A100A CVR: *Part Number 93-A100-80, Serial Number 62388.*

as colours ranging from green (low intensity) to red (high intensity).

The UK Civil Aviation Authority have published an Aeronautical Information Circular (AIC) 81/2004 (Pink 66), entitled '*THE EFFECT OF THUNDERSTORMS AND ASSOCIATED TURBULENCE ON AIRCRAFT OPERATIONS'*, which sets out the limitations of, and recommended practices to be adopted when using, weather radar. Of relevance to this incident are the following paragraphs:

> *'Para 2.4.1*
>
> *Stability in the upper atmosphere results in the characteristic anvil shape of the spreading out of the top of the Cumulo-nimbus cloud and strong upper winds will often cause hail to fall from the overhang. Flight beneath the overhang should be avoided'.*

> *'Para 2.10.3 (b)*
>
> *Although wet precipitation is the most reflective of radar signals, other water products will reflect lesser amounts of incident radar energy. In descending order (ie from most to least reflective) these are: wet hail, rain, hail, ice crystals, wet snow, dry hail and dry snow.'*

Conclusions

The aircraft encountered a small but intense area of hail whilst in IMC during its departure from Palma. The weather radar was in use at the time in accordance with the Operator's SOPs but this did not detect the hail. Whilst the hail encounter resulted in severe damage to the radome and other aircraft components, the flight was safely continued to its destination.

ACCIDENT

Aircraft Type and Registration:	Boeing 777-236, G-ZZZC
No & Type of Engines:	2 GE 90-76B turbofan engines
Year of Manufacture:	1995
Date & Time (UTC):	10 January 2006 at 0840 hrs
Location:	London (Heathrow) Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 14 Passengers - 106
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to left wing tip
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	8,600 hours (of which 3,600 were on type) Last 90 days - 150 hours Last 28 days - 78 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and a detailed incident report from the aircraft operator

Synopsis

During the pushback from stand, the aircraft's left wing tip struck the right winglet of a Boeing 747-400 which was parked on the adjacent stand. The location of the stand necessitated a non-standard pushback procedure which potentially reduced clearance with aircraft on the adjacent stand, so additional staff in the form of wing / tail observers were required. During the pushback, ramp equipment at the edge of the stand interfered with the activities of the left wing tip observer who was distracted from his prime task of monitoring wing tip clearance. Although he signalled the driver to stop the pushback, there was insufficient time for the driver to stop his aircraft before it collided with the parked Boeing 747-400. A report by the aircraft operator made nine internal safety recommendations.

Description of the accident

G-ZZZC had been prepared for a departure from Stand 422 at Heathrow Airport's Terminal 4. The stand was situated at the head of the 'Victor cul-de-sac', which necessitated a pushback onto the taxiway centreline. The adjacent stand (Stand 423) was occupied by a company Boeing 747-400, which was correctly positioned on the stand. It was daylight, the visibility was good and the apron surfaces were dry.

The pushback team would normally consist of four members; the towbarless tractor (TBL) driver, the headset operator and two wing / tail observers. However, on this occasion only one observer had been allocated, due to staff shortages. The proximity of the head of the 'cul-de-sac' necessitated a modified pushback procedure. This entailed turning the aircraft tail to the right initially, as viewed by the TBL driver, then pushing the aircraft back to the rear of Stand 423 until there was sufficient room to reverse the turn. The tail was then turned to the left as the aircraft was pushed back onto the taxiway centreline in readiness for taxiing out of the 'cul-de-sac' (Figure 1). The specific duties of the observers were to ensure safe clearance of the left wing tip during the initial pushback, and then to ensure clearance of the tail from the blast screen at the 'cul-de-sac' head during the latter stages of the manoeuvre. Any hazard was required to be communicated directly to the TBL driver by the use of approved hand signals, and this requirement meant that the observers were to remain in direct sight of the driver at all times during the pushback.

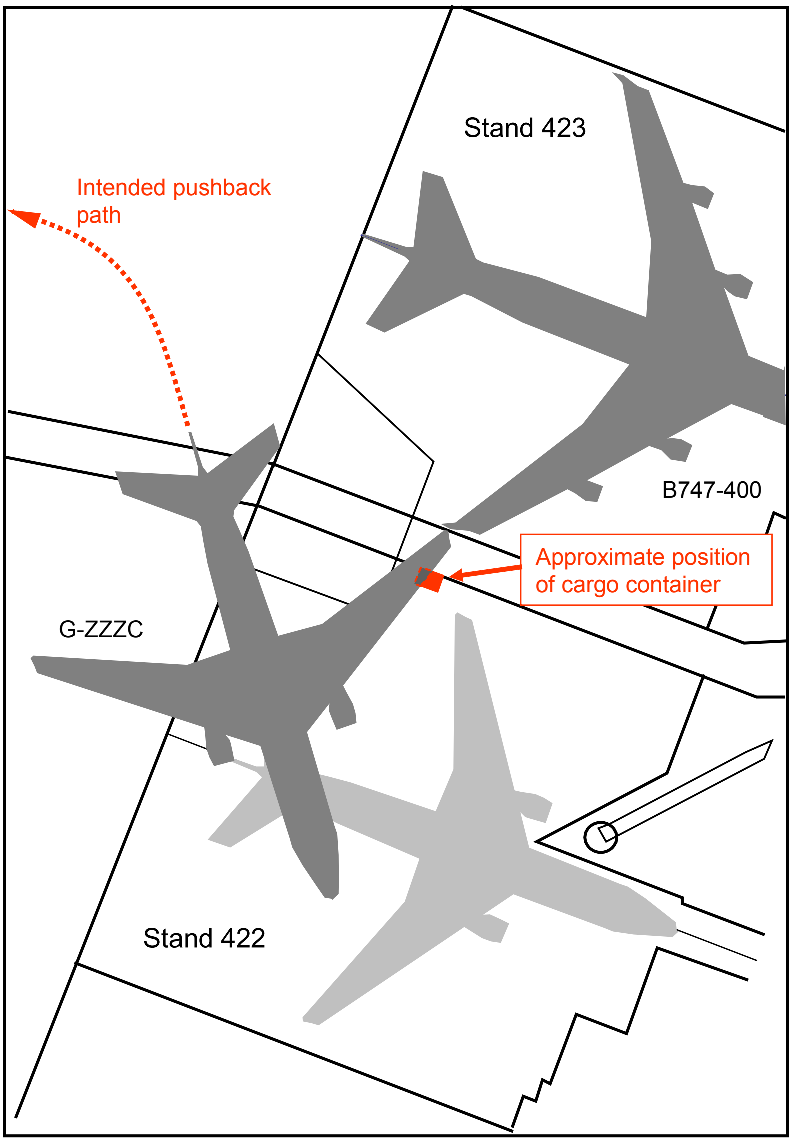


Figure 1

Aircraft positions at point of collision

It was common practice for aircraft cargo / baggage containers and their dolleys to be parked at the edge of the stand areas and in the clearway areas between stands. On this occasion, four container dolleys and one cargo container on its dolley were parked on the edge of Stand 422. The TBL driver and the headset operator had discussed the location of the container and dolleys, and had agreed they did not present a hazard to the pushback manoeuvre.

When ATC clearance for the pushback was received by the flight crew, only the TBL driver and headset operator were present, so there was a short delay to the departure before the third team member arrived. As he did so, he parked his vehicle in the interstand clearway area, made his way directly to an appropriate position to observe the left wing tip for the commencement of pushback and gave a 'safe' hand signal to the TBL driver. There was no discussion between the third team member and the driver or headset operator regarding the container and dolleys. The driver then commenced pushback, turning the aircraft so that it could be pushed back in a straight line behind the adjacent Boeing 747-400. The driver later considered that he might have oversteered the initial turn, but was conscious that the wing observer would warn him if there was insufficient wing tip clearance.

As the pushback progressed and the wing of G-ZZZC approached the Boeing 747-400, the wing observer found himself behind the container and may have been momentarily out of the driver's sight. As the wing observer moved around the container he continued to indicate a safe clearance by holding his arms out horizontally but shortly afterwards quickly changed the signal to an arms crossed 'stop' signal and shouted to the TBL driver. The driver saw the signal and stopped the pushback, but not before the left wing tip had struck the right winglet of the parked aircraft.

Damage to aircraft

The Boeing 747-400 right winglet was punctured by G-ZZZC's left wing tip, which suffered damage to three static discharge wicks and the navigation light assembly. Both aircraft were taken out of service for repairs.

Personnel information

All three members of the push back team were correctly trained and experienced in their respective tasks. Additionally, both the TBL driver and the wing observer were trained and experienced in each other's position as well as that of headset operator. All team members were within their company's working hours limitations and were fit for their duties. Both the driver and wing observer had received specific training with regards to operations from Stand 422.

Discussion

The overall plan for the pushback was in accordance with the company procedures for Stand 422, though these required that two observers be allocated to the manoeuvre. This requirement had been introduced after a similar accident in 2002.

The TBL driver had initially over-steered to the extent that the subsequent straight pushback took the aircraft on a collision course with the Boeing 747-400. Since this was a recognised risk with pushbacks from Stand 422, the driver was dependent upon the presence and effectiveness of the wing tip observer who would be expected to signal if clearance was inadequate. Prior to pushback, the headset operator had drawn the driver's attention to the container and dolleys, and together they had agreed that these did not present a hazard to the pushback. Although the items may have presented no physical hazard to the aircraft, they were situated in the general area that the wing observer would be required to walk across, at a time when his attention would be focussed on the wing tip. As such they did represent a hazard to the overall operation.

The wing tip observer, who had not been involved in the earlier discussion about the container, arrived very shortly before the pushback. In fact, it was only his arrival at the stand which was delaying the departure. It is unlikely that he had time to consider fully the significance of the container and dolleys, or appreciate that they could, at some point, impede him and obstruct his direct line of vision to the driver. However, once the pushback was under way he would have had the option of signalling a temporary stop to the driver whilst he negotiated the obstacles and re-positioned himself. It was as, or shortly after, the wing tip observer negotiated the obstacles that he became aware of the lack of clearance and signalled the TBL driver to stop. The signal was not given, or not noticed, in sufficient time for the driver to bring the tractor and aircraft to a stop.

It is likely that the presence of the container and dolleys in his path distracted the wing tip observer at a critical time from his primary task of monitoring wing tip clearance, and may have prevented the driver from seeing the 'stop' signal straight away.

Safety actions

In its report into the accident, the operator made nine internal safety recommendations with the aim of preventing a similar accident from happening again. All of the recommendations were accepted by their addressees.

Among the areas addressed by the recommendations were:

a. the provision of visual guidance to assist drivers with the initial turn from Stand 422,
b. adherence to the requirements for minimum numbers of team members for pushback from certain stands, including Stand 422,
c. the need for staff to arrive on stand with time to plan and execute their allocated tasks adequately, including the recording of times when staff are allocated duties,
d. the need for ramp equipment to be parked in designated safe areas, with particular emphasis on Stand 422 and other stands where wing observers are required.

ACCIDENT

Aircraft Type and Registration:	Cessna 421C Golden Eagle, N421CA
No & Type of Engines:	2 Continental TCM GTS10 piston engines
Year of Manufacture:	1976
Date & Time (UTC):	30 September 2005 at 1817 hrs
Location:	Northrepps Airfield, Cromer, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial to landing gear, engines, wings, and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	2,475 hours (of which 255 were on type) Last 90 days - 182 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation and video evidence provided by a member of the public

History of flight

Northrepps Airfield has a single grass runway, orientated 18/36, and 1617 ft (493 m)[1] long, with a down slope of 1.8% on Runway 18. On the day of the accident, the short grass was wet and an aftercast indicated that the wind at Northrepps was from approximately 210º at 10 to 13 kt. The pilot first flew an approach to Runway 18 and touched down close to the threshold; he subsequently reported that, looking at the slope of the runway ahead of him, he decided to go around and re-position for a landing on Runway 36, to take advantage of the up-slope on that runway.

The pilot stated that, during the approach to Runway 18, he had assessed that the braking effect of the wind would be insignificant in comparison to the braking effect that would be afforded by the uphill slope when landing on Runway 36. The pilot recalled seeing a "shortened" and "non-standard" windsock mounted on a caravan adjacent to the Runway 18 threshold, but he did not believe that it could be relied upon for an accurate wind strength determination. He did not recall having seen the airfield's other, larger, windsock.

The approach for a short field landing on Runway 36 was normal and the pilot closed the throttles just before

Footnote

[1] In this report, all distances are in feet, since the aircraft manufacturer's Flight Manual data is presented in feet.

the threshold. The aircraft touched down close to the threshold, and the pilot immediately retracted the flaps.

The pilot reported that he had lost two thirds of his touchdown speed by about the mid-point of the runway, and that the braking was within his expectations. He subsequently stated that he "seemed to get to a point… when I realised that I was effectively getting no braking at all from the wheels and the uphill slope had petered away"; he then experienced a sensation which he described as being similar to aquaplaning, with all braking authority seemingly lost.

The aircraft continued along the runway, crossed the grassed overshoot area, ran over an earth bank beyond the end of the runway and came to rest on a public road just north of this bank. The pilot shut the aircraft down and all three occupants vacated the aircraft without difficulty.

Video evidence

A member of the public recorded portions of the flight including both the touchdown and go-around on Runway 18 and the approach and landing on Runway 36, from a position adjacent to the northern end of the runway. The moment of touchdown on Runway 36 was not recorded, as the southern end of the runway was obscured from view by the slope of the terrain.

Background to the flight

The pilot had bought the aircraft two weeks prior to the accident, and had flown 17 hours in the aircraft in that time. Previously, he had flown over two hundred hours in an aircraft of the same type, ceasing that flying some two and a half years before the accident. He had not received any refresher training on the aircraft.

Although the pilot had considerable experience of operating from 'short' grass strips including the aircraft's base (which has a grass runway 2,532 ft long), he had not flown to Northrepps before. He had however, consulted a proprietary flight guide and made telephone enquiries from the airfield operator and had decided that the operation into Northrepps was feasible. He did not inspect the aircraft flight manual to determine landing distance or ground roll required, but reported that he considered that it would be "easily within (the aircraft's) capabilities of landing with the arresting force of grass and up hill" in the distance available at Northrepps.

Performance information

The aircraft Flight Manual, approved by the FAA, provides information on landing distance and ground roll, presented in tabular form, and for various weights, temperatures, and pressure altitudes. To achieve the given landing performance, the Flight Manual states that the throttles should be fully closed at 50 ft above the runway and the aircraft should be fully stalled at touchdown.

Given a temperature of +20ºC, in still air, at a weight of 6,000 lb, and at an airfield at mean sea level, the quoted landing distance was 2,070 ft, and the associated ground roll was 500 ft.

The aircraft Flight Manual did not provide a means of allowing for runway slope, but CAA Safety Sense Leaflet 7C suggests that a 2% runway down-slope increases landing distance by 10%, and states that '*Effect on ground run/roll will be greater*'. The Leaflet does not suggest a reduction in distance in the case of an upslope. However, in the following calculations this factor has been applied in the reverse sense (although it should be emphasised that this does not imply that this would provide an acceptable basis for the safe conduct of operations). The aircraft Flight Manual stated that the distances should be reduced by 3% per 4 kt of headwind and increased by 8% per 3 kt of tailwind. The Flight Manual did not offer a means of allowing for a runway surface other than a 'level, hard surface' but the Safety Sense Leaflet states that:

> *'Very short (wet) grass may be slippery, distances may increase by up to 60%'*

Applying these factors to the landing at Northrepps, the landing distance required to land on Runway 18 was 3,343 ft, and on Runway 36, 3,879 ft. These figures are the result of calculations which would have satisfied the pilot's obligation under FAR 91.103.

The aircraft was registered in the United States of America and the relevant Federal Aviation Regulation (91.103) stated:

> *'Each pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight. This information must include…*
>
> *'For any flight, runway lengths at airports of intended use, and…*
>
> *'For civil aircraft for which an approved Airplane or Rotorcraft Flight Manual containing takeoff and landing distance data is required, the takeoff and landing distance data contained therein'.*

Analysis

The Cessna 421C Golden Eagle is one of the largest light aircraft commonly flown by private pilots, and the runway at Northrepps, at only 1,617 ft long, is short by UK standards. A pilot operating a large aircraft onto a short runway should consult the appropriate documents (particularly the Flight Manual, information about the aerodrome, Safety Sense Leaflets, and others) to ensure that the proposed operation would be carried out safely and with adequate margins. In this case, as the aircraft was registered in the United States of America, the Federal Aviation Regulations applied and the pilot was required to comply with these regulations. The pilot was aware that the runway was short, had a grass surface which was likely to be wet, but he did not make a formal assessment of the performance aspects of the landing.

Where a runway has a significant slope, it is usual for pilots to elect to land uphill and takeoff downhill, provided that the wind is calm or favours those directions of operation. Operations from sloping runways become most complex when the wind blows up the slope for landing, or down the slope for takeoff. The combined effects of wind and slope may make it necessary to take off uphill or to land downhill, to derive the benefit of the headwind. It may even be that, for certain periods the wind prevents safe operation at all.

The landing roll information might have suggested to the pilot that the landing was possible, even with a 10 kt tailwind. However, this would require that the aircraft touched down at, or very close to the threshold, in a stalled condition, and with the throttle closed.

Although the video evidence did not show the touchdown zone, which was obscured from the cameraman's view by the runway slope, there was no suggestion that the touchdown occurred substantially late after the aircraft passed the landing threshold. There was also no evidence of the speed at touchdown. However, the aircraft did not decelerate sufficiently to stop before the end of the runway, and ran onto the road at some speed.

Several sources of wind information were available to the pilot, including the two windsocks at Northrepps, the unofficial observations and reports from the airfield operator by radio and the official observations and reports from the nearby airfields (Coltishall and Norwich). He could also have compared the indicated airspeed with the groundspeed displayed on the two GPS receivers on board the aircraft to determine headwind or tailwind component. Any of these sources of information would have shown that there was a significant tailwind component for landing on Runway 36.

Conclusion

Prior to the flight, the pilot did not use the aircraft flight manual to calculate his landing performance. Given the wind and the surface conditions at Northrepps at the time of the intended operation, performance calculations showed that a landing could only be made safely if both the precise landing parameters and adequate braking were achieved. There was no evidence regarding the point of touchdown or the associated speed; it is therefore not possible to say with any certainty whether the failure to stop was the result of an imperfectly executed landing or the lack of braking effect on the short, wet grass.

INCIDENT

Aircraft Type and Registration:	Cessna 560XL, G-WCIN
No & Type of Engines:	2 Pratt & Whitney Canada PW545A turbofan engines
Year of Manufacture:	2000
Date & Time (UTC):	8 July 2005 at 1435 hrs
Location:	On departure from Gibraltar
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Engine damage
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	6,000 hours (of which 500 were on type) Last 90 days - 50 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries by AAIB

Synopsis

As the aircraft rotated for takeoff, the right engine vibration alert caption became illuminated and the pilot reduced power on that engine. He consulted the aircraft Check List and then continued his flight to the planned destination using reduced power on the right engine.

It was established that the aircraft's fuel filler dust cover had detached and struck the fan of the right engine. The cover was found on the runway close to the rotation point.

History of the flight

The aircraft was being used for a private flight from Gibraltar to Jersey. The commander had asked for the aircraft to be refuelled and had completed his pre-flight external checks before the refueller had arrived. At about that time, the passengers arrived and the commander continued with the preparations for the flight, leaving the refueller to continue.

After the aircraft had been refuelled, the aircraft was dispatched without the commander, personally, re-checking the security of the fuelling point on the aircraft. The takeoff progressed normally until the point of rotation when the right engine vibration alert caption became illuminated. The commander established the aircraft in the climb, reduced power on the right engine and reported to ATC that he might have a problem. An external observer on the airport had noted that the aircraft was making an unusual noise at takeoff and reported this to ATC, who subsequently informed the pilot. The pilot informed ATC that he had a minor engine vibration and was intending to continue to his destination. The aircraft completed the flight to its destination using reduced power on the right engine.

During the inspection of the runway, prompted by these reports of engine vibration and an unusual noise, a heavily damaged piece of red-painted metal was found. This was subsequently identified as the dust cover which is fitted over the refuelling point and attached to the airframe by a lightweight chain. On Cessna 560 XL aircraft this is positioned behind an openable panel in the wing root fairing, directly ahead of the leading edge of the right wing. After landing, inspection of the fan of the right engine of G-WCIN showed it to be severely damaged.

Figure 1

Condition of fan of right engine after landing

INCIDENT

Aircraft Type and Registration:	DHC-8-311, G-BRYW, and others
No & Type of Engines:	2 Pratt & Whitney PW123 turboprop engines
Year of Manufacture:	1997
Date & Time (UTC):	28 September 2005 at 0829 hrs
Location:	En route: Aberdeen to Manchester
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 17
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	4,379 hours (of which 1,207 were on type) Last 90 days - 130 hours Last 28 days - 41 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft experienced a restriction of the elevator nose down trim control in the cruise. This was one of a number of similar occurrences of pitch trim restrictions on the operator's DHC-8 fleet. The operator has since increased the frequency of lubrication of the elevator trim screwjacks, in accordance with recommendations published by the aircraft manufacturer.

History of the flight

The aircraft, which was being hand-flown because of an unserviceable autopilot, was on a scheduled passenger transport flight between Aberdeen and Manchester. In the cruise at FL230, the commander, who was the handling pilot, found that he could not move his elevator trim hand wheel forward of its current position. It could be moved in a rearward direction and then forwards, but only as far as its initial position. When the Quick Reference Handbook (QRH) drill for an elevator manual trim failure was actioned, it was found that the standby electric trim system[1] would not move the elevator pitch trim wheels in either direction. The out of trim forces were, however, manageable and the flight was continued to its destination. As the aircraft descended through FL150, the manual elevator trim operation improved, allowing some nose down trim input.

Footnote

[1] The standby electric trim allows the elevator trim to be controlled electrically via the autopilot elevator servo.

Later examination of the aircraft did not identify any obvious defect that might have caused the incident; however, as a precaution, the trim screwjack actuator drive chains were cleaned and lubricated.

Elevator trim system description

The elevator trim (or pitch trim) is controlled via two trim tabs, one at the outboard trailing edge of each elevator. In normal operation, the position of the trim tabs is controlled manually, via the captain's or co-pilot's trim hand wheels located on the centre console. The trim hand wheels are mounted on a common shaft and are connected to the trim tab screwjacks, one for each tab, by a series of cables and pulleys. Forward movement of the trim hand wheels provides nose down trim and rearward movement nose-up trim.

Movement of the trim hand wheels is transmitted through the cables and pulleys, to provide a rotary input to each screwjack, via a chain driving a sprocket on the input end of the actuator. The output side is connected to the trim tab by a fixed length push rod and idler assembly. Depending on the direction of the input command, the screwjack will either extend or retract, causing the trim tab to move up or down.

An elevator trim tab position indicator is mechanically operated by and located alongside, the captain's elevator trim hand wheel.

A standby elevator trim system is provided to maintain trim tab control in the event of a trim cable break occurring forward of the elevator trim servo location in the rear fuselage. In this mode, elevator trim is commanded electrically to drive the autopilot elevator trim servo. The standby elevator trim system is armed by selecting a guarded switch on the pilot's side console to 'ARM'. Elevator trim may then be controlled by either of two spring-loaded trim switches, one on the pilot's side console and one on the co-pilot's side console.

Other similar occurrences

The operator had experienced a number of other similar events on other aircraft in its DHC-8 fleet, which were reported to the AAIB. These incidents are briefly described below, and are identified by the date of the incident, aircraft registration code and the sector flown:

<u>17 November 2005 - G-NVSA, MAN-ABZ</u>

When passing FL170 in day visual meteorological conditions (VMC), with a static air temperature of -3 ºC, an 'ELEVATOR MISMATCH' annunciation appeared. The autopilot was disconnected and the QRH drill for an elevator manual trim failure actioned, whereupon the standby electric trim system was found to be inoperative. As the out of trim forces were not excessive, the autopilot was re-engaged and monitored by the crew. The pitch trim response returned to normal after the aircraft had levelled out. Subsequent inspection of the aircraft revealed the presence of water in the elevator trim screwjacks.

<u>12 November 2005 - G-NVSA, ABZ-MAN</u>

When passing FL190 in day VMC, a 'NOSE DN PITCH MISTRIM' annunciation occurred. It was found that the elevator trim hand wheels could not be moved in a forward direction, but rearward movement was available. When the autopilot was disconnected, the standby pitch trim was also found to be inoperative. The pitch trim returned to normal at FL090 (the approximate freezing level), after which the autopilot was re-engaged. Engineering inspections of the aircraft revealed the presence of hardened grease in the elevator trim mechanism. This was cleaned off and the pitch trim screwjack chains and sprockets re-lubricated.

01 October 2005 - G-NVSA, GLA-MAN

Following reports of the elevator trim being stiff to operate in flight, the elevator trim screwjacks were cleaned and re-lubricated.

27 September 2005 - G-NVSA, EDI-MAN*

When leaving FL090 for descent to the cleared FL080 in day VMC, the autopilot failed to adjust the pitch trim. When the autopilot was disconnected, the aircraft pitched sharply nose-up. It was found that the elevator trim hand wheels could not be moved forwards, but rearward movement was possible. The aircraft was then hand-flown, with moderate effort required to maintain the required pitch attitude. The pitch trim operation returned to normal around FL080, where the static air temperature was approximately -3ºC. Engineering inspections did not highlight any pitch trim system faults. However, as a precaution, the autopilot servo and elevator trim screwjacks were cleaned and re-lubricated.

30 July 2005 - G-NVSB, EDI-MAN

At FL200 in day instrument meteorological conditions, a 'NOSE DN PITCH MISTRIM' annuniciation occurred. When the autopilot was disconnected, the elevator trim hand wheels would not move in the 'nose down' (ie forward) direction, although 'nose-up' trim selection was available with difficulty. When the QRH drill for elevator manual trim failure was carried out, the standby nose down pitch trim was found to be inoperative. The pitch trim operation reverted to normal after exiting icing conditions. The elevator trim screwjacks were subsequently lubricated. The last lubrication of the screwjacks had been 395 flying hours previously.

14 July 2005 - G-BRYX, SOU-MAN

When passing FL101 at 230 KIAS in day VMC, a 'NOSE DN PITCH MISTRIM' occurred with the pitch trim jammed in a nose down setting. When the autopilot was disconnected, the elevator trim hand wheels were found to be stiff to operate. The elevator trim screwjacks were lubricated after the incident.

05 July 2005 - G-BRYX, MAN-GLA*

Passing FL150 in day VMC, a 'NOSE DN PITCH MISTRIM' annunciation occurred. When the autopilot was disconnected, the elevator trim hand wheel could not be moved in a 'nose down' sense, but 'nose up' trim was available. When the QRH procedure was carried out, the standby nose down pitch trim failed to operate. This flight and the previous three flights had reportedly been in very wet and icy conditions. Following the incident, the elevator trim screwjacks were lubricated, during which some moisture contamination was found in the right-hand elevator trim actuator.

* These two incidents were included in a previous AAIB Bulletin EW/C2005/03/09, issued in April 2006, as they were believed to have been caused by the freezing of rehydrated residues of thickened de/anti-icing fluids. (Such residues are a common cause of control restrictions on aircraft with non-powered flight controls.) However, on reviewing the incidents, it is more likely that they were attributable to the freezing of moisture in the elevator trim screwjacks.

Elevator trim actuator modifications

In-service operation of the DHC-8 has shown that the elevator trim screwjacks can accumulate water internally, which can freeze at altitude, causing a restriction in the elevator trim system. This led to modifications 8/0415 and 8/0569 being issued, to add a drain hole and install a grease fitting on the screwjack, respectively. Modification 8/0415 was mandated by the United States Federal Aviation Administration (FAA) under Airworthiness Directive 86-25-03.

Manufacturer's advice to operators

The incidents listed in this bulletin occurred to aircraft which were fitted with modified elevator trim screwjacks. Service experience has shown that this type of screwjack can still be susceptible to moisture ingress, which freezes, causing elevator trim restrictions in flight. The problem can usually be eliminated by more frequent greasing.

The aircraft manufacturer, Bombardier Aerospace, recommends greasing at a 'C' Check, which has an interval of 5,000 flying hours. Recognising that some operators have continued to experience problems, the manufacturer provided the following advice to operators in 'Dash 8 In Service Activity Report Article 2005-09-2730', issued in October 2005:

> *'Operators continue to report in-flight elevator trim screwjack freezing.*
>
> *In accordance with the MRB Report (PSM 1-8-7) and the AMM, lubrication of the elevator trim screwjacks is at the 'C' Check interval. The environment in which an aircraft is operating may dictate a more frequent inspection and lubrication schedule. AMM 12-20-00 and MTCM 2730/04 are currently being revised (Temporary Revisions to follow). In the interim, Operators are encouraged to perform the following:*
>
> *Lubricate the elevator trim screwjack while moving the elevator trim control through its full range of movement. Continue this lubricating process until clean grease (moisture-free) is observed to be expelled from the drain hole. After lubrication servicing, cycle the elevator trim screwjack through its full range of movement a minimum of fifteen times to remove excess grease. After completion of the lubrication task, close and seal the access panels.*
>
> *CAUTION: Failure to remove the excess grease may result in excessively high loads required to move the elevator trim screwjack at low temperatures.'*

The operator has since increased the lubrication frequency of its elevator trim screwjacks in accordance with this advice.

ACCIDENT

Aircraft Type and Registration:	Auster J1N (Modified), G-AHCL
No & Type of Engines:	1 Lycoming O-320-A2B piston engine
Year of Manufacture:	1946
Date & Time (UTC):	11 March 2006 at 1446 hrs
Location:	Caernarfon Airport, Gwynedd
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to wing and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	649 hours (of which 21 were on type) Last 90 days - 7 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst taxiing in a crosswind, on a down sloping apron, the pilot lost control of the aircraft, the tail lifted and the aircraft's nose struck the ground.

History of flight

After an uneventful landing, the pilot taxied the aircraft to the apron where he carried out a 'U' turn to facilitate his re-entry onto the taxiway after disembarking a passenger and baggage. As the aircraft started to taxi with the control column fully aft, the effect of a quartering crosswind began to turn the aircraft left towards a hangar. The pilot applied full right rudder and used progressive application of right wheel brake to correct the turn, which brought the wind onto the aircraft's tail, whereupon it began to rise. The pilot immediately released the brakes and closed the throttle, in an attempt to lower the tail, but it continued to rise until the nose of the aircraft struck the ground, damaging the propeller and engine cowlings. The pilot considered that the combination of the down slope of the apron, the aircraft's forward CG position and the fact that there was now only a single occupant, negated his efforts to bring the aircraft under control.

ACCIDENT

Aircraft Type and Registration:	Cessna 172M, Skyhawk, G-BHCC
No & Type of Engines:	1 Lycoming O-320-E2D piston engine
Year of Manufacture:	1976
Date & Time (UTC):	24 January 2006 at 1325 hrs
Location:	Gloucestershire Airport
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose wheel, nose leg and firewall
Commander's Licence:	None
Commander's Age:	49 years
Commander's Flying Experience:	52 hours (of which 21 were on type) Last 90 days - 12 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after takeoff, on a solo training flight, a red warning light illuminated. The pilot requested a priority landing from ATC. Following a high and fast approach the subsequent landing was heavy damaging the aircraft in the vicinity of the nose landing gear.

History of flight

The weather at Gloucestershire Airport was hazy with visibility of 7 km and no cloud below 3,500 ft agl. There was little or no wind.

The pilot had recently completed the Joint Aviation Requirements, Private Pilot's Licence (Aeroplanes) syllabus and skills test and had applied to the UK CAA for his licence. Because he had not yet received his licence, the pilot's instructor authorised and supervised the flight.

Initially the pilot planned to fly a solo cross country flight but after consulting his instructor about the poor visibility he decided to fly some visual circuits. Having completed his pre-flight checks the pilot taxied out to Runway 09 where he carried out the engine power checks uneventfully.

After takeoff, at approximately 200 ft agl, a red warning light illuminated on the instrument panel. The pilot assumed the light was a starter warning light. Believing he had an emergency he commenced a left turn downwind from a height of about 500 ft agl. He informed ATC of his problem and requested a priority landing; this was approved.

Upon rolling out downwind for Runway 09 the pilot realised he was too close to the runway in order to complete the finals turn. He advised ATC of this. They informed the pilot that, as the wind was very light, he could land on any runway (09/27, 04/22 or 18/36). The pilot then attempted to position for Runway 04, but again ended up too close to the runway. ATC then suggested that the pilot's best option was to reposition for Runway 27, which he accepted.

Once established on final approach for Runway 27 the pilot realised he was too high and too fast. Believing he had an engine problem, he was reluctant to go around in case it aggravated the problem. He continued with the approach and touched down "extremely" heavily at least half way down the 1419 m long runway (997 m LDA). The aircraft bounced two or three times and stopped near the threshold of Runway 09.

After shutting down the engine the pilot realised that he had misidentified the warning light. It was a LOW VOLTAGE warning light that had illuminated. He had misidentified the light because he did not read the writing on the placard below the light. He assumed it was the STARTER warning light because the Cessna 172's LOW VOLTAGE light is the same size, shape and position as the STARTER warning light in a Piper Warrior, the aircraft type in which he had done most of his flying training.

Upon inspection of the aircraft the maintenance organisation found that the nose wheel had been damaged and the nose leg fork had been bent. Further examination also discovered that the firewall had been creased and the floor panelling behind the firewall had been buckled. The LOW VOLTAGE light had illuminated because of an alternator drive problem.

Starter warning light

The STARTER warning light indicates that the engine starter has engaged and is turning the engine. The Cessna 172 checklist only gives actions to be taken for the STARTER warning light illuminating on the ground. This is because it is assumed that the starter has remained engaged after engine start.

The pilot's instructor reported that he not heard of a STARTER warning light illuminating in flight. He added that the actions to be taken, in this event, would be dependent on whether the engine was still working and what other symptoms were present. Ultimately it could lead to the engine being shut down in flight and a forced landing being flown.

Instructor's comments

The pilot was extensively debriefed on the event by his instructor. As a result, the flying school have modified their training practices so that pilots understand why a warning light may illuminate and the correct actions to be taken if it does illuminate.

Conclusion

As a result of a misidentified warning soon after takeoff, an inexperienced pilot became anxious. In a bid to land his aircraft expeditiously, he repeatedly misjudged his positioning in the circuit and the final approach to land. Subsequently, he landed very firmly, damaging the aircraft.

ACCIDENT

Aircraft Type and Registration:	Cessna FR172E, G-OMAC
No & Type of Engines:	1 Continental Motors IO-360-D piston engine
Year of Manufacture:	1969
Date & Time (UTC):	7 August 2005 at 1717 hrs
Location:	Bracklesham Bay, West Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Commercial Pilot's Licence with Instrument Rating
Commander's Age:	25 years
Commander's Flying Experience:	373 hours (of which 170 were on type) Last 90 days - 127 hours Last 28 days - 69 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot and aircraft had been involved in two consecutive days of banner-towing operations. The accident occurred on a positioning flight towards the end of the second day. Shortly after takeoff the aircraft was seen to turn left, with an increasing angle of bank, until it stalled and impacted the ground after turning through approximately 310º. Although the banner hook installation showed evidence of interference with the rudder, it was considered that this was not a factor in the accident. The most likely cause was a stall following the turn to the left with an increasing bank angle. This may have resulted from an attempt to maintain visual contact with a point on the ground, and would have been exacerbated by an increasing tailwind. It was also considered that the pilot may have been affected by fatigue after the two intensive days of banner-towing.

Recommendations have been made relating to the banner hook installation and on fatigue associated with banner-towing operations.

Background to flight

The pilot involved in the accident had started flying for a banner-towing company in May 2005. The company had one aircraft and two pilots involved in the operation. The owner of the company, who was the other pilot, had flown with the pilot involved in this accident on several occasions, including banner-towing flights. He considered the pilot to be safe and conscientious.

Several banner flights had been contracted for the weekend of 6/7 August 2005 and the pilot involved in this accident had agreed to operate them. He left his home at approximately 0500 hrs on 6 August to drive to an airstrip in Kent where G-OMAC was based. He took off at 0746 hrs and flew to Compton Abbas Airfield. Subsequently, he flew a further five flights during the day. His total flying for the day was approximately 5 hours 20 minutes, including three sessions of banner-towing. He landed back at Compton Abbas at 1730 hrs and spent the night at a local hotel.

History of flight

On 7 August, the pilot took off from Compton Abbas Airfield at 0808 hrs for a positioning flight to a private airstrip at Bracklesham Bay. Once there, he completed a banner-towing flight before returning to Compton Abbas for refuelling. He then carried out a further banner-towing flight from Compton before returning to Bracklesham Bay for the final banner-towing flight of the day. He took a passenger on this flight, who later confirmed that the pilot had made no comment about any problems with the aircraft. The passenger had met the pilot before and also confirmed that he appeared his normal self. After takeoff the pilot had made a left turn to position the aircraft for the banner uplift. At the end of the flight, the pilot had completed 6 flights totalling 4 hrs 12 minutes during the day.

Following this final banner-towing flight, the pilot loaded his equipment into G-OMAC and had a cup of tea before boarding the aircraft for the flight back to Kent. There were several witnesses to the subsequent takeoff. The previous passenger watched the aircraft start up and taxi to the eastern end of the airstrip for a takeoff in a westerly direction. One other witness on the airstrip, who was a pilot, also saw the aircraft use the full length of the airstrip for takeoff. He recalled that he heard the pilot do his magneto checks and exercise the propeller control. He also recalled that there appeared to be about 15º of flap selected on the aircraft and that the engine note increased before brake release. This witness had seen the aircraft operate many times from the airstrip and considered that lift off appeared to be at the usual position. One other witness, who was positioned about 100 to 150 m to the north of the airstrip, also heard the magneto checks being done, saw that there was some flap selected and also had the impression that the pilot did a control check.

Shortly after takeoff the aircraft turned to the left, with what appeared to be an increasing bank angle, until the aircraft was heading back towards the start of the airstrip. By now the bank appeared to be close to 90º and all three witnesses saw the nose of the aircraft come down. One witness lost sight of the aircraft behind a hangar, but the other two saw the aircraft impact the ground with the nose and left wing simultaneously. The witnesses alerted the emergency services and two of them ran immediately towards the crash scene. Once there, one witness checked the pilot for signs of life but could not detect any.

One of the witnesses subsequently stated that she had not been aware of any change in engine noise during the accident flight. The other two witnesses considered that the engine noise remained constant until shortly before impact when the engine noise seemed to reduce.

Other witnesses were located on a caravan site positioned to the west of the airstrip. One of these saw the aircraft airborne and approaching his position. He saw the aircraft do a “sharp left turn” and then lost sight of it for a short time behind some vegetation. When he saw it again, it began to descend quickly and impacted the ground. He later recalled that the engine went quiet at some stage in the turn.

The emergency services recorded the initial call at 1724 hrs and the first fire vehicle arrived at the scene at 1740 hrs.

Aircraft description and history

G-OMAC was a Reims Cessna FR172E with a TCM IO-360-D fuel injected, six cylinder, wet sump, horizontally opposed, air-cooled engine driving a constant speed MacCauley propeller. The aircraft was constructed in 1969 and had accumulated around 4,029 hours at the time of the accident; the engine was fitted in November 1998 and had completed 1,149 hours since a zero time rebuild at the factory. A 50 hour inspection had been completed on 29 July 2005. There were no outstanding maintenance issues.

Wreckage examination

The aircraft had initially impacted the ground in a 20-30º nose down attitude and approximately wings level on a heading of 320º M. The general disposition of the wreckage suggested a low speed impact, with a degree of sideslip to the right. The impact position was located approximately 170 m south of the centre point of the airstrip. It was established that the aircraft was intact prior to impact.

There was evidence of some chordwise scoring on the propeller, suggesting at least some engine power. The propeller had remained attached to the engine crank shaft during the impact. However, during the recovery it became detached. It was subsequently found that the crankshaft had failed in torsion, consistent with there having been some power from the engine and the propeller having stopped very quickly in the impact.

Approximately 100 litres of fuel, with the visual appearance and odour of Avgas, were recovered from both wing fuel tanks. There was no fire.

The fuselage structure had been disrupted in the impact. However continuity of the elevator, aileron and rudder control systems was confirmed and there was no evidence of any pre-impact failures.

Engine examination

Strip inspection of the engine showed that it had been mechanically sound before the accident and could still be turned by hand. The combustion chambers had normal amounts of combustion deposits and the cylinder bores were mostly free from scoring and other damage. However, the No 3 cylinder did show evidence of some scoring from the piston pin, although this was not excessive. This wear was confirmed by a small amount of metallic contamination in the oil filter.

The accessory gearbox was intact; all the gear teeth were undamaged, lubricated, and exhibited normal operating wear. The oil sump was intact and the oil recovered appeared to be in satisfactory condition.

Both magnetos were tested and found to function satisfactorily. The spark plugs were in a serviceable condition; the electrodes were clean with only light deposits.

The throttle position on the fuel metering unit was found approximately $^1/_3$ open, which was consistent with the position of the throttle lever in the cockpit.

The engine-driven fuel pump was free to rotate and the drive was intact. The pump was tested and showed low flow figures at high rpm. There were no leaks and, following adjustment, fully met the specification. The fuel injection system manifold and nozzles were tested and were found to meet the flow requirements. The throttle body was checked in accordance with the maintenance manual; this showed fuel flows higher than the specification, suggesting the throttle had been adjusted to counter the low fuel flow from the fuel pump.

Flaps

The wing flaps were electrically operated. When the flap switch was selected, electrical power was supplied to a motor located in the right wing. This powered an actuator which transmitted the movement to both flap surfaces via a system of drive pulleys, cables and push-pull rods. The position of the flap was sensed by a potentiometer and transmitted to a cockpit gauge located on the right hand side of the instrument panel. In order to select a flap setting the pilot must hold the flap switch until the desired position is indicated on the gauge and then release the switch. There were no detented positions. However the Flight Manual quotes positions 0º, 10º, 20º, 30º and fully down 40º.

Measurement of the exposed threaded portion of the flap actuator indicated that the flaps were at a position of approximately 25º, which was consistent with the found position of the flap surfaces themselves.

Modification for banner towing

In 1985 the aircraft had been approved by the CAA for use in banner towing. The modification used a standard Cessna supplied hook with the addition of a subsidiary base plate to prevent the assembly rotating. This main hook was attached to the rear tie down fitting at the rearmost point of the main fuselage, and operated by a flexible cable located on the cockpit roof. In addition a grapnel hook was fitted on the aircraft underside forward of the main hook, surrounded by a container designed to stow the grapnel cable. The grapnel release was actuated by an upward pull on a Tee-handle located on the cockpit floor.

To prepare for banner towing, the aircraft would take off with the cable attached to the main hook but stowed within the grapnel container. The cable would then be released by operating the grapnel hook Tee-handle on the cockpit floor and the cable would stream behind the aircraft from the main hook. Having collected the banner and completed the task, both the banner and cable would be dropped from the aircraft prior to landing. This would have been accomplished by operating the main hook release mechanism in the cockpit roof. The release of the hook mechanism latch allows the hook itself to spring rearwards contacting the lower rudder surface. Once the hook has released the banner cable, the hook would be free to float and gravity would allow it to return to its 'normal' vertical position against the latch.

Evidence of repeated operation was apparent on G-OMAC by long term damage to the base of the rudder (see Figure 1). There was a possibility that the hook could become lodged within the rudder. However, given the lightweight fibreglass structure it is likely that rudder pedal pressure would liberate the hook and allow the rudder to move freely again.

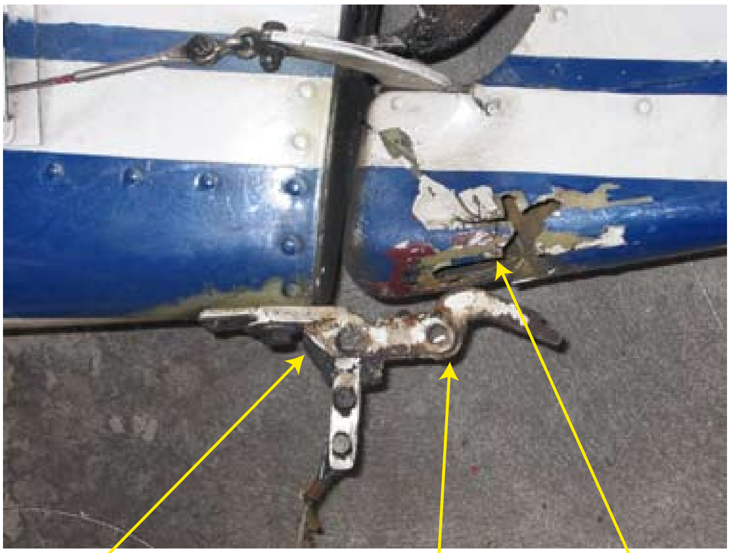


Figure 1

Cessna stated they have not had any experience of these types of tow hooks interfering or jamming the flight controls, although damage such as found on G-OMAC is not uncommon.

Recorder information

The aircraft had a Skyforce SkyMap IIIc GPS mounted in the instrument panel. The unit was removed and downloaded for interpretation. It had recorded samples of latitude, longitude, altitude, magnetic track and ground speed every 30 seconds. The start and finish of a flight was automatic with the first point being recorded at 24 kt (approximately 27 mph). This was the only data point recorded for the accident flight. This position was compared to previous recordings of takeoffs by G-OMAC from Bracklesham Bay that day and the positions were close indicating no abnormalities in the takeoff at that point.

Downloaded information was reviewed to confirm previous aircraft flights. Records were available for all flights from 3 August 2005 up to the accident flight. This confirmed the aircraft movements on 6 and 7 August showing that the aircraft had flown 6 flights on 6 August and 7 flights, including the accident flight, on 7 August. Total flight time on 7 August was 4 hours 12 minutes. The flight time for 6 August could not be determined accurately because the unit stopped prematurely on 5 of the flights but totalled approximately 5 hours 20 minutes.

Weather information

An aftercast from the Met Office at Exeter showed the synoptic situation at 1800 hrs on 7 August 2005. There was a ridge of high pressure over the British Isles with a light northerly flow over Sussex and Hampshire. It was estimated that the surface visibility was 30 km, cloud was FEW/ SCT with a base at 6,000 ft amsl, the surface wind was 350º/ 07 kt and the air temperature was 21ºC with a dew point of 9ºC. At 500 ft amsl, the wind was estimated to be from 010º/ 05 to 10 kt.

The airstrip operator, who was also a witness to the accident, stated that a portable windsock had been positioned near where the accident flight had commenced takeoff. He also confirmed that the surface wind was from the north and that he had noticed, when he was operating a model aircraft, that the wind speed was slightly stronger at about 100 ft agl, although from the same direction.

Medical information

A Post Mortem examination was carried out on the pilot. It was concluded that the crash had not been survivable and that the pilot had died from multiple injuries consistent with an aircraft crash. There was no evidence of any natural disease, which could have caused or contributed to the accident. Additionally, toxicological examination showed that the pilot was not under the influence of alcohol or drugs at the time of the flight.

The weight of the pilot was approximately 180 lb.

Operational information

Airstrip

Bracklesham Bay Airstrip has a grass surface and a length of some 550 m; at the time of the accident, the grass was dry and short and the surface of the airstrip was firm. The airstrip is orientated east/west and has a grass parking area at the eastern end where there is a small hangar and a caravan. To the west of the airstrip is a caravan site and pilots operating from the airstrip are asked to avoid this site whenever possible. The prevailing wind is generally south-west and the normal procedure used by pilots after takeoff on the westerly runway was to turn left towards the coast.

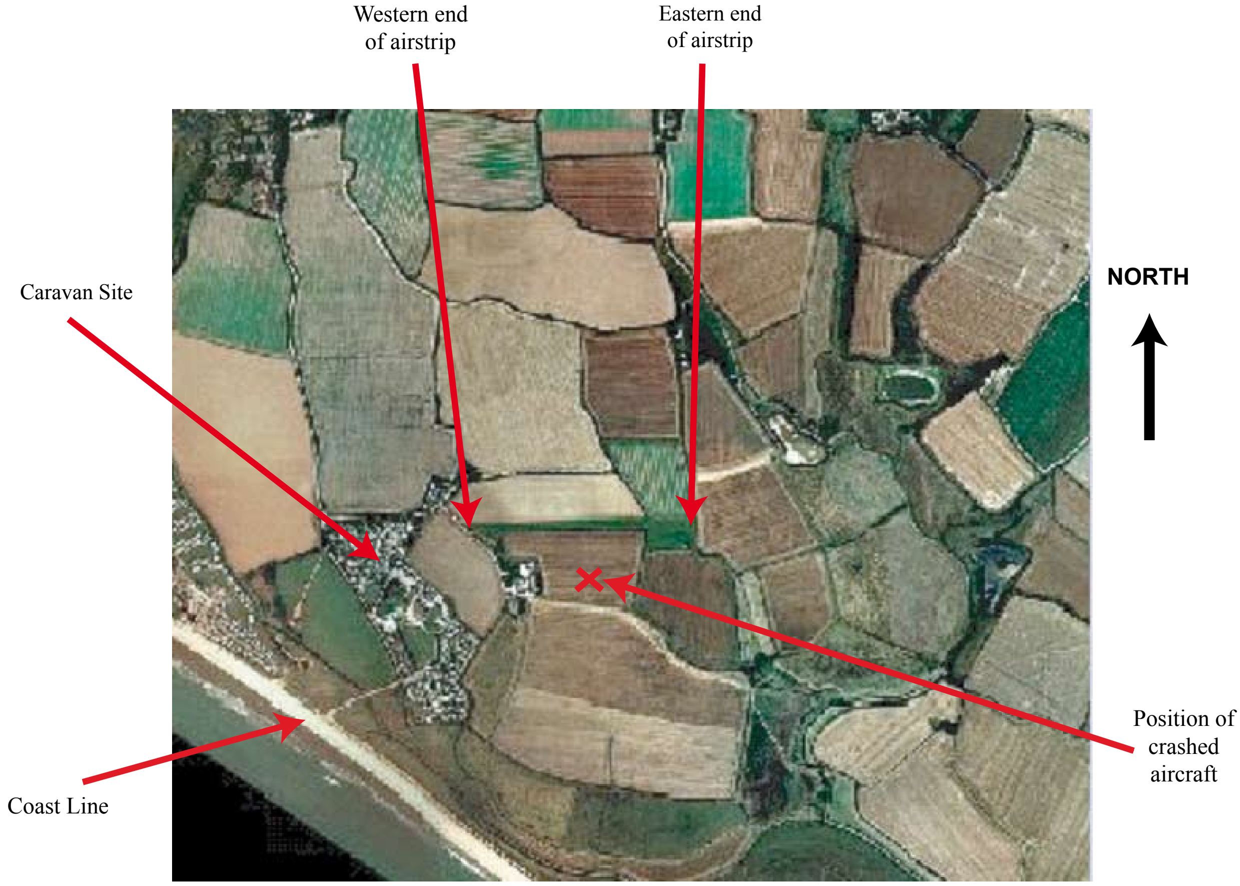


Figure 2

Fuel information

After the accident, a total of some 100 litres of fuel was downloaded from both wing tanks. Enquiries revealed that the aircraft had refuelled on three occasions on 6 August and on one further occasion on 7 August, at approximately 1340 hrs. For the last refuelling, a total of 131.94 litres (approximately 35 USG) was uplifted. With a maximum aircraft fuel load of 52 USG, it was probable that the aircraft was then fully loaded with fuel. Following this final fuel upload, the aircraft completed a further 1 hour 9 minutes of flying prior to the final takeoff. By then, the fuel on board would have totalled approximately 38 USG, based on a fuel flow of approximately 12 USG/hour.

Weight and CG

The aircraft basic weight was 1,561 lb and the total equipment in the aircraft cabin weighed 103 lb. With a pilot weight of 180 lb and a fuel weight of 254 lb, the weight of the aircraft on the final takeoff was estimated as 2,098 lb, which was well below the maximum allowable weight of 2,500 lb.

Calculations also indicated that the aircraft was within normal CG limits for the takeoff on the accident flight. The severity of the impact was such that the original location of the banner-towing equipment in the cabin could not be confirmed but normal practice was to stow it in the rear seats and to the right of the front right seat.

Aircraft performance

The aircraft manual detailed that normal takeoffs should be accomplished with flaps up and that maximum performance takeoffs should be accomplished with 20º flap; soft field takeoffs can be performed with 20º flap. Normal climb speed was 95 mph and maximum performance take-off climb speed was 70 mph.

The aircraft owner's manual detailed the stall speed with zero angle of bank, at maximum weight, flaps 20º and with power off as 58 mph. In the same configuration, the stall speed at 40º angle of bank was 67 mph and at 60º angle of bank was 83 mph. The manufacturer calculated the power off stall at 2,050 lb and 60º angle of bank as 73 mph. Power on stall speeds would be lower than these figures.

The manufacturer also provided an estimate of the aircraft turn performance. This indicated that the turn diameter after a takeoff at 2,050 lb using 20º flap would be 864 ft at a constant 30º angle of bank and 288 ft at 60º angle of bank; the estimates were based on nil wind. The final position of the crashed aircraft was some 558 ft south of the airstrip.

Banner towing regulations

For commercial banner towing, the pilot required a professional licence. The company involved in operating G-OMAC also had a '*Banner Towing Manual*', issued in October 1984, detailing rules and procedures for the operation. There was no reference to duty hours or flight time limitations within the manual. Any aircraft used for banner towing was required to be properly modified and approved by the CAA and to be operated in accordance with a supplement to the aircraft Owner's Manual. G-OMAC had been approved for the operation and the Owner's Manual contained the necessary supplement.

Fatigue

With the number of hours achieved by the pilot over the previous 28 and 90 day periods of 69 hours and 127 hours respectively, it was considered relevant to consult a human factors specialist about the possibility of fatigue being a factor in the accident. The specialist considered the following aspects:

1. Cumulative fatigue as a result of a high work rate over the previous days/weeks. It was concluded that there were periods of high workload during the previous month but also that there were a sufficient number of rest days. There was no indication that the pattern of work would have contributed directly to an accumulation of fatigue.
2. Inadequate sleep prior to the final duty period. The early start on 6 August and a long duty period would have resulted in a tiring day. However, evidence indicated that the pilot was aware of his requirement for sleep and had retired to bed early that night. It was considered that he should have been able to obtain sufficient sleep to overcome most of the deficit from the previous day.
3. Workload leading up to the accident. At the time of the accident the pilot had been at work for almost 10 hours, had flown for over four hours, including nearly 2 hours 40 minutes of banner towing, and was just starting his seventh flight of the day. It was concluded that a fair degree of tiredness would have built up by the end of the day.

It was concluded that the cumulative effect of long hours of work and a heavy workload over two consecutive days could have resulted in tiredness, which may have increased the likelihood of an error of judgement by the pilot.

Flight time limitations

There are no regulations relating to limitations on flying times for private flights or on duty times for aerial work such as Banner Towing. CAP 393: '*Air Navigation: The Order and the Regulations',* details the following general requirement for pilots:

> *'32 (4): A person shall not be entitled to act as a member of the flight crew of an aircraft registered in the United Kingdom if he knows or suspects that his physical or mental condition renders him temporarily or permanently unfit to perform such functions or to act in such capacity.'*

LASORS 2006, Safety Sense Leaflets 1 '*General Aviation Good Airmanship Guide'* and 24 '*Pilot Health'* provide practical advice on pilot fitness, stress and fatigue. Additionally, CAP 755 '*Recreational Aviation Activities Manual',* published in June 2005, provides guidance to organisations undertaking a recreational aviation activity. It was recommended that such organisations should produce a manual to ensure a satisfactory level of operational safety. Within the manual, there should be an exposition of the company flight and duty time limitation scheme based upon the guidelines contained in CAP 371.

CAP 371 details the duty and flight time limitations for Air Operator Certificate (AOC) holders carrying out public transport operations. In general, a pilot is restricted to 190 duty hours and 100 flying hours in a 28 day period. Annex C of the publication includes requirements for 'Pleasure Flying', which does not place any restriction on the number of flights during the day. It includes a limit on the duty period of 10 hours when carrying passengers but this can be extended to 12 hours to allow the aircraft to be positioned from and to the operator's base.

There was no reference in any publication to 'Banner Towing' operations.

Discussion

The accident occurred after takeoff when the pilot was returning to the aircraft's base. Witnesses saw the aircraft turn left with an increasing bank angle shortly after takeoff. The engine noise was constant until possibly just before impact, which occurred some 558 ft south of the airstrip. At impact, the aircraft had turned left through some 310º from the take-off direction.

Engineering

The aircraft was intact and the engine was producing power at the point of impact. There were two anomalies found during the subsequent engineering investigation.

Firstly, the flaps were found at approximately 25º, which was not a normal take-off configuration. However, the flap system relied on the pilot to hold the switch and judge when the actual flap surface position from the gauge reached the desired setting before releasing it. The location of the gauge on the far side of the instrument panel from the pilot could introduce parallax errors in judging indicated flap position. It is therefore possible that he intended to takeoff with flaps at 20º using the soft field technique, and the difference in the 'as found' position from the actuator could be accounted for by errors in judging the position from the gauge. It was not considered that an additional 5º flap would have had any bearing on the accident.

Secondly, damage had occurred to the rudder surface over time as a result of the banner towing hook springing back as the banner was released. It was considered possible that this could result in a restriction to the normal operation of the rudder system. However, the material in the contact area was frangible and it was considered unlikely that the hook would have remained in a jammed position. Any such restriction would normally only occur after banner release and the accident occurred on takeoff when the hook would have been in the 'normal' vertical position against the latch. In that position, it was considered unlikely that the hook would then make contact with the rudder. There was a slight possibility that, during takeoff on a grass surface, the hook could bounce around its 'normal' position and contact the bottom of the rudder. However, it was considered highly unlikely that this would have resulted in a permanent jam to the rudder system.

The tow hook was supplied by the manufacturer and is fitted to a large number of aircraft. Although there have been no reported instances of flying control restrictions caused by a tow hook, and it is considered unlikely that the banner-towing hook had any bearing on the accident to G-OMAC, any possibility of the hook impinging on a primary flight control is undesirable. The following recommendation is therefore made.

Safety Recommendation 2006-42

It is recommended that the European Aviation Safety Agency review the design of tow hooks fitted to banner-towing aircraft with particular regard to eliminating any possibility of the hook interfering with the aircraft's primary flying control surfaces.

Operational

The weather had been good throughout the day and the pilot was on his fourth takeoff that day from Bracklesham Bay. Prior to takeoff, witnesses were aware of the pilot doing engine checks and probably completing control checks. The completion of these checks, on an aircraft that he had flown 6 times before that day, indicated conscientious behaviour by the pilot. However, one aspect that a pilot would also normally consider was the direction and strength of surface wind. With a takeoff to the west and a northerly wind, the pilot should have been aware that a turn to the south after takeoff would be downwind with a resultant increase in groundspeed.

On the takeoff there was no apparent problem prior to the aircraft becoming airborne when it was seen to enter a left turn and with an increasing bank angle. This was the normal turn direction although a turn to the right was not prohibited and would still have avoided the caravan site, while also having the advantage of turning into wind. With the pilot's intended route being towards the east, the pilot had the option of turning in either direction after takeoff; however, once airborne and turning left with an increasing bank angle, the effect of the tailwind would become more critical. This tailwind, together with a higher stall speed due to the bank angle, could have resulted in the aircraft eventually stalling. The pilot could have recovered the situation by rolling out of the turn and flying wings level. However, this would be dependent on him recognising the developing situation and having the necessary aircraft control authority and altitude to effect the recovery.

It is possible that the pilot was not aware of the developing situation after takeoff. His intended route was to the east and therefore a turn was necessary both to avoid the caravan site and to establish the required heading. This was to be his final flight of the day and it is possible that he intended to fly over the eastern end of the airstrip before setting course towards his home airfield. If this had been his intention, he may have started his turn to the left after takeoff and then started looking to the left to acquire the airstrip visually. In that situation, it would be difficult to maintain accurate aircraft control and it is possible that the northerly wind resulted in an unintended increase in bank angle as the pilot maintained his planned track over the ground. The final location of the aircraft indicated that the turn after takeoff would have required an average bank angle between 30º and 60º.

If this scenario is correct, the pilot had attempted his intended manoeuvre without a full evaluation of all the relevant factors. All the indications are that he was conscientious in his approach to flying. He went to bed early the previous night following a busy day and he appeared to have completed the engine and control checks prior to the accident flight. He would have been aware of the surface wind at Bracklesham Bay, having operated all day from the airstrip but may not have appreciated the significance of it for his intended manoeuvre. This aspect, together with the possibility that he did not continue close monitoring of the aircraft bank and airspeed after takeoff, raises the possibility that fatigue may have been a factor in the accident. It was concluded that the cumulative effect of long hours of work and a heavy workload over two consecutive days could have resulted in tiredness, which may have increased the likelihood of an error of judgement by the pilot.

A review of CAA publications indicated that there was no specific guidance for duty or flying hour limitations for banner-towing operations. The accident to G-OMAC occurred during a private flight and the responsibility for fatigue avoidance remains with the pilot. Nevertheless, the purpose of this private flight was to position the aircraft back to its base after a period of banner-towing operations. Banner towing is an activity generally involving one pilot and requiring a high degree of concentration. The current guidance in CAP 755 only relates to organisations involved in 'recreational activities' and recommends that limitations should be based on CAP 371. With the possibility that the pilot's workload and working hours may have been a factor in this accident, it would seem appropriate to provide more guidance on duty and flying hours during commercial operations such as banner towing. Additionally, no evidence could be found of any studies relating to tiredness/fatigue for operations involving a single pilot and requiring high concentration levels. The following recommendation is therefore made.

Safety Recommendation 2006-43

It is recommended that the Civil Aviation Authority initiate a study into the fatigue aspects associated with flying operations such as banner towing and provide guidance on duty and flying hour's limitations to such operators.

Conclusion

With no conclusive evidence of any technical malfunction it was considered that the accident resulted from a loss of control, possibly whilst positioning to fly over the departure airstrip. It was also considered probable that fatigue may have resulted in an error of judgement by the pilot. Finally, the investigation could not rule out the possibility that the banner hook may have caused a jam of the rudder system.

ACCIDENT

Aircraft Type and Registration:	DA40D, G-CCLB
No & Type of Engines:	1 Thielert TAE 125-01 piston engine
Year of Manufacture:	2004
Date & Time (UTC):	20 October 2005 at 1430 hrs
Location:	Rochester Airport, Kent
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose gear, propeller and engine shock loaded
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	6,692 hours (of which 420 were on type) Last 90 days - 125 hours Last 28 days - 31 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft, which was operated by a flight training school based at a grass airfield, was being manoeuvred into wind prior to pre-takeoff power checks when the nose landing gear wheel separated from the nose leg. The engineering examination revealed that a failure had occurred in the nose wheel swivel/castoring pivot by a fatigue cracking mechanism and that the initiation of the cracks was due to the pivot material being below the minimum specified strength. This resulted from a failure in the manufacturing process to heat treat the pivot material correctly, an error which had not been identified by post-manufacturing quality checks. The aircraft operator found cracks in a similar area on another of their aircraft of the same type and of similar age and usage. The aircraft manufacturer has issued a Mandatory Service Bulletin, which the Austrian Civil Aviation Authority has made mandatory by an Airworthiness Directive, detailing inspections for cracking of the nose wheel swivel/castoring pivot. The aircraft manufacturer is also exploring the possibilities of strengthening the area of the nose wheel swivel/castoring pivot and simplifying the manufacturing process.

History of the flight

The purpose of the intended flight was for an existing PPL (A) holder to be converted to the aircraft type. He had carried out the pre-flight checks according to the checklist, with the instructor advising, with no faults or problems being found. After starting the engine and allowing time for it to warm up, the pilot taxied the aircraft onto the taxiway and then along it for approximately 800 m, to a 'mown' turning area which was used as an engine run-up area. Upon entering the turning area the aircraft was gently turned to the right prior to making a sharp turn to the left in order to face into wind for the engine power checks. With the aircraft taxiing very slowly, as the sharp left turn commenced, the nose pitched down and pieces of propeller blades, earth and grass rained down onto the aircraft. Upon exiting the aircraft it was found that the castoring nose landing gear wheel had separated from the nose leg, allowing the propeller to strike the ground. Examination of the aircraft's track on the grass surface did not show any evidence of ruts or depressions that may have contributed to the accident.

Engineering examination

General

The manufacture of the nose landing gear (NLG) strut, Figure 1, is sub-contracted by the aircraft manufacturer to a metal fabrication organisation. This organisation manufactures the NLG from two different types of steel, 1.3477.4 sheet steel and SAE 4130 steel for the main structure, which includes the pivot. Post manufacture, a hardness test is carried out with the intention of ensuring that the assembly has been correctly heat treated and has achieved the required combination of strength and toughness. The NLG struts are not individually serial numbered, and only feature a manufacturer's batch number, printed on a label attached to the inside of a section of the leg. Once the NLG is mounted on an aircraft it is difficult to access and view this label.

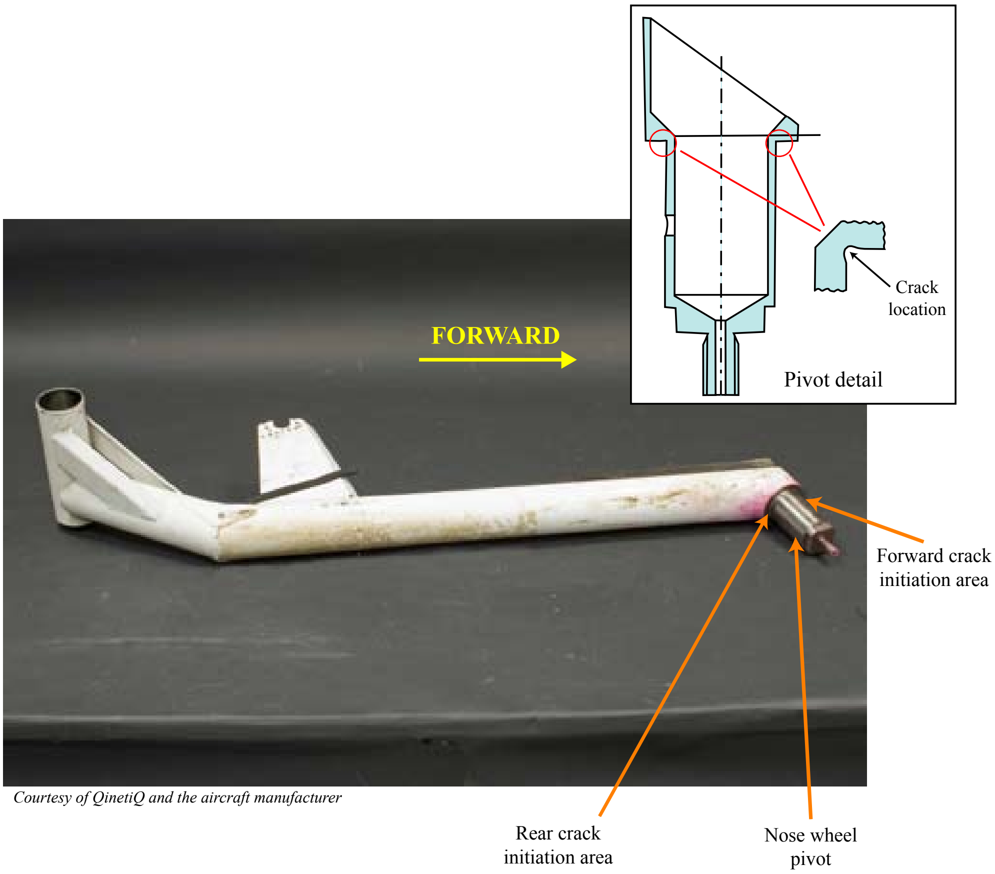


Figure 1

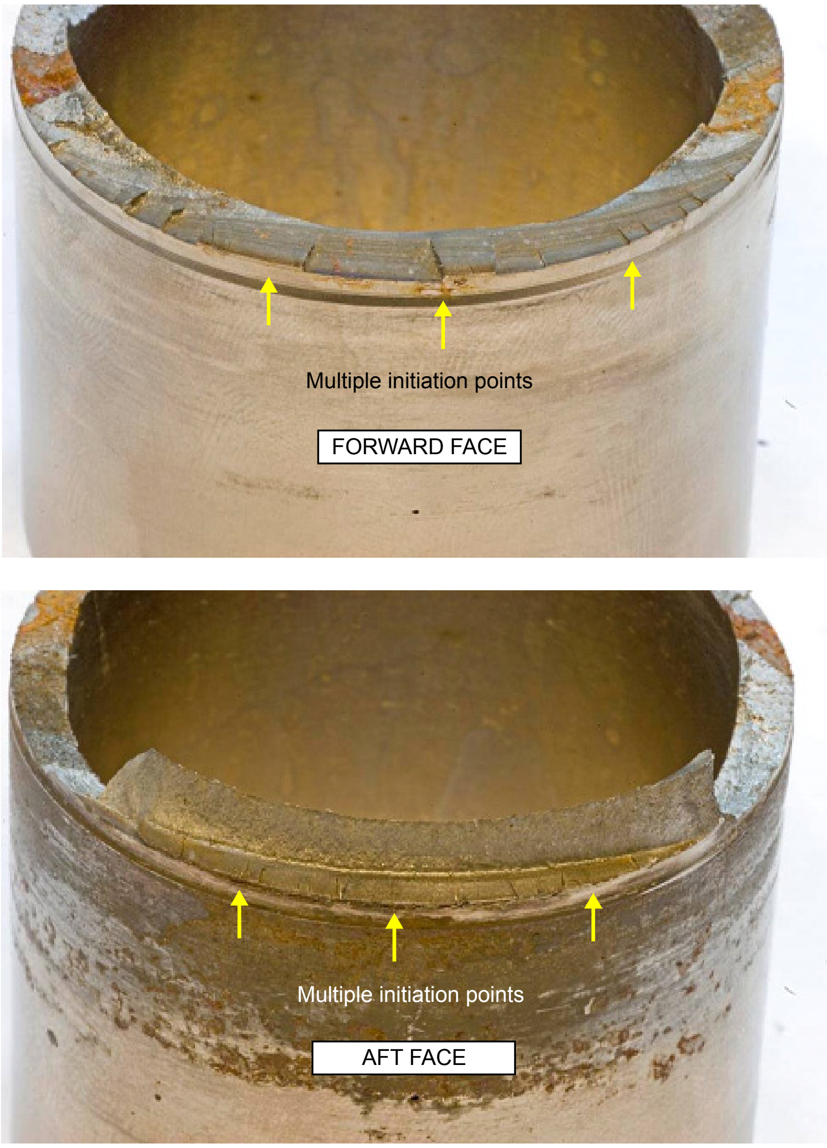
Initial examination

Initial visual examination of the failure area by a local aircraft engineer revealed what appeared to be a region of long term 'staining' on the failure surface, which indicated to him that there may have been a crack present for a period of time prior to the failure. This led the engineer to inspect the NLG of the other DA40D operated by the flight training school, G-CCUS ('US), where he found evidence of a crack in the same area where the failure had occurred on G-CCLB ('LB).

Metallurgical examination

The NLGs from both aircraft were sent to AAIB for a detailed examination, which was carried out in conjunction with the Materials Centre at Qinetiq, Farnborough. The results of this showed that fatigue cracking had occurred at the top of both nose wheel swivel/castoring pivots in an undercut/ radius adjacent to an abutment shoulder, Figure 1. In both cases the fatigue cracks had initiated at multiple points in the radius at the forward and rear sides of the pivots, Figures 2 and 3. The cracks in the pivot from 'LB had propagated around the majority of the circumference before the final overload failure occurred. The cracks in the pivot from 'US were very similar to those found on 'LB, albeit at an earlier stage of development and, as such, would almost certainly have eventually propagated to final failure in a similar manner.

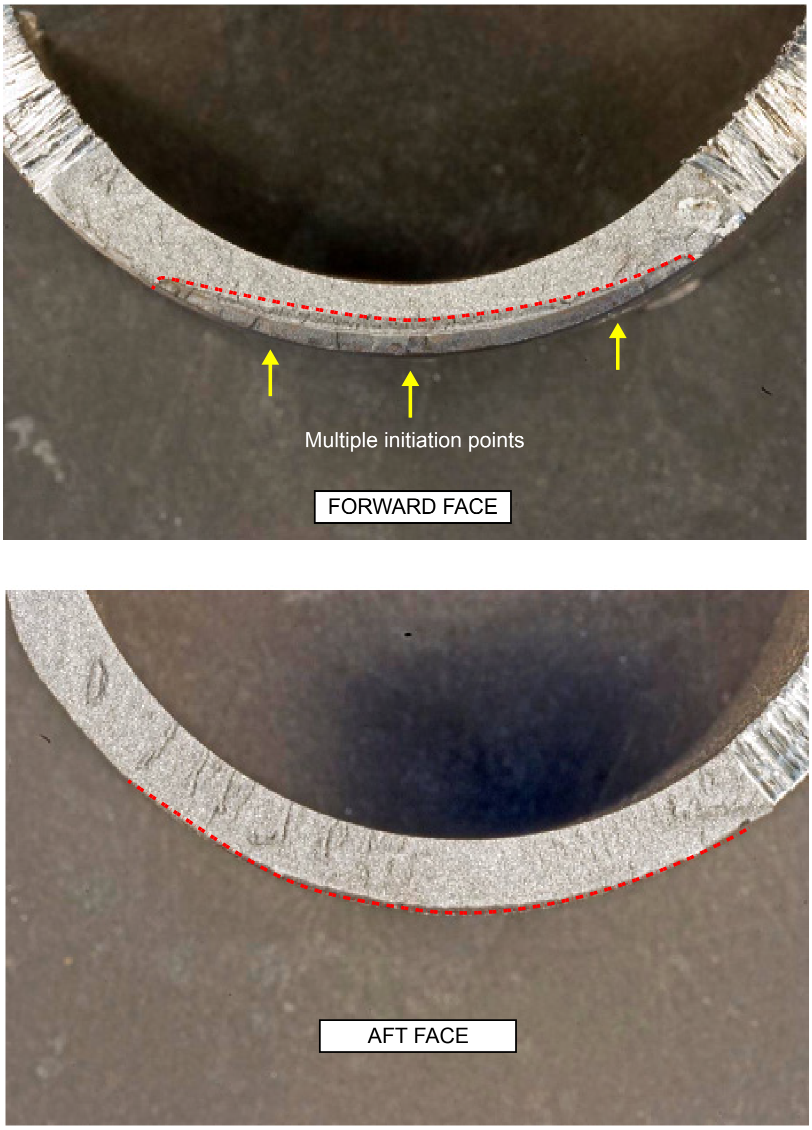
The fracture surfaces of the pivots were examined in the scanning electron microscope (SEM) to confirm that crack growth was by a fatigue mechanism. Detailed examination of the fracture surfaces showed evidence of corrosion which had removed a large area of the fine fatigue striation detail. However, the fracture topography was typical of the propagation of a fatigue crack in steel. The area of the overload failure of the pivot from 'LB showed evidence of ductile dimples typical of an overload failure. There was no evidence of any material defects or machining abuse which could have influenced the initiation of fatigue cracks, although there was evidence of corrosion on



Courtesy of QinetiQ

Figure 2

Forward and aft face of the fractures pivot from G-CCLB



Courtesy of QinetiQ

Figure 3

Forward and aft face of the fractures pivot from G-CCUS

the outer surfaces of the pivots, especially on their aft facing surfaces. This, however, did not appear to have influenced the initiation of the fatigue cracking as there was no evidence of corrosion pits at the fatigue crack initiation points.

Micro samples were taken from both pivots and these were visually examined and subjected to hardness tests using a Vickers hardness testing machine. The average hardness of the pivot from 'LB was found to be 232 HV10, equivalent to a minimum ultimate tensile strength (UTS) of 734 MPa, and that of the pivot from 'US was 236 HV10, equivalent to a minimum UTS of 746 MPa. The specified minimum hardness on the aircraft manufacturer's drawing for the pivot is 320 HV, ie, a required minimum UTS of 1080 MPa, and thus both pivots were below the specified minimum strength required. A material composition check was carried out on both pivots, which showed that they had been manufactured from Society of Automotive Engineers (SAE) 4130 low alloy steel, the correct material as specified in the aircraft manufacturer's drawing. It was noted that the manganese and sulphur levels of their composition appeared to be slightly higher than those specified in SAE Aerospace Material Specifications (AMS) 6374 for this material, but this was not considered to have influenced the initiation or propagation of the fatigue cracking.

Additional information

The manufacturer has established that the heat treatment process applied to NLG struts was only appropriate for the 1.3477.1 sheet steel and not for 4130 steel. In addition, the post manufacture hardness checks were only being carried out on the sheet steel section of the struts, which generally gave the correct result, and not on the parts made from 4130 steel, which would have given incorrect results. Since this accident occurred, hardness tests on three additional NLGs held in the manufacturer's stock, found that the swivel/castoring pivots were also below the specified hardness by a similar amount as the ones fitted to 'LB and 'US.

The types of steel used in the construction of this NLG strut are usually supplied in their softest condition, to allow easier machining and fabrication (welding, for example). Following manufacture, a specified heat treatment may be carried out to give the required combination of toughness and strength. These are low alloy steels that can achieve varying levels of strength depending on the tempering temperature. After quenching from a relatively high temperature, at low tempering temperatures, the steel remains strong but with low toughness, ie, it becomes more brittle. At higher tempering temperatures the toughness increases with a resultant drop in strength.

Aircraft usage information

Both 'LB and 'US had been operated since new by a flight training school located on a grass airfield. The airframe hours and number of flights for both aircraft, at the time of the accident were obtained and are presented below in Table 1. The airframe hours data is considered reliable, whereas the number of landings, which includes 'touch and go's,' is a best estimate figure in each case.

Crack growth

No fine detail was observed on the fracture surfaces from 'LB so an estimate of the time/cycles for crack propagation, from initiation to failure, could not be determined. However, as both aircraft were operating from the same airfield by the same training school, were being used in similar ways and had similar strength nose wheel swivel/castoring pivots, it could be assumed that the difference in landings, flights or airframe hours between the two would give an approximate indication of the time required for an initial crack to propagate to failure. The usage data showed that 'LB had carried out 308 landings, 152 flights and 117 airframe hours more than 'US.

However, when detected, the cracks in the pivot from 'US were considerably less well developed than to those associated with 'LB. If it is assumed that landing and taxiing loads are primarily responsible for crack propagation, then the minimum time/cycles for an incipient crack to propagate to failure would be around 308 landings/152 flights. It should be noted that these figures are only an estimate for crack growth and assume that the pivot material characteristics are identical, the fatigue cracks in both aircraft would initiate after the same time in service and that both would experience identical loading spectra. In reality this is unlikely to be the case.

Analysis

The region between the cylindrical section of the pivot and its abutment shoulder at its upper end is an area where fatigue cracking might be expected to develop as

G-CCLB	Total airframe hours:	634
	Total number of flights:	794
	Estimated total number of landings:	1,659
G-CCUS	Total airframe hours:	517
	Total number of flights:	642
	Estimated total number of landings:	1,351

Table 1

this is an area where stress concentrations are likely to occur due to the fairly abrupt change in cross-section. In order to minimise such concentrations, an undercut/radius is incorporated. Although the radius is the most likely region for a fatigue crack to develop, both the failure of the nose wheel swivel/castoring pivot from 'LB and the cracking found in the pivot from 'US should not have occurred. In both cases, the material checks identified that the pivots were of a much lower strength than that specified, and this would seem to account for the shorter than expected service life. The reduced strength of the pivots was not considered to have been due to the slightly higher levels of manganese found in their composition, but more likely to have followed from the inappropriate heat treatment with respect to the SAE 4130 steel. In this case, it is likely that the heat treatment carried out resulted in a situation which possibly allowed the stress levels induced by normal in-service loading to be above the material's fatigue limit, ie, at a level which would be likely to precipitate fatigue cracking.

Safety action taken

On 11 November 2005 the aircraft manufacturer issued a Mandatory Service Bulletin (SB) DAI MSB40-046 which requires that a visual inspection of the upper shoulder radius of the nose landing gear swivel/castoring pivot, using a x10 magnifying glass, be carried out to look for evidence of cracks. (A dye penetrant inspection method can be used were there is doubt). This inspection is to be carried out on:

A. Airplanes operated on grass surface within the next 25 hours of operation, not later than 31 Dec 2005, and every 100 hours inspection thereafter.

B. Airplanes operated on paved surface within the next 100 hours of operation and every 200 hours inspection thereafter.

On 15 November 2005, the Austrian Civil Aviation Administration (Austro Control) issued Airworthiness Directive A-2005-005 which made the aircraft manufacturer's SB mandatory with effect from 23 November 2005.

Proposed further safety action

The aircraft manufacturer is exploring the possibility of increasing the strength of the nose landing gear wheel swivel/castoring pivot with a view to modifying or removing the requirement for the heat treatment process during manufacturing.

ACCIDENT

Aircraft Type and Registration:	Europa, G-BVOS
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	1988
Date & Time (UTC):	23 March 2006 at 1220 hrs
Location:	Sandtoft Airfield near Scunthorpe, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the landing gear and fairing, propeller, right wingtip and right flap
Commander's Licence:	Private Pilot's Licence
Commander's Age:	67 years
Commander's Flying Experience:	560 hours (of which 84 were on type) Last 90 days - 5 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot commenced the landing flare too early, stalling the aircraft and landing heavily, causing the right landing gear leg to collapse.

Background

The pilot was co-owner of the aircraft which originally had a 'mono-wheel' main landing gear. He and the other owner converted the aircraft to a 'tail-dragger' configuration. The conversion work took about a year during which time both owners did very little flying. Conscious of this fact, once the aircraft's landing gear conversion was complete, both owners each conducted their first flight in their modified aircraft with an experienced PFA coach, in order to regain their experience. The accident pilot completed his coaching flight in January 2006. The owners then conducted some further flying together in the days prior to the accident.

History of flight

The pilot completed a normal approach to land but stated that he commenced the landing flare too high. The aircraft stalled, landing heavily and the right landing gear leg collapsed. The right wingtip and flap mechanism then scraped along the runway until the aircraft came to a halt. Both occupants were able to vacate the aircraft normally and without injury.

PFA Pilot Coaching Scheme

The PFA describes its pilot coaching scheme as follows:

> *'The PFA Coaching Scheme provides members with a range of specialised training from type conversion to strip landing training. Diploma courses develop pilot skills, increase confidence and maximise safety. We are also able to offer the continuation training flight required for licence revalidation by experience through our national network of coaches. This also has the advantage of being conducted on your own aircraft from your home base. Becoming a better pilot is a goal of many members. It is our goal to help you achieve this.'*

Comment

The pilot was frank in his attribution of the cause of the accident and cited his lack of recent currency as a contributing factor. The PFA coaching scheme has laudable aims and the aircraft owners' decision to make use of it showed an equally wise response to their lack of recent currency. It is unfortunate that despite these precautions, the accident pilot appears to have misjudged the landing flare on this occasion.

ACCIDENT

Aircraft Type and Registration:	Jodel D120A Paris-Nice, G-BMLB
No & Type of Engines:	1 Continental Motors C90-14F piston engine
Year of Manufacture:	1965
Date & Time (UTC):	9 April 2006 at 1025 hrs
Location:	Lydd Airport, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left landing gear collapsed and left wing damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	158 hours (of which 27 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a takeoff with a crosswind from the left the aircraft went off the right side of the runway.

History of the flight

The pilot was using Runway 03 for takeoff on a local flight, which would have been his second flight of the year; his first flight had been on 6 April. The weather was good with a reportedly steady surface wind of 320º/12 kt which, on Runway 03, created an 11 kt crosswind component. The initial take-off run was normal until the pilot applied elevator control to raise the tailwheel from the ground. As the tailwheel came off the ground, the aircraft started to swing to the left. The pilot corrected for this swing with rudder but in so doing, he inadvertently started a yaw oscillation that he was unable to control. He closed the throttle as the aircraft went off the right side of the runway onto the grass. The left gear leg collapsed and the aircraft came to rest.

ACCIDENT

Aircraft Type and Registration:	MCR-01, G-TBEE
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2000
Date & Time (UTC):	2 October 2005 at 1159 hrs
Location:	Near Lymington, Hampshire
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:	53 years
Commander's Flying Experience:	1059 hours (estimated - of which 290 were on type) Last 90 days - 8:30 hours estimated Last 28 days - 6:30 hours estimated
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was flying a route which took it along the north shore of the western Solent when the accident occurred. Within minutes of the pilot's last transmission to ATC, and without any indication that he was experiencing a problem, the aircraft deviated from its course and descended to low level in the vicinity of the town of Lymington in an apparent attempt to land. Whilst manoeuvring at low level the aircraft was seen to pitch up and depart from controlled flight before descending steeply to the ground. The technical examination eliminated mechanical or structural failure as a cause of the accident but concluded that a partial engine failure may have contributed to it. Post mortem results raised the possibility that the pilot may have been medically incapacitated prior to the accident itself.

History of the flight

The pilot had intended to fly from Shoreham Airport in Sussex where the aircraft was based, to Dunkeswell Airfield in Devon where a 'fly in' event was being held. The pilot was accompanied by a passenger with whom he had flown on numerous occasions. There were other aircraft owners present in the vicinity during the pilot's pre-flight preparations, some of whom spoke to the pilot, though none described anything unusual until the point of engine start. One of those present recalled that, at that point, G-TBEE's engine was started but then shut down again after a short while. It appeared to be a normal shutdown, without faltering. The engine was started again and the aircraft taxied to the fuel pumps, arriving there at 1116 hrs.

There was CCTV coverage of the refuelling area which was made available for the investigation. The pilot initially requested 40 ltr of Avgas 100LL, but subsequently revised his requirement to 35 ltr. The refuelling supervisor recalled nothing unusual about the fuelling process or the aircraft's two occupants. However, the pilot did not start the engine and taxi immediately after completion of the fuelling paperwork. Instead he manhandled G-TBEE to the edge of the refuelling area where he and the passenger boarded the aircraft, and sat with the canopy open for some 5 minutes before eventually starting the engine and taxiing away.

The aircraft taxied to the holding point of Runway 02. A Cessna aircraft was also at the holding point and its pilot, who was familiar with G-TBEE and its owner, saw G-TBEE but did not recall seeing anything unusual about the aircraft. The Cessna departed first and headed west from Shoreham, and G-TBEE took off 3 minutes later at 1135 hrs. As the Cessna was flying west at 2,000 ft, G-TBEE overtook it on its right hand side at the same height with a separation of about 200 m. When G-TBEE had drawn ahead of the Cessna, it was seen to rock its wings in a pronounced manner, which the Cessna pilot took to be an acknowledgement by the pilot of G-TBEE that he had seen his aircraft. As G-TBEE was rocking its wings, the Cessna pilot saw it pitch up suddenly and briefly before recovering again to level flight. The pitch-up appeared to be the result of a deliberate control input. The extent or duration of the pitch-up was insufficient to cause a marked change of height, but was regarded as unusual by the Cessna pilot.

G-TBEE then continued on a westerly track which took it close to Chichester and overhead Portsmouth. The pilot made routine radio contact with Goodwood Airfield at 1142 hrs, and reported that he was maintaining 3,000 ft amsl. At 1152 hrs the pilot contacted Solent Radar, based at Southampton Airport; at this time he was overhead Gosport and flying at a reported 2,300 ft amsl. The pilot declared that he was routing to Calshot then Sandbanks; both are visual reporting points, located near the entrances to Southampton Water and Poole Harbour respectively. The pilot requested, and was given, a Flight Information Service (FIS) and advised that he would have to be below 2,000 ft when passing abeam Calshot in order to remain below controlled airspace.

G-TBEE was seen from another aircraft as it flew past the entrance to the Beaulieu River and appeared to be flying normally in straight and level flight. At 1157 hrs the pilot reported that he was abeam Calshot at 1,300 ft amsl and was instructed to contact Bournemouth Radar. The pilot acknowledged the frequency change, but no further radio calls were received from the aircraft, either on the new Bournemouth frequency or the Solent Radar frequency. The aircraft's radio was found after the accident to be selected to the Bournemouth frequency.

Although several witnesses reported seeing the aircraft in a steep descent, the ground impact was not seen and none of the witnesses realised that the aircraft had crashed. The wreckage was discovered in a field nearly an hour later by the land owner who contacted the emergency services at 1305 hrs. The fire brigade arrived on scene at 1312 hrs, followed a few minutes later by the ambulance service. Both occupants of the aircraft had sustained immediately fatal injuries.

GPS derived information (see Figure 1)

G-TBEE was equipped with a GPS navigation system that recorded the time, position, groundspeed, track and GPS altitude every 30 seconds during the flight. GPS altitude can be subject to substantial error but the recorded values suggested that for much of the flight, where the aircraft had apparently been flown approximately level, the GPS altitude had been accurate to within ±100 ft. Data from the GPS showed that the aircraft flew a steady track of about 255º(M) which took it along the north shore of the western Solent towards Lymington, flying at between 124 kt and 129 kt ground speed. The GPS data showed that, at the time the pilot made his last confirmed radio transmission, the aircraft was actually 3 nm west-south-west of Calshot, and only 1.5 nm from the accident site, the lateness of this transmission having been caused by the Solent frequency being blocked for a while with other transmissions.

At about the time of this transmission from G-TBEE, and about 2 minutes before the estimated time of the accident, the data from the GPS showed deviations from the previous steady state. The GPS altitude first showed a dip to 1,153 ft, and then the next point, 30 seconds later was recorded as being 1,318 ft (Position A, Figure 1). Both of these values were outside the narrow height band within which the aircraft had been flying during the few minutes since the aircraft had completed the descent requested by ATC.

Point A was the last recorded point on the aircraft's original track. The next and penultimate point (B) showed a GPS altitude of 1,234 ft and a reduced groundspeed of 95 kt. The average rate of descent from A to B was less than 200 ft per minute (ft/min), though this increased to about 1,400 ft/min between B and C. The next and final recorded point was 800 m from the previous, and almost due north of it, though the aircraft's track at this stage was just south of west, similar to that of the previous position. Groundspeed at C was 80 kt and the recorded GPS altitude was 513 ft. Based on the position

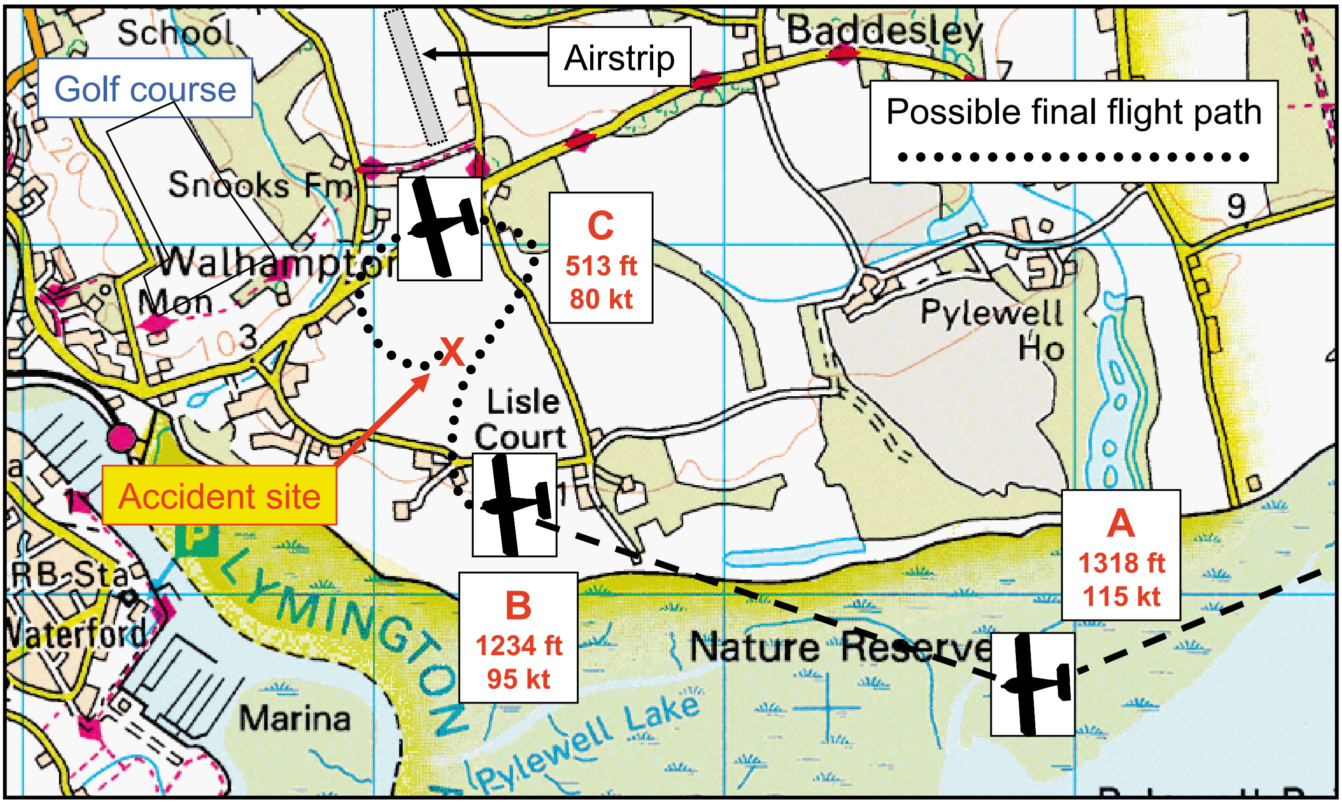


Figure 1

Accident area and GPS derived data

of the accident site and the time of the last recorded GPS position, the accident is estimated to have occurred at about 1159 hrs.

Witness information

Several witnesses reported seeing an aircraft matching the general description of G-TBEE but the accounts of its behaviour and how long it had been in the area differed. In general terms, witnesses reported seeing an aircraft manoeuvring at low altitude in the area of the accident site before pitching up and entering a steep final descent which it maintained until it disappeared from view behind trees. A witness on a nearby golf course (see Figure 1) reported seeing an aircraft flying in a left turn near to the south-eastern part of the course. It was quite low and gave the impression that it was in a gradual descent. Although there was some noise associated with the aircraft, it was not possible to say whether this was engine or airframe noise. As the aircraft was flying away from the witness, it was seen to pitch up with the left wing slightly low, until it reached a quite steep nose-up attitude. The aircraft then yawed and rolled to the left, eventually pointing steeply down as the aircraft descended quickly.

Some witnesses reported seeing the aircraft flying with a 'porpoising' motion prior to the final pitch up and some of these reported the aircraft being in view for several minutes beforehand. Other witnesses were not aware of the aircraft until shortly before seeing either a final pitch-up, roll and steep descent, or just the aircraft in its final descending attitude.

The timings of the various reports differed quite markedly, only two sightings being accurately matched to known times. One was from a car being driven along the road to the north of the accident site, which matched closely the last recorded GPS position and time. This witness saw the aircraft at an unusually low height in substantially straight flight, but with a gentle 'wing rock.' The other sighting was by a deck hand on a ferry in the Lymington River, who saw an aircraft circling at low level in the area for up to 5 minutes. The recorded docking time of the ferry showed that this sighting had been a few minutes before G-TBEE was known to have been in the area.

The accident site was 6.5 nm from Southampton Airport, but because the radar there was not recorded, it was not possible to trace or identify any other light aircraft in the area. Enquiries were made with local flying clubs and flying training organisations, in an attempt to establish if any of their aircraft were in the area at the time, but these were inconclusive.

Personnel information

The pilot had begun flying microlight aircraft in 1983 and accumulated approximately 700 hrs on microlights before converting to single engine piston types. During that time the pilot had undertaken a number of long distance or otherwise remarkable flights and had become well-known in microlight circles. The pilot trained on Cessna 152 aircraft and gained his Private Pilot's Licence (Aeroplanes) in 1999. He then flew Cessna 152 and Piper PA-28 aircraft until G-TBEE was completed in November 2000.

The pilot's last logbook entry was on 29 May 2005; last entries in the aircraft and engine logbooks were in February 2005. An assessment of total hours and recent flying experience was made with help from ATC records and the GPS memory log. Since the last logbook entry, the pilot is believed to have flown some 11 hours, taking his total hours on type to 360 hrs. In the 3 months preceding the accident the pilot had flown an estimated 8:30 hrs over 6 flights. Much of the pilot's flying time was spent touring, with frequent flights to Europe.

The passenger had flown in the aircraft on a number of occasions. In June 2004 she had commenced training towards a Private Pilot's Licence but completed only three lessons in a Cessna 152 before withdrawing from training due, it was believed, to work pressures. There is no record of her having undergone any further formal flying training.

Aircraft description

The MCR-01 VLA Sportster is one of a family of very light kit-built aircraft; the type is popularly referred to as a 'Banbi'. It has two seats, side by side, and is predominantly a carbon fibre composite structure with aluminium skinned wings and horizontal stabiliser. It is a high performance aircraft, marketed as having handling qualities akin to a fighter aircraft, with powerful and sensitive flying controls.

It is powered by a Rotax 912 ULS, horizontally-opposed water-cooled four-cylinder piston engine which drives a three-bladed variable pitch propeller through a reduction gearbox. The fuel system consists of a single fuel tank located between the cockpit instrument panel and the engine firewall. The fuel is fed through a coarse fuel filter to a stopcock, on the floor, located in the centre of the cockpit. It then passes through to the electric fuel pump, containing a fine fuel filter and the gascolator, forward to the mechanical fuel pump located on the side of the reduction gearbox. From there, the fuel is fed back through the firewall into the cockpit and passes through a fuel flow transducer and fuel pressure sensor, before returning forward through the firewall to the two carburettors. Unused fuel is routed back to the fuel tank by the use of a return line; this reduces the chance of vapour lock by ensuring a continuous flow of cool fuel through the system.

G-TBEE was equipped with a carburettor heat system which is an optional fit; aircraft kits are normally provided without such a system. The manufacturer, during development work, had taken measurements of the air temperature within the carburettors of the MCR-01, during normal operation. These were found to be some 15 to 20°C higher than the ambient air temperature. With this increased air inlet temperature, the likelihood of carburettor icing is considerably reduced and the addition of a carburettor heat system, when used, further reduces the chances of such icing.

The aircraft has manual flying controls, with feel augmentation by the use of elastic bands. The aileron and flap functions are combined using a single flaperon on each wing. The aileron function is controlled via push rods from the two control sticks, and the flap function is operated by an electric motor rotating a screwjack driving a flap carriage that transfers motion to the flaperon surface. The electric flap motor is controlled by two push buttons on each control stick. Microswitches, operated by the flap carriage, act as the flap travel limiters.

The rudder is cable-operated from adjustable foot pedals mounted to the floor. Pitch control is effected by an all moving horizontal stabiliser with a coupled anti-balance trim tab. The stabiliser is controlled by carbon fibre push rods operated by the control sticks. The anti-balance tab is operated by a fixed push rod connected between the tab drive-arm and a fixed bracket in the vertical fin. Pitch trim is effected by an electric motor driving a screwjack which positions a carriage connected to the stabiliser control push rod, via elastic bands. A second set of elastic bands connect between the stabiliser control push rod and the airframe structure at frame 7. These balance the forces exerted on the push rod by the pitch trim control elastic bands. As the trim motor drives the trim carriage, the spring forces of the elastic bands change the neutral position of the stabiliser control push rod and in turn change the trimmed position of the stabiliser. The pitch trim motor is operated by push button switches on each of the control sticks; there is no cockpit pitch trim position indication except for the control stick position and feel.

G-TBEE was fitted with an Angle of Attack (AOA) indication and warning system which was based on the angle of attack of the wing to the airflow. The system utilised the pressures from two ports on the wing, one on the upper surface and the other on the lower surface, and the pressures from the aircraft's static and pitot ports. The pressures were correlated, in a control unit, to calculate the wing's coefficient of pressure (C_{pw}), which had an almost linear relationship with the wing's angle of attack, over the measured range. For the system to operate correctly, two specific values of C_{pw} had to be determined during a calibration flight. One value was the C_{pw} in the 'zero lift' condition. The other was the C_{pw} at the AOA related to about 1.15 times the wing stalling airspeed; this was known as the 'angle advisory' C_{pw}. Having calibrated the device, it would have provided two means of identifying an impending stall. The first was by a visual indicator consisting of a bank of eight LEDs (two green, three amber and three red) in the cockpit; the LEDs illuminated in a sequence based on the calculated angle of attack, with green being normal flight through to the red showing a high angle of attack near the stall. The other was an audio voice warning, "ANGLE, ANGLE, PUSH", which was triggered when the 'angle advisory' C_{pw} was reached.

Accident site

The accident site was just over 1 km east of Lymington town, in a large open field amongst other fields and wooded areas. Immediately to the north of the field, across a small road, was a private grass airstrip, originally part of a wartime airfield. The airstrip was orientated north-south and was equipped with a small hangar and a windsock (Figure 1).

Evidence from the accident site indicated that the aircraft struck the ground with some left roll, yawed about 20° to the left and at a significant nose-down attitude. The aircraft's heading was about 005°M and the initial ground marks indicated a very high rate of vertical descent but with a small amount of horizontal speed; the aircraft travelled only 12 m before finally coming to rest. Following the initial contact with the ground, the aircraft bounced and yawed further to the left with the right wing pointing in the direction of travel. The nose leg then dug into the ground, causing the right wing to hit the ground. The main fuselage pitched over toward the right wing, detached from the left wing and the engine rolled over until it was inverted. During this sequence the fuel tank ruptured and spilt fuel across the field. Later wilting of the vegetation revealed that a large quantity of fuel was being carried but there was no fire. The aircraft finally came to rest on a heading of 319° M.

The propeller remained attached to the engine reduction gearbox. However, one of the three blades exhibited no signs of any damage; of the other two, only one blade was extensively damaged as this had entered the ground as the engine had inverted. The remaining blade had a large nick on its tip but otherwise was relatively undamaged. The propeller damage was consistent with an engine producing little or no power at the point of initial contact with the ground.

Detailed wreckage examination

The aircraft was taken to the AAIB at Farnborough for further investigation.

Engine and propeller

The engine was examined in detail with the assistance of the UK representatives for the engine manufacturer. A strip examination of the engine and carburettors did not reveal any pre-existing defects and their condition was consistent with an engine of its age running with Avgas 100LL as the main fuel. Because the engine had rolled inverted, any fuel in the carburettor float bowls had already dissipated; there were, however, no signs of debris in them. Due to the disruption to the engine and cockpit, it was not possible to establish the position of the throttle or the choke position at the time of the accident. This was also true of the carburettor heat control. A test of a sample of the coolant showed it to be a mixture of 42% water to 58% ethylene glycol.

The propeller examination did not reveal any pre-existing defects. During the accident the forces on the damaged propeller blade had caused the swash plate within the variable pitch mechanism to be forced onto the mechanical stop for coarse pitch; this was beyond the electrical stop microswitch. Witness marks on the shank of the damaged propeller blade revealed that the propeller blade pitch was set at its mid-range of about 24° at the time the propeller blade had made contact with the ground. The magneto ignition switch was found in the ON position and selected to BOTH. Later testing of the magnetos showed them to be satisfactory and the battery master switch was also found ON.

Flying controls

The rudder and flaperon controls were established to have been without fault and continuous prior to the accident. Measurements of the flap screwjack carriage, when compared to those on a similar MCR-01, indicated that the flaps had been set to a position of about 5° flap down. However, after allowing for minor differences in construction and set up between the two aircraft, the measurements indicated that the flaps had been positioned within the range between fully up and 5°.

The horizontal stabiliser control system was also determined to be continuous prior to the accident. During the examination of the system it was established that the aft-most pushrod, between the aft bell crank and the stabiliser, had been constructed from two pieces with an aluminium insert connecting the two halves. The upper half of the rod was found detached from the insert in a manner consistent with the probable forces on the rod as the aircraft struck the ground. The build manual for the aircraft indicates that the aft-most push rod should be constructed from a single carbon fibre tube.

Another anomaly was rub marks on the forward-most push rod consistent with contact with a cut-out in frame 7, just behind the seats. It was established that the cut-out was not to the dimensions stated in the build manual and that, when the rod was at its highest position, it rubbed against the right upper quadrant of the cut-out. The rubbing on the rod only occurred over a short distance and was in the mid-range of the horizontal stabiliser movement. As this error in construction had been in existence since the original manufacture of the aircraft and the friction forces it would have induced would have been negligible, it is unlikely that the pilot was aware of the rubbing.

The stabiliser trim system was also tested and found to be satisfactory. The elastic bands which attach between the trim carriage and the stabiliser push rod were still attached and consisted of the required five doubled-up bands at the upper and lower rod trim attachment points. The trim position was compared with a similarly constructed MCR-01 and was found to be about 9° stabiliser trailing edge down (aircraft nose down) compared to a full nose down position of 10° stabiliser trailing edge down. Differences in construction between the two aircraft could account for some error in the comparison. There was no evidence of any work having recently taken place on the anti-balance trim tab; however, there were signs of wear between the trailing edge of the stabiliser and the top of the leading edge of the trim tab, with little clearance between the two.

The AOA indication system was recovered from the aircraft, but damage sustained as a result of the accident forces precluded determination of its serviceability prior to the accident. An account from a friend of the pilot who had flown with him in G-TBEE, five or six weeks before the accident, indicated that the AOA system was not providing the appropriate alerts.

Fuel system

The fuel system was closely examined. Due to the accident, the fuel feed and return lines had become detached from the fuel tank. However, it was possible to establish that all the fuel lines, unions and fuel cock were free of any pre-existing defects. The fuel lines were checked for blockages and found to be clear. The coarse fuel filter and the fine fuel filter in the electric fuel pump were both clean. A test of the mechanical engine driven fuel pump was carried out and it was found to have a flow rate greater than that required by the engine.

Due to the rupture of the fuel tank and the engine being inverted, the only fuel from the aircraft that was available for a fuel sample was about 5 ml taken from the bottom of the electric fuel pump. This was analysed and found to be similar to Avgas 100LL, but the sample also contained Butylated Hydroxytoluene, a substance found in mineral oil. It was not possible to determine where this contamination may have come from, or what effect it would have had on the engine operation. A sample of fuel from the fuel bowser used to refuel G-TBEE on the morning of the accident was free of any contamination and conformed to the specification for Avgas 100LL.

Aircraft history

The aircraft was built, by the pilot, in 2000 and had completed approximately 300 flying hours. The last annual inspection, required for the renewal of the aircraft's Permit to Fly, had been completed in April 2005 at 286 flying hours. In September 2004, the aircraft suffered an engine failure in flight, resulting in a forced landing in a field. The examination of the engine, following this event, revealed contaminated spark plugs and severe corrosion in the carburettor float chamber. Extensive work was carried out on the engine, fuel system and the propeller which resulted in the aircraft not flying again until 12 January 2005. In April 2005, to resolve problems with engine starting, some components including the spark plug leads were replaced.

In May 2004, following problems with the electrical earth of the engine indication system, the AOA indication and warning system control unit was replaced. There was no record that a calibration flight had taken place following the installation of the new unit.

As part of the process for the initial issue of a Permit to Fly, G-TBEE was subjected to a flight test which was satisfactory in all respects. The flight test included exploration of the aircraft's stalling characteristics. It was determined that natural pre-stall buffet occurred at 69 kt with the wing flaps retracted and engine at idle power, and the stall itself occurred at 65 kt. The aircraft exhibited a wings-level, gentle nose-down pitch at the point of the stall.

Medical and pathological information

Post mortem examinations were carried out on the pilot and passenger. Toxicological analysis revealed no evidence of carbon monoxide inhalation and excluded the effects of alcohol intoxication or drugs as contributory factors in the accident. Both occupants had sustained severe multiple injuries, any of which could have been sufficient to cause death. Bruising on the body of the pilot was consistent with him wearing his four-point harness at the moment of impact.

The pilot was found to have been suffering from a liver condition in which excess fat accumulates within the liver cells. Medical opinion is that, particularly when combined with chemical imbalances in the body, this condition can be associated with collapse and sudden death, which is attributed to cardiac arrhythmia. Enquiries were made with the pilot's general practitioner into his medical history, but there was no record of the pilot having complained of any symptoms that may have been associated with the condition.

Meteorological information

An aftercast was obtained from the Met Office which described the weather conditions at the time of the accident. An area of high pressure was lying to the south-west of the British Isles feeding a fine, dry, northerly flow over southern England. There was scattered cumulus cloud in the area with a base of 3,500 ft to 4,000 ft, and very good visibility. The surface wind was from the north at about 12 kt. The surface temperature was 14ºC; the temperature and humidity at 1,000 ft and 2,000 ft, when plotted on the accepted chart to predict the likelihood of carburettor icing, indicated that there was a serious risk of such icing at all power settings.

Survival aspects

Harnesses

The accident was not survivable. The injuries to the two occupants indicated a high energy impact with very high peak deceleration. The pilot and passenger had both been wearing four-point harnesses and despite the high forces involved, the harness attachment points had remained intact. However, the pilot's harness became detached at the right lap strap adjustment buckle, with the harness pulling through the buckle. Similarly, the passenger's harness had also detached from the right lap strap adjustment buckle. In addition, the stitching between the shoulder straps and the piece of harness which attaches to the upper structural attachment point had totally failed on the passenger's harness and was stretched on the pilot's harness. The forces of the crash were outside the limits of human tolerance and, had the harnesses remained intact, this would not have altered the fatal outcome.

Search and Rescue

This accident was unusual in that the aircraft crashed in fine weather at a weekend, in a relatively well-populated area and, despite the pilot's recent contact with ATC, it was not realised that the aircraft had crashed until it was discovered by chance nearly an hour later. Although the two occupants suffered immediately fatal injuries in the accident, had they been less seriously injured their chances of survival may have been seriously prejudiced by the delay in attending to them.

The pilot had told friends of his intention to fly to Dunkeswell but he had not contacted the airfield itself, so his aircraft was not expected there. During the flight, the pilot was not required to contact Solent Radar provided he remained below 2,000 ft, which was the base of controlled airspace in the area. However, he requested and received a Flight Information Service (FIS) from Solent Radar. As the pilot was only receiving a FIS, which is a non-radar service, there was no requirement for the Solent Radar controller to formally identify the aircraft. For handover to Bournemouth, the arrangement was for the controller's assistant at Bournemouth to be passed the basic details of the aircraft, so that the controller there would at least have some information about the aircraft and its route when the pilot made initial contact. On this occasion it was actually the controller at Bournemouth who took the details of G-TBEE by telephone from Solent Radar.

Although the controller had been notified of G-TBEE's presence and intentions, there was no requirement for the pilot of G-TBEE to contact Bournemouth. However, other than deliberate failure to do so would have been poor practice. Nevertheless, the controller at Bournemouth stated that it was not unknown for pilots in similar circumstances to fail to make contact. It was only some time later that she realised that the pilot had not in fact done so and she became concerned. The controller contacted Dunkeswell at 1255 hrs and established that the aircraft had not landed there. The controller then contacted Solent Radar to say that the aircraft had not called, and learnt that the pilot had been transferred to Bournemouth at 1157 hrs. The Bournemouth controller instructed her assistant to contact other airfields in the area to see if the aircraft had landed at any of them. When this proved not to be the case, the assistant phoned the Distress and Diversion (D&D) centre at West Drayton at 1330 hrs. At 1339 hrs D&D called back to report that an incident had occurred in the New Forest, and then confirmed shortly afterwards that G-TBEE had been involved in an accident.

Analysis

General

The accident occurred to an experienced private pilot, in fine weather, over flat terrain. Within a minute of the pilot's last transmission to ATC, the aircraft deviated from the flight path which the pilot had stated he intended to follow and was seen by witnesses to be flying low and perhaps erratically in the accident area. The final descent as described by witnesses, and supported by evidence at the accident site, indicated that the aircraft suffered an aerodynamic stall after an exaggerated pitch up manoeuvre, leading to a departure from controlled flight. It is probable that whatever event prompted the route deviation and initial descent was also a causal factor in the accident itself. This analysis therefore concentrates primarily on the likely reasons for the apparently unplanned deviation from the stated intended flight path.

The route deviation

It is possible that the pilot deviated from his route intentionally, to practise a forced landing pattern, or simply to have a closer look at a ground feature. However, the pilot's normal practice when flying from one airfield to another was to do so expeditiously and he would rarely combine such flights with training exercises. Additionally, there was little of interest in the immediate accident area and neither occupant had any connection with the locality. There was also no record of G-TBEE ever having visited the private airstrip nearby. Indeed, the presence of the airstrip and the proximity of the town of Lymington would have acted to discourage unnecessary low flying in the area. The pilot had notified Solent Radar of his routeing, which was consistent with his known intentions of a transit flight to Dunkeswell. Although he was not required to, the pilot gave no indication to ATC that he might deviate from his route, and acknowledged the last instruction from Solent Radar to change to the Bournemouth Radar frequency without further comment. It is therefore very unlikely that the pilot had planned to depart from his route at the point he did.

If the route deviation was unplanned, it must have been brought about by an event which appeared to threaten the safety of the aircraft to the extent that an immediate landing was considered necessary, and the handling of which made a radio call to ATC a lower priority. Such events may include a significant engine malfunction, a serious control problem which prevented the pilot from maintaining cruise conditions, an in-flight fire and a medical incapacitation. The investigation considered the likelihood of each of these events being responsible for the aircraft's deviation from its route.

Engine malfunction

Examination of the engine ruled out a catastrophic failure but concluded that a partial power loss or a rough running engine remained a possibility, whether caused by carburettor icing, vapour lock in the carburettors or contamination of the fuel system. Had the pilot been experiencing engine problems for some time, and had he anticipated a precautionary or forced landing, then he might have tried to increase altitude initially (the aircraft was at 1,300 ft, some 700 ft below controlled airspace) and inform ATC of the problem, though neither of these occurred. If engine problems were encountered then the onset must have been sudden and severe enough to warrant an immediate landing. However, the engine magneto switch and master electrical switch were found in their normal 'flight' positions; if a forced landing without power were being attempted, these switches would normally have been selected off.

Carburettor icing

From the weather conditions on the day of the accident and using the generally accepted carburettor icing prediction chart, the aircraft was operating in a region which would give serious carburettor icing at any power.

G-TBEE had been equipped with a carburettor heat system; this is an optional fit as the aircraft kits are normally provided without such a system. Discussing the issue of carburettor icing with the manufacturer revealed that they had previously undertaken measurements of the air temperature within the carburettors of the MCR-01, during normal operation, and found these to be some 15 to 20°C higher than the ambient air temperature. With this increased air inlet temperature the likelihood of carburettor icing moves to the area of 'light icing at any power', and the addition of a carburettor heat system, when used, further reduces the chances of such icing.

Vapour lock

Another consideration was the possibility of vapour lock within the twin carburettors; this was because of the close routing of the exhaust to the tops of the carburettors. Discussions with the manufacturer revealed that vapour lock does sometimes occur, but is limited to ground operations and is usually experienced when attempting an engine start shortly after the engine has already been run and shut down which allows a heat soak of the engine due to the lack of a cooling air flow or a full flow of cool fuel. It is also of note that the vapour lock is more prevalent on aircraft operating with Mogas; G-TBEE was operated with the less volatile Avgas 100LL. Had vapour lock been evident this would have exhibited symptoms a lot earlier in the flight. Therefore, vapour lock was considered extremely unlikely.

Fuel contamination

Butylated Hydroxytoluene was found in the very small fuel sample taken from the aircraft's electric fuel pump. However, due to the size of the sample it was not possible to establish if the fuel was indeed contaminated or whether the contamination occurred during the accident sequence. It is known that the fuel that was used to refuel G-TBEE on the morning of the accident was clean, so any contamination would have had to have been present some time prior to the accident flight. The examination of the engine did not show any signs of contaminated fuel and the fuel tank, although completely destroyed and split open, also appeared clean.

Flying control malfunction

An extensive examination of the flight control systems identified no technical defect of the pitch control, pitch trim or flap systems that could have accounted for the pitching motion described by witnesses in the accident area or by the aircraft which left Shoreham at about the same time as G-TBEE. The trim and flap switches for this type are located on each control column top and, although it was known that they could be operated inadvertently, it is very unlikely that such inadvertent operation could have produced the described manoeuvres.

Had the pilot experienced a severe and un-commanded pitch excursion shortly after takeoff, it is probable that he would have returned to Shoreham as a precaution. In the event, he continued the flight and, from GPS data, the cruise appears to have been at normal cruise speed and at a steady altitude. Had there been a control problem in pitch which manifested itself again shortly before the accident, the pilot's most probable course of action would have been to maintain a safe altitude, if possible, while assessing the problem, and quite possibly notifying ATC.

The aircraft was positively identified flying low in slow, mainly straight flight in the region of the last recorded GPS position. If a malfunction of the flying control system had occurred then it was either intermittent in nature, or was not sufficiently serious to cause a loss of control from cruise flight. It is therefore improbable that a flying control malfunction could have been responsible for the pilot's decision to depart from his route and descend to low level in the accident area.

In-flight fire

There were no signs of a pre-impact fire either within the engine compartment or the cockpit area, and so an event of this nature could not have contributed to the accident.

Medical incapacitation

The pilot's extensive microlight background would have given him a great deal of experience of flying into unprepared sites. Combined with his considerable number of hours on type and the good weather and favourable wind of the day, this would make it improbable that he would have had significant difficulty making a successful landing in the area in the event of an engine malfunction, which is considered the most likely of technical scenarios. The investigation therefore considered the possibility of a medical incapacitation of some nature. It is unlikely that it was the passenger who would have been affected, since in this case the pilot would have tried to land at a place where medical help was available and, as two airports were close by, he would most probably have diverted to one of them.

The passenger's limited flying training had been carried out in Cessna 152 aircraft, a popular training type with appropriate handling qualities. In contrast, G-TBEE was a high performance aircraft, not suited to a novice pilot. Nevertheless, it is probable that the passenger would have been able to maintain the aircraft in straight and level flight if the pilot had suffered a complete incapacitation, though the undoubted stress of such a situation would make this uncertain. As the radio had been in recent use and she had obviously heard the exchanges with Solent Radar, there is the possibility that she would have attempted a radio call on either the Solent or Bournemouth frequency, but this did not happen. Given the passenger's very limited flying training, it would seem doubtful that she would immediately commit to a landing, although her familiarity with the aircraft as a passenger, combined with her training and the urgency of such a situation may have encouraged her to make an attempt.

It is possible that the pilot, recognising a developing situation and being aware of his passenger's dependence on his skills, initiated a landing attempt. The initial departure from the route appears to have been controlled and was towards a suitable area, suggesting that the pilot was either in control at this point or was able to influence the flight path. If this were the case, his condition must have further deteriorated, to the extent that his judgement and handling of the aircraft suffered, or the passenger had no option but to assume control. The eye witness account that the aircraft appeared to be rocking its wings when it was seen to the north of the accident site may indicate that the passenger was indeed in control of the aircraft, which was known to be sensitive in roll. Additionally, the pitch trim setting, at nearly full applied 'nose down' is not one which an experienced pilot would be expected to get to, given the known flight conditions.

The short-term effects of inhaling fuel fumes or exhaust gasses may have affected the pilot's ability to control the aircraft. However, although some fuel lines and components were located within the cockpit area, these were found to be free of pre-existing faults, and toxicological tests on the two occupants did not show that they had been exposed to carbon monoxide. The possibility that noxious fumes may have contributed to the accident is therefore considered unlikely. The post mortem examination raised the possibility that the liver condition from which the pilot was suffering could, in certain circumstances, be associated with incapacitation or sudden death. However, cases of this association being made as a cause of death are relatively few, and are generally restricted to those instances when no other potential cause of death is detected.

Final flight path

Analysis of the GPS data provided information regarding the final stages of the flight. The average ground speed between points A and B (Figure 1) is 105 kt, and a direct time/distance calculation between the points provides a groundspeed of 105.6 kt. Therefore it is probable that the aircraft flew a fairly direct line between A and B, and in this case point A is the point at which the aircraft deviated from its initial track.

Based on the available evidence, the most likely flight path between points B and C was in the form of an 'S' turn, whilst descending. The maximum time from point C to the point of impact is 30 seconds, since this is the time interval of the GPS recordings. The minimum time, based on a groundspeed of 80 kt and the most direct feasible flight path to the accident site is about13 seconds. Information from a witness that the aircraft appeared to cross the extreme south-eastern edge of the golf course in a left turn whilst descending only gradually suggests that the aircraft flew the longer of the two options. This would also mean that at least some power was being produced by the engine and this is supported by the cockpit switch positions. As the aircraft turned through a south or south-easterly heading, it appears to have entered the final manoeuvre which resulted in the accident.

A general view of the accident area from about point A is at Figure 2. The accident site can be seen to be in the largest field in the area and would have been an obvious choice for a landing, even before the aircraft reached point A. With the northerly wind, the pilot would have been well positioned to land in the field without extended manoeuvring. At this point, it is doubtful whether the airstrip to the north would have been obvious and, in any case, it would not necessarily have presented a better option than the large field.

As the field in which the aircraft crashed appears to be the largest and most suitable in the area, it may be expected that, if an immediate landing was desired, then by point B the aircraft would be lower and manoeuvring for a landing in a northerly direction, which does not appear to be the case. A view of the accident area from about 1,200 ft at point B is at Figure 3, which shows that, as well as the field itself, the airstrip and field to the north would have been available.

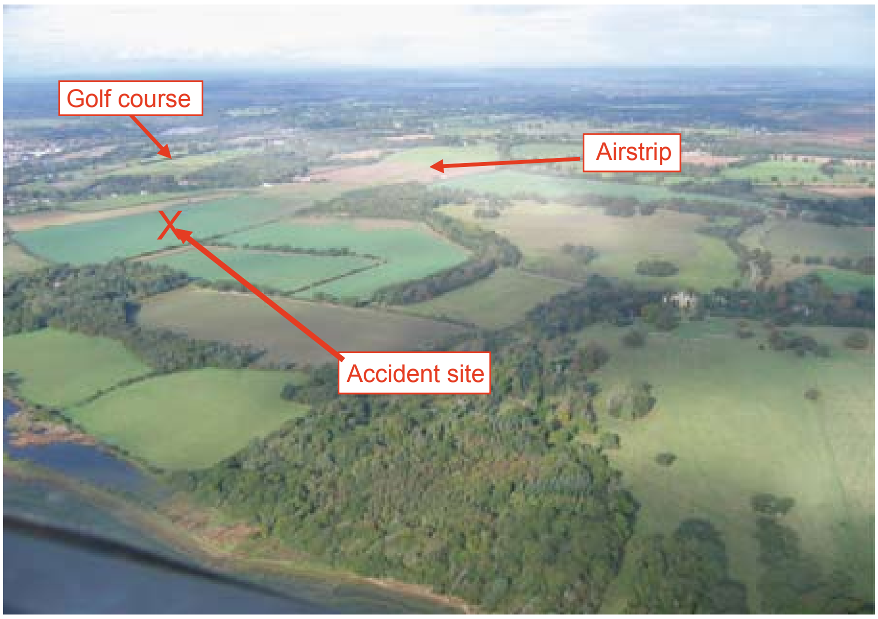


Figure 2 (left)

Accident area as seen from point 'A' of Figure 1 (page 96)

Figure 3

Accident area as seen from point 'B' of Figure 1 (page 96)

Eye witness accounts

Information from some witnesses indicated that G-TBEE had been in the area for several minutes before the actual accident, although this was not supported by the GPS data. The possibility that electrical power to the GPS failed, or that the aircraft electrical supply was deliberately isolated after the aircraft had arrived at low level in the accident area was considered but was not supported by the available technical evidence, including cockpit switch selections, and therefore thought improbable. Witness information from the ferry hand, which could be positively tied to the recorded docking time of the ferry, indicated that another aircraft had been in the area very shortly before G-TBEE. No witness reported seeing two aircraft together before the accident so, although it is unlikely that the presence of another aircraft in the area contributed to the accident in any way, it may have influenced the recall of some witnesses.

Conclusions

The aircraft may have suffered a partial loss of engine power, but this alone would not account for the accident. Furthermore, the nature of the terrain, the weather conditions and the pilot's experience would all suggest a more successful outcome to any forced or precautionary landing attempt. Alternatively, the pilot may have suffered from a medical incapacitation which either seriously degraded his ability to fly the aircraft to the extent that he lost control, or which forced his passenger to take control of the aircraft. The final aircraft manoeuvre is consistent with an aerodynamic stall and departure from controlled flight, resulting in an abrupt loss of lift at a height from which recovery was not possible.

ACCIDENT

Aircraft Type and Registration:	Pioneer 300, G-OPFA
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2004
Date & Time (UTC):	20 December 2005 at 1213 hrs
Location:	Gloucester Airport, Gloucestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to left landing gear, left wing tip and tail
Commander's Licence:	Private Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	660 hours (of which 65 were on type) Last 90 days - 60 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following an uneventful landing, the left landing gear collapsed during the taxi back to the parking area. The accident is believed to have been caused by a microswitch being knocked out of adjustment with the result that the left landing gear operating mechanism did not move into the over-centre position.

History of the flight

Shortly after departing from Gloucester Airport the pilot and his passenger both felt some airframe vibration, which the pilot identified as coming from the retracted nose wheel. He continued the flight in the local area and following an uneventful landing decided to undertake some further fault diagnosis during the taxi back to the parking area. The pilot stated that whilst carrying out several sharp turns to right and left, with a ground speed of approximately 12 kt, the left wing and tail of the aircraft sank to the ground. The propeller, which was still rotating under power, did not contact the ground. The pilot immediately shut down the engine, turned off the fuel and contacted Gloucester Tower, on 122.9 MHz, who dispatched the Aerodrome Fire Service.

Description of landing gear

The aircraft is equipped with an electrically operated, retractable tricycle landing gear. The landing gear electric motor is connected to a gearbox by a belt drive. The gearbox turns three screwjacks, which are connected to each of the landing gear leg operating mechanisms. As the screwjacks extend, the operating mechanisms move into the over-centre position, which then locks the landing gear legs in the down position. The system is equipped with down-lock and up-lock microswitches, which isolate the electrical power to the motor when the landing gear legs reach their extended or retracted position. However, the down-lock microswitch is triggered by a plunger connected to the body on the right landing gear screwjack. Operation of this microswitch signifies that this jack has extended by a certain amount but does not directly indicate that the operating mechanisms have moved into their over-centre positions.

The system also contains three cockpit warning lights. A green light illuminates when the down-lock microswitch operates and a flashing blue light illuminates when the landing gear moves between the up-lock and down-lock positions. A red light and buzzer will operate if the flaps are selected down and the down-lock microswitch has not operated.

Engineering investigation

The owner, who was the pilot on the accident flight, reported that the left screwjack failed approximately two thirds of the way along its length; there was also some distortion to the nose and right screwjacks. The part of the jack connected to the landing gear leg had then fallen downwards under gravity preventing the left landing gear leg from fully retracting into the wheel well, thus limiting the damage to the aircraft. On checking the operation of the down-lock microswitch the owner discovered that the microswitch would operate before the landing gear leg operating mechanism had moved into the over-centre position. The owner stated that on this aircraft it was occasionally necessary to remove the seat base in order to adjust the seat belts and it is possible that whilst adjusting the belts he had inadvertently knocked the down-lock microswitch. The owner believes that the accident occurred because the landing gear leg operating mechanism had not moved into the over-centre position and hence the landing load was taken on the screw jack, which subsequently failed during the sharp turns. The initial airframe vibration was believed to have been caused by the retracted nose wheel transferring engine vibration into the airframe, which only occurred when the landing gear was retracted and full right rudder applied.

Action by manufacturer and UK agent

The UK agent stated that neither they nor the manufacturer were aware of any instances of the landing gear collapsing, or the microswitches being knocked out of adjustment. However, the UK agent did confirm that the microswitch is very sensitive and that 1 mm movement of the microswitch could make the difference between the landing gear being locked and not locked down.

Following the accident, the UK agent wrote to all the owners in the UK, warning them of the potential problem and reminding them of the importance of adhering to the instructions in the maintenance manual. On 14 March 2006 the manufacturer issued Service Letter 2006/02, which introduced a transparent guard to prevent the landing gear microswitches from being accidentally knocked out of adjustment. The manufacturer is also working on a second modification to introduce additional microswitches that will only allow the landing gear cockpit warning light to illuminate once all the landing gear leg mechanisms have moved to the over-centre position. The PFA has been in discussion with both the UK agent and the aircraft manufacturer and intends to classify these upgrades as PFA mandatory modifications.

Comment

The accident appears to have been caused by the down-lock microswitch being out of adjustment, with the result that the left landing leg operating mechanism did not move into the over-centre position. It is possible that the sharp turns played no part in the failure of the screwjack and collapse of the landing gear leg. However, manoeuvring aircraft on the ground at relatively high speeds can place high loads on the landing gear and should, therefore, be avoided whenever possible.

The introduction of the modifications should increase the robustness of the system and provide the pilot with a positive indication that the landing gear is down and locked.

ACCIDENT

Aircraft Type and Registration:	Rans S6-ES Coyote II, G-BZKF
No & Type of Engines:	1 Rotax 582-48 piston engine
Year of Manufacture:	2000
Date & Time (UTC):	19 March 2006 at 1424 hrs
Location:	North Togston, near Amble, Northumberland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear, propeller and nose cowling
Commander's Licence:	Private Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	50 hours (of which 43 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

Following an engine stoppage in flight the pilot carried out a successful forced landing with minor damage. The engine was found to have seized due to lack of lubrication.

History of the flight

The aircraft took off from Eshott Airfield at 1335 hrs for a flight in the local area. Approximately 45 minutes later, whilst in the cruise, the engine began to run roughly and stopped. The aircraft was approximately 900 ft above the ground and the pilot immediately selected a field in which to carry out a forced landing. He attempted to restart the engine but, although this was successful, it continued to run roughly and he shut it down. The pilot carried out the forced landing, holding the aircraft off the ground as long as possible before touching down. The nose landing gear failed as soon as it contacted the ground and the aircraft pitched forward causing damage to the propeller and nose cowling. The pilot commented that the weather had been very wet in the few days prior to the accident leaving the ground in a waterlogged condition which may have contributed to the damage sustained during the forced landing. He exited the aircraft without injury.

The engine was examined after the accident by the pilot's usual maintenance organisation and was found to have seized. The engine fitted to G-BZKF is a Rotax 582-48 two cylinder, two-stroke, liquid-cooled engine. Generally these engines are designed to run on a mixture of gasoline and 2% oil. However, this particular engine had been equipped with an integrated oil pump. This delivers the exact amount of oil required for engine lubrication defined by the engine rpm and is supplied from a separate 2 litre capacity oil tank. The engine oil tank was found to be empty. The pilot stated that he checked the oil tank prior to flight and he noted that some oil was present.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna FA152 Aerobat, G-BGAF
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1978
Date & Time (UTC):	6 April 2006 at 1253 hrs
Location:	Southend Airport, Essex
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose landing gear, propeller, engine and wing
Commander's Licence:	Student pilot
Commander's Age:	24 years
Commander's Flying Experience:	20 hours (all on type) Last 90 days - 7 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On landing the student pilot flared the aircraft too high and then released back pressure on the control wheel, causing the aircraft to land heavily on its nosewheel which separated from its mountings.

History of the flight

During training with an instructor at Southend Airport, the student pilot completed three circuits and landings on Runway 24. The instructor was satisfied with his performance and instructed him to carry out three more circuits solo. The student reported that the first solo circuit and landing were satisfactory, but whilst attempting to land at the end of the second circuit, he flared the aircraft too high. As it began to drift to the left, he reacted by releasing back pressure on the control wheel, which caused the aircraft to descend rapidly and touch down heavily on its nosewheel. The aircraft bounced and drifted further left before coming to rest on grass near the left hand edge of the runway. The uninjured student vacated the aircraft before the AFRS arrived.

Visibility at the time of the accident was reported to be in excess of 10 km and there was no cloud below 5,000 ft. The surface wind was from 270° at 13 kt, giving a crosswind component of approximately 7 kt. The flying school's operations manual stated that student pilots should not fly solo if the crosswind component exceeds 8 kt.

Aircraft damage

The nose landing gear leg had broken off its mountings; the engine, propeller and one wing were damaged.

Discussion

The instructor, who had not flown with this student before, stated that during their flight together the student demonstrated an ability to cope with distractions and to position the aircraft correctly. On one occasion the student had noted that the aircraft was higher than usual on final and was able to correct the approach unprompted. The instructor commented, however, that it was difficult to assess the student's ability comprehensively in one flight and that another instructor, with whom the student flew more regularly, was more likely to have a thorough understanding of his abilities.

The student, who had flown solo only once before, considered that he had caused the accident by releasing back pressure on the control wheel. The school's Chief Flying Instructor reported that since the accident, the student has undergone training aimed specifically at improving his judgement and conduct of landings, including a reminder to execute a missed approach if a safe landing is not assured.

ACCIDENT

Aircraft Type and Registration:	Scheibe SF25E motorglider, G-BHSD
No & Type of Engines:	Limbach SL1700-EAI piston engine
Year of Manufacture:	1980
Date & Time (UTC):	13 December 2005 at 1445 hrs
Location:	Nene Valley Gliding Club, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Undercarriage collapsed
Commander's Licence:	National Private Pilot's Licence (UK)
Commander's Age:	68 years
Commander's Flying Experience:	466 hours (of which 17.5 were on type) Last 90 days - 17 hours Last 28 days - 5.5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and examination by the AAIB

Synopsis

After a normal approach and touchdown, the aircraft appeared to decelerate more rapidly than normal. On leaving the aircraft the pilot found that the monowheel landing gear had collapsed. An inspection of the aircraft revealed that the collapse was due to the failure of a previous poor quality repair to the landing gear swinging arm assembly.

History of flight

Whilst in flight, the pilot had shut down the engine of the motorglider and feathered the propeller in the horizontal position to carry out a 'glide' landing. After completing a normal circuit and approach the aircraft crossed the airfield boundary at approximately 55 kt, the pilot intending to touch down halfway down the runway to minimise taxiing. He reported that the flare and initial touch down were normal but that the aircraft decelerated rapidly and the 'ride' over the ground appeared to be firm. After leaving the aircraft it was discovered that the monowheel landing gear had collapsed. Inspection of the aircraft revealed that the swinging arm assembly attachment points had broken away from the surrounding structure, which showed clear evidence of previous weld repairs in this area.

Investigation

The aircraft was transported to a maintenance organisation where a full assessment of the damage to the aircraft was carried out. The failed sections of structure were dispatched to the AAIB for detailed investigation.

The fracture surfaces of both swinging arm attachment fittings showed regions of discolouration and surface corrosion, indicating that a crack had been present for some time prior to the incident. The crack had probably propagated due to a fatigue mechanism, but due to repeated contact between the crack faces no estimation of the rate of progression of this crack, or identification of any initiation sites, could be made.

Several weld repairs to the failed attachment fittings showed evidence of poor fusion, excessive bead build up and incomplete welds. A review of the aircraft's log book and repair history showed that there have been six occasions since June 1981 when the aircraft needed repairs to its landing gear and surrounding structure, due to damage and cracking, the last of which was in May 2000. However, it was not possible to ascertain details of the extent or exact location of these repairs.

Given the aircraft's repair history and the quality of welding observed on the failed structure, it is probable that this incident was the result of the progression of either undetected or incompletely repaired damage. It was not possible to identify positively when the weld repairs to the failed attachment points had been carried out.

ACCIDENT

Aircraft Type and Registration:	Stampe SV4C(G), G-BWEF
No & Type of Engines:	1 De Havilland Gipsy Major piston engine
Year of Manufacture:	1946
Date & Time (UTC):	19 November 2005 at 1140 hrs
Location:	Redhill Aerodrome, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right wing damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	15,800 hours (of which 7 were on type) Last 90 days - 150 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB

Synopsis

The aircraft struck a marker board whilst taxiing after landing. The marker board, which indicated the hold position for the displaced threshold of Runway 19, was correctly positioned and properly notified to aerodrome users. The pilot acknowledged that his lookout from the rear cockpit of the tailwheel aircraft had been inadequate. However, the investigation also revealed that communication between the aerodrome authority and the home-based flying organisations was not fully effective and a recommendation has been made for the establishment of regular formal meetings.

History of the flight

The pilot landed on Runway 08L at Redhill Aerodrome and vacated the runway to the left. He requested and was cleared by ATC to follow Taxiway 'A' back to his parking area. However, when G-BWEF was abeam Runway 19 threshold, the pilot turned left towards his parking area on the west side. Having crossed the western edge of the runway, the lower right wing of the aircraft struck the edge of marker board G3 which indicated the holding position for Runway 19. The weather was good with a light surface wind.

Aerodrome information

The runways at Redhill Aerodrome have grass surfaces, with associated marker boards indicating threshold positions. Each marker board is attached to two vertical metal structures, which are set into a rectangular concrete base. The markers are approximately 1.2 m wide and 1 m high. Each board is set at right angles to the runway direction and has a 'Day-Glo' covered square at each edge for improved conspicuity.

Marker board G3 was installed in August 2005 and was located some 40 m to the west of Runway 19 centre-line. Information about the new board was circulated to all home-based flying organisations and published on the aerodrome web site from the date of installation.

Other information

In his report, the pilot acknowledged that he was familiar with the aerodrome but his lookout from the rear cockpit had been inadequate. However, he also considered that the marker boards were poorly positioned, difficult to see edge-on and should be more frangible.

Since 2000, there has been one other report involving an aircraft colliding with a ground marker at Redhill. This occurred on 20 May 2001 and involved a Taylorcraft aeroplane colliding with metal poles which were marking an area of rough ground. The aerodrome authority confirmed that there had been no formal approach from any home-based flying organisations regarding the position or construction of the marker boards.

CAP 168 defines the dimensions of each runway strip, which should be kept clear of all obstructions except permitted aids to navigation. Runway 19 at Redhill is a Code 2 runway and as such, the area within 40 m of the centre-line was required to be free of obstructions. The aerodrome is subject to periodic inspections by the CAA Aerodrome Standards Department and the Authority was content with the positioning and construction of the marker boards.

Analysis

The collision occurred in good visibility when the pilot turned off the taxiway onto the grass towards his parking area. The position of marker board G3 had been promulgated and the pilot was familiar with the aerodrome. Although the forward visibility from most tailwheel aircraft is limited, the pilot has the final responsibility to ensure that his proposed route is clear. In this case, he acknowledged that his lookout had been inadequate.

However, the pilot also considered that the positioning of the marker boards is poor and that they are difficult to see when viewed side-on. Additionally, he considered that they could have been made of more frangible material. These points are relevant for a grass airfield where manoeuvring aircraft can include tailwheel types with restricted forward visibility. Nevertheless, enquiries confirmed that the positioning of the G3 marker board was in accordance with CAP 168, that the runway was correctly marked and that there was a designated taxiway. Furthermore, it is accepted that the priority of any marker boards sited outside the obstruction free area of the runway strip should be conspicuity and weather resistance rather than frangibility.

The investigation also indicated that communication between the aerodrome authority and the user flying organisations was not fully effective. Some home-based flying organisations considered that there was tension between them and the aerodrome authority regarding the marker boards whereas the aerodrome authority had reportedly received no complaints. Unlike most airfields, recently there had been no regular formal meetings between the aerodrome authority and the home-based flying organisations.

It would therefore be sensible for the aerodrome authority to establish regular formal meetings with the home-based flying organisations to monitor operating procedures and to enable any issues to be resolved at an early stage.

Safety Recommendation 2006-044

It is recommended that Redhill Aerodrome Ltd establishes a programme of regular formal meetings with flying organisations based at the aerodrome to discuss and monitor operating procedures.

Safety action taken

The aerodrome operator reported that there had been a users' committee for many years but meetings were suspended in 2004 because no agenda items had been put forward for some time. Since that time changes to aerodrome procedures or layout have been communicated to all Redhill based users and groups through e-mails.

In response to Safety Recommendation 2006-044 the aerodrome operator stated:

> *'Redhill Aerodrome Limited will consult with the based flying training organisations as to the benefits of re-establishing the User's Committee in addition to the consultation/notification presently undertaken by e-mail and the Redhill Aerodrome web site'.*

ACCIDENT

Aircraft Type and Registration:	Lindstrand 105A hot air balloon, G-RIMB
No & Type of Engines:	None
Year of Manufacture:	2002
Date & Time (UTC):	11 December 2005 at 1455 hrs
Location:	Darwen, Lancashire
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 3
Injuries:	Crew - None Passengers - 1
Nature of Damage:	Basket and burner support structure bent, arcing damage to burner
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	950 hours (all on type) Last 90 days - 20 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and information provided by the Met Office

Synopsis

The balloon encountered an unexpectedly strong wind during an attempt to land at the crest of a hill and collided with power cables. It was dragged along the cables until one set of flying wires broke and the basket fell about 12 ft onto a road. It was then dragged across the road by the envelope until finally coming to rest against a high stone wall.

History of the flight

The commander reported that after a normal takeoff in calm conditions the flight proceeded uneventfully in an easterly direction, with ground speeds between 7 and 20 kt at altitudes between 500 and 1,500 ft. The ground speeds were indicated on a handheld GPS carried in the basket. The commander was accompanied by the holder of a PPL (Private Pilot's Licence (Balloons)) and three fare-paying passengers.

After a flight of approximately 40 minutes the balloon approached a wooded area at the head of a valley running north to south at the foot of Darwen Moor. The commander was aware that the terrain beyond Darwen Moor was less favourable for landing. He had hoped that the local topography would cause the wind to veer sufficiently to carry the balloon into this valley for a landing in open ground. As the balloon descended, however, it became clear that it would not enter the valley and would instead need to climb over Darwen Hill (at the northern tip of Darwen Moor, one mile south-west of Darwen town centre) for a landing further to the east. Once clear of Darwen Hill, a descent was initiated into the next valley, during which the ground speed dropped from 20 kt to approximately 8 kt.

A landing site was chosen on ground which sloped gently upwards in the direction of flight towards the crest of the next hill. However, the presence of several power and telegraph lines prevented an approach at hedge height to the chosen landing site and, after clearing all of them, a final descent was initiated from approximately 150 ft agl with a ground speed of 10 kt. The commander reported that the descent seemed slow at first and was "encouraged" with a very short pull on the parachute line[1], but on passing 25 ft agl the descent accelerated and a short burn was used to slow the approach. Immediately afterwards, the balloon, which was then descending "positively", encountered a strong wind which carried it 50 m further up the landing field than intended. The pilot opened the parachute vent and estimated that the balloon touched down at a speed of 25 to 30 kt, causing it to drag across the ground for a further 50 m. The strong wind then picked up the partially deflated envelope which, acting as a sail, carried the entire aircraft another 100 m downwind at a height of approximately 8 ft, over two substantial wooden fences and across a narrow road.

Initially, the basket came to rest against a telegraph pole supporting a set of insulated power cables which ran north-west to south-east along the west side of the road. The envelope, which had drifted beyond the cables, pulled the basket upwards until the burner frame rested against them. At first, there was no electrical arcing and the pilot was able to isolate the burner fuel supply. However, the balloon was dragged along the power cables in a south-easterly direction until the basket came to rest against the next telegraph pole. Chafing of the balloon's flying wires during this motion resulted in arcing, which caused one set of flying wires to break. The subsequent sudden movement of the balloon caused the power cables themselves to break which in turn allowed the basket to fall approximately 12 ft to the road. It was then dragged across the road by the envelope until finally coming to rest against a high stone wall. The envelope was draped over trees and the roof of a nearby house.

Footnote

[1] The parachute line opens a section of the envelope, which allows hot air to escape, thus reducing the buoyancy of the balloon.

Injuries to persons

The PPL holder and the two younger passengers, one of whom may briefly have been unconscious, sustained bruising. The older passenger, contrary to the commander's briefing, had put his arm outside the basket and had sustained cuts to his hand and elbow, both of which required stitches. The commander sustained bruising and scratches, some of which were caused when the spectacles he was wearing broke during the accident sequence. Police, fire and ambulance services arrived shortly afterwards and the air ambulance was called to take the older passenger to hospital. The two younger passengers were taken to hospital by road. The commander stated that he and the PPL holder did not require medical assistance.

Damage to the balloon

Members of the emergency services assisted with the recovery of the balloon envelope which was severely damaged. The basket top-tube was twisted and the burner sustained damage from the various impacts and from electrical arcing. The commander stated that the basket and envelope were repairable but that the burner required replacement.

Other damage

The location of the second touchdown of the basket was indicated by a rectangular impact mark in the field adjacent to the power lines and by scraping of the grass corresponding to the direction of subsequent drift of the balloon.

A power line and a telephone cable running to the house were broken but no other damage to property was evident.

Meteorological information

Pilot report

The commander reported that he obtained a weather forecast prior to the flight, which indicated a surface pressure of 1036 hPa. He extracted from Form F214[1] information for position 52°30'N, 002°30'W, which indicated a 10 kt wind from 270° at 1,000 ft and a variable wind of 5 kt at 2,000 ft. He recalled that the North and Central regional ballooning wind forecasts obtained from the Met Office indicated a westerly surface wind of 2-7 kt.

Met Office report

An aftercast provided by the Met Office indicated an area of high pressure centred over south-west England feeding a moderate to fresh westerly flow over northern England, becoming stronger further north. Radiosonde ascents from locations around the accident site indicated a marked inversion between 1,000 and 3,000 ft amsl. The estimated wind at the accident location was from 270°, with a speed of 15-18 kt both at sea level and at 500 ft amsl. The accident occurred near position 53°41'N, 002°26'W. Inspection of Form F214 valid for 1500 hrs on 11 December 2005, interpolating between data for position 52°30'N, 002°30'W and position 55°N, 002°30'W, suggested that the local wind at 1,000 ft amsl would have been from 260° at 17 kt.

The regional ballooning forecast for the North area, valid from midday to dusk on 11 December 2005 predicted a surface wind from 230° at 7-10 kt, increasing to 12-15 kt locally and 8-12 kt generally in the north of the area. In discussions with the AAIB, the Met Office commented that stronger winds would be likely over higher ground due to topographical forcing which may have existed between the Pennines and the inversion.

Operator's limitations

The operator's Operations Manual, approved by the Civil Aviation Authority, stated that:

> *'The balloon shall not normally be operated in a wind speed exceeding 8 kt at the surface, and not in wind speeds between 8 kt and the flight manual limit of 15 kt without the specific approval of the Chief Pilot'*

Because the commander was the operator's sole commercial pilot, he was in effect the Chief Pilot and able, therefore, to authorised himself to operate in a wind speed up to 15 kt.

Landing site information

The landing site was on gently rising ground near the top of a ridge whose summit is at 1,063 ft amsl. Upwind, approximately 2 nm to the west of the landing site, the northern tip of Darwen Moor rises to almost 1,300 ft amsl. This promontory is visible in the background of the photograph in Figure 1. The area is dominated by numerous hills and valleys, aligned broadly north-south, with typical gradients of approximately 7%.

Footnote

1 UK low level spot wind chart, produced by the Met Office, which showed forecast winds at various levels at intervals of 2°30' of latitude and 5° of longitude.

Figure 1
View west towards Darwen Hill

The touch down area was crossed by two sets of telegraph wires running north to south. A line of high tension cables and associated pylons, whose path is marked on the relevant Ordnance Survey "Explorer" 1:25,000 map (one of which was carried in the balloon), was aligned with the ridge downwind of the road and garden wall where the balloon finally came to rest. The surface was predominantly rough grass which was damp and flattened. During the approach, most of the visible trees were deciduous and had no leaves.

Recorded data

A handheld GPS, carried in the balloon and switched on during the flight, was successfully downloaded. The data points recorded provided Latitude, Longitude and GPS time but no altitude information. The difference between the locations of the data points and the time taken to travel between them was used to generate an average speed between the points. Similarly, the bearing of the line between data points was used to calculate mean track direction.

The flight recorded on the day of the accident started at 1402 hrs UTC, lasted 52 mins and covered 12 nm. The flight path of the accident flight is shown in Figure 2. Figure 3 shows a plot of the average ground speed of the GPS unit between the recorded track points. Figure 4 shows the end of the flight overlaid on an aerial photograph, aligned by reference to photographs of the landing points provided.

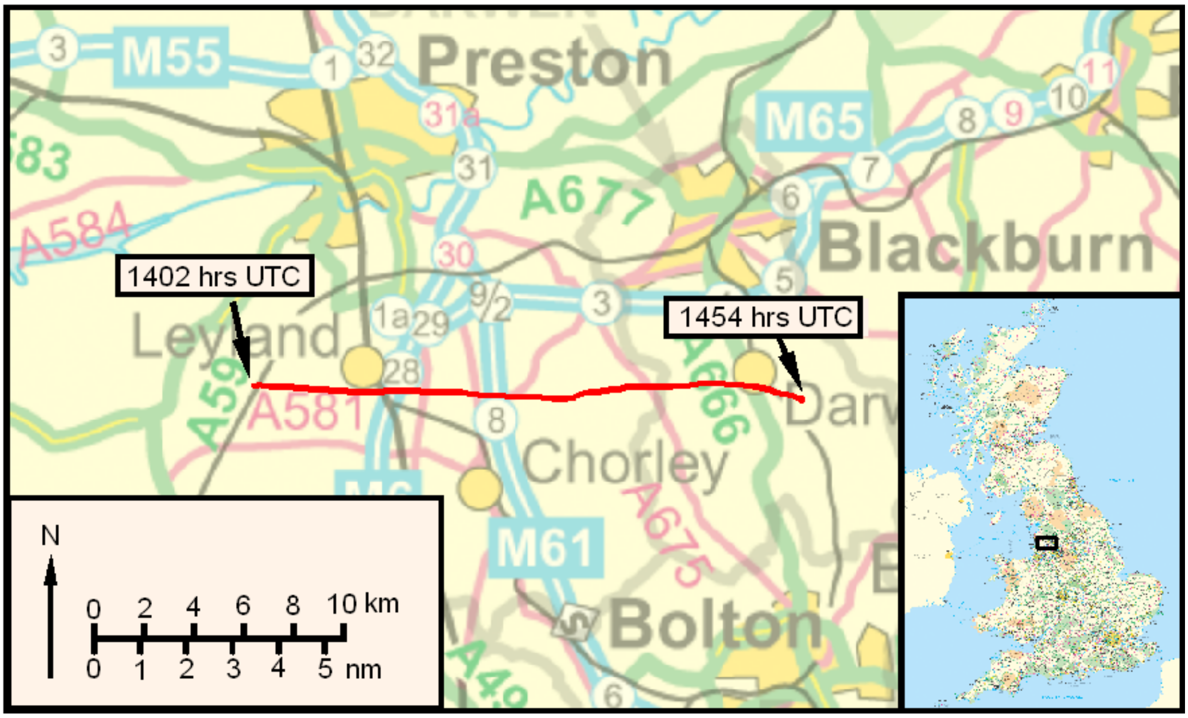


Figure 2

Flight path overview

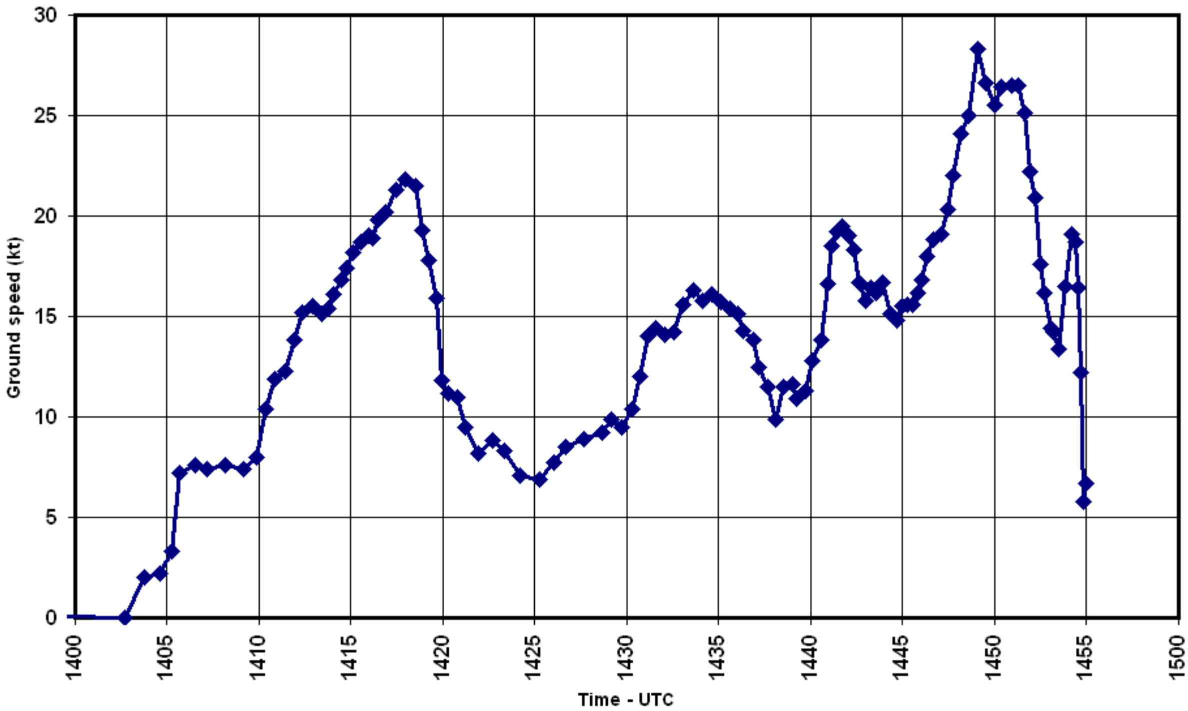


Figure 3

GPS speed

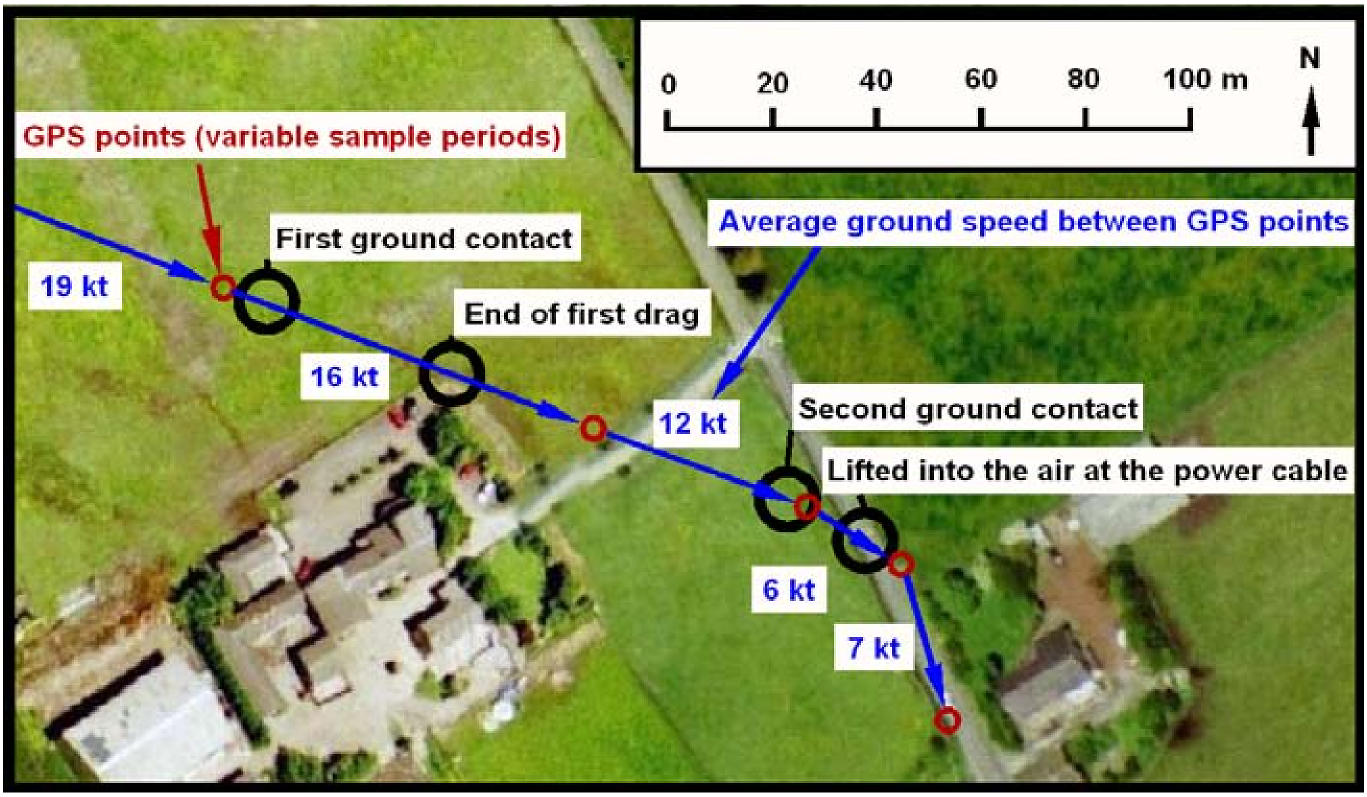


Figure 4
Final flight path

The ground speed of the balloon rose to approximately 22 kt during the first 15 minutes of flight. It then dropped to about 7 kt during the next 7 minutes and then climbed again, peaking at just over 28 kt, 5½ mins before the first touch down. The average ground speed between points then reduced to a minimum of just over 13 kt and climbed again by 6 kt in less than a minute, with an average 19 kt ground speed in the 21 seconds before the first touch down.

Survival aspects

Hand holds were provided inside the basket for each passenger in accordance with the requirements of CAP 494 – *British Civil Airworthiness Requirements, Part 31 – Manned Free Balloons*, published by the CAA. There was no requirement for additional passenger restraints, such as harnesses. The passengers stated that they received a safety brief, in accordance with the provisions of CAP 611 – *AOC Operation of Balloons*, prior to departure. This included the instruction to make use of the hand holds and to keep all parts of the body within the basket during landing. Those occupants who complied with the safety brief appeared not to have suffered serious injury.

Other information

The pilot of the air ambulance that attended the scene stated that he was surprised to encounter a marked increase in wind strength at 200 ft agl. He aborted his first attempt at landing and flew a clover leaf pattern in order to assess the lower wind strength and direction. He commented that during his second approach he had to use an unexpected amount of tail rotor thrust to turn against the wind.

Analysis

The '*Handboook of Aviation Meteorology*', published by the Met Office, suggests that the wind speed at the surface, over land, will be "about one third to one half of the geostrophic value[1]. The widely accepted practical application of this statement is that the wind speed at the surface over land will be approximately half that at 2,000 ft. The commander's interpretation of meteorological information available before the flight indicated that surface wind speeds would not exceed 10 kt during the intended flight. On that basis, he had a reasonable expectation of operating the flight within the provisions of his Operations Manual. An estimate for the latitude at which the flight was conducted, based on data for position 52°30'N, 002°30'W and position 55°N, 002°30'W, would have indicated that the wind speed might be higher. The regional ballooning forecast for the North area, valid for the duration of the flight estimated a maximum surface wind speed of 15 kt.

Local topography can have a significant effect on surface wind speed, however. For example, an air mass will accelerate as it approaches the crest of an isolated hill and decelerate on the other side. The presence of an inversion will exaggerate this effect because it acts as a barrier and forms, with the hill, a venturi in which pressure decreases locally but wind speed increases. The air mass will also accelerate around the nose of a promontory. Strong winds, steep slopes and the presence of other hills and valleys will complicate this process greatly. The terrain over which the accident flight passed comprised a series of hills and valleys and, immediately downwind of the landing site, a promontory. The wind encountered in the valley preceding the touchdown was relatively calm but it accelerated as it approached the crest of the hill upon which the landing was attempted. Textural evidence of local wind conditions, such as the movement of leaves and grass, was not available because of the season and recent weather. Recorded evidence suggested that indications of ground speed provided by the GPS would have confirmed the commander's assessment that wind speed was reducing to acceptable levels as the balloon approached the landing site, but that very shortly before touchdown, it increased to a speed at which a normal landing could not be accomplished.

Footnote

[1] The wind speed calculated from pressure gradient, air density, rotational velocity of the Earth and latitude.

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2004

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

Published February 2004.

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

Published April 2004.

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

Published June 2004.

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

Published July 2004.

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

Published August 2004.

2005

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

Published February 2005.

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

Published November 2005.

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

Published December 2005.

2006

1/2006 Fairey Britten Norman BN2A Mk III-2 Trislander, G-BEVT
at Guernsey Airport, Channel Islands
on 23 July 2004.

Published January 2006.

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