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None

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ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

ACCIDENT

Aircraft Type and Registration:	Boeing 777-222, N786UA
No & Type of Engines:	2 Pratt & Whitney PW4090 series turbofan engines
Year of Manufacture:	1997
Date & Time (UTC):	26 February 2007 at 1000 hrs
Location:	London (Heathrow) Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 20 Passengers - 185
Injuries:	Crew - None Passengers - None
Nature of Damage:	Heat and fire damage to the right main power distribution panel, surrounding structure and components inside the Main Equipment Centre
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience: (Hours all approximate)	18,000 hours (of which 2,800 hours were on type) Last 90 days - 215 hours Last 28 days - 65 hours
Information Source:	AAIB Field Investigation

The investigation

The aircraft operator's duty manager at Heathrow notified the Air Accidents Investigation Branch (AAIB) of the accident at 1140 hrs on 26 February 2007 and the investigation commenced the next day. The Chief Inspector of Air Accidents has ordered an Inspector's Investigation be conducted into the circumstances of this accident under the provisions of the *Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*. This is a preliminary report detailing the facts of the accident: no analysis has been attempted.

History of the flight

The aircraft was pushed back from the stand with the auxiliary power unit (APU) running, the towbar was disconnected and both engines were started in quick succession. The flight crew, comprising a commander, operating co-pilot and relief co-pilot (occupying the jump seat), reported that the engine starts appeared to be normal. At about the time when the engine integrated drive generators (IDGs) would normally come online, the flight crew saw the instrument displays flicker and heard a low-pitched, intermittent growling noise coming from the aft right side of the flight deck. A

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

few seconds later, they received an Engine Indication and Crew Alerting System (EICAS) caution for 'ELEC AC BUS R', indicating that the right Main AC Bus had failed. The right 'GEN CTRL OFF' light also illuminated on the overhead panel, which indicated that power had been cut from the right IDG. Subsequently they observed that, on the 'R BUS TIE' switch, the 'ISLN' caption had illuminated, which indicated that the right bus tie breaker had been triggered to open.

The Flight Data Recorder (FDR) revealed that 40 seconds after both engines had stabilised at ground idle, the smoke detector inside the Main Equipment Centre (MEC)[1] detected smoke. Coincident with this, the Cockpit Voice Recorder (CVR) recorded sounds of equipment powering down and crew comments to the effect that the whole right main bus had failed.

The flight crew selected the EICAS 'ELEC AC BUS R' irregular checklist and completed the first action of selecting the right generator control switch to OFF and then to ON again. About two and a half minutes after the electrical failure they became aware of a faint electrical burning smell and shortly afterwards noticed the 'EQUIP COOLING OVRD' message on the EICAS. At this point the commander ordered the co-pilot to shut down the right engine.

The ground handling crew observed smoke emanating from the MEC vent at the front of the aircraft and alerted the flight crew. Two minutes later ATC advised that smoke had been seen coming from the aircraft and that the fire service had been requested to attend as a precaution. The aircraft was taxied onto a nearby stand using the left engine. Once on stand the flight crew shut down the left engine and the APU, by which time light smoke was present in the flight deck. ATC further advised that smoke had been seen coming from the forward outflow valve. Approximately twelve and a half minutes after the electrical failure the batteries were switched off and the passengers and crew disembarked the aircraft via steps placed at door 2L.

Airfield Fire Service personnel checked the aircraft's MEC, which was filled with smoke, but did not detect any fire. They manually opened the forward cargo compartment and removed two cargo pallets to check for any additional signs of fire, but none were found. The smoke slowly cleared in the MEC to reveal obvious signs of fire damage.

Smoke detection within the Main Equipment Centre

A smoke detector is connected to the supply and vent lines of the Forward Equipment Cooling System within the MEC. When smoke is detected, the cooling system transitions to override mode and an 'EQUIP COOLING OVRD' message is displayed on the EICAS. The override mode relies on a differential between the cabin and ambient pressure to vent smoke. This method is ineffective whilst the aircraft is stationary on the ground. However, no Master Warning, Master Caution or 'smoke' message is triggered.

Electrical power distribution

The electrical power system on the Boeing 777 normally operates as two independent l power channels. Each channel has a Main AC Bus. During normal flight operations the Left Main AC Bus receives power from the left engine IDG and the Right Main AC Bus receives power from the right engine IDG. On the ground, the APU or external power sources can be used to provide power to both main busses. A top level schematic of the

Footnote

[1] The MEC is located beneath the flight deck and contains the majority of the aircraft's electric and avionics equipment. The FDR parameter which indicates smoke in the MEC is identified as 'EE Bay Smoke Warn'.

power distribution system is shown in Figure 1. The flow of power is controlled by contactors which open and close; seven contactors are shown in Figure 1 which include the right generator circuit breaker (RGCB) and right bus tie breaker (RBTB). The RGCB, RBTB and Right Main Bus are components of the P200 Electrical Load Management System (ELMS) power panel located in the right forward section of the MEC.

Damage to the aircraft

An inspection inside the MEC after the accident revealed extensive heat and fire damage to the P200 power panel as shown in Figure 2. The worst affected components of the power panel were the RGCB and RBTB contactors, parts of which had melted and vaporised. There was evidence that molten metal had dripped down onto the insulation blankets beneath this panel. Extensive fire damage to the fire-retardant insulation blankets located behind and beneath the power panel under the floor, had occurred as shown in Figure 3. Nearby components including a floor panel, equipment cooling system ducting, other wire bundles and some structural frames and stringers in the vicinity were later determined to have suffered sufficient heat damage to require replacement.

Detailed examination

The P200 power panel was removed from the aircraft for a more detailed examination. The examination revealed that both the RBTB and RGCB had suffered from extreme heating and electrical arcing. The main moveable contacts within both contactors were destroyed. There was some insulation damage to the bus bars within the panel in the vicinity of the RBTB. The damage to the surrounding components of the power panel appeared to be a consequence of a failure within either the RBTB or RGCB.

History of the contactors

The serial numbers on the RBTB and RGCB contactors were unreadable as a result of the fire damage, but an initial inspection of the aircraft's maintenance records revealed that neither component had been replaced since the aircraft was manufactured in 1997. At the time of the accident the aircraft had completed 6,622 flight cycles and flown for 43,519 hours. The RBTB and RGCB share the same contactor part number and there is no maintenance requirement to replace either contactor after a fixed time or flight cycle period.

Previous incidents and preventative action

Prior to this accident the aircraft manufacturer was involved in investigating 11 in-service reports of power panel overheat events, three of which involved major damage to the panels. The affected panels were the P200 and P300, and the affected contactors were the RBTB, Auxiliary Power Breaker (APB)

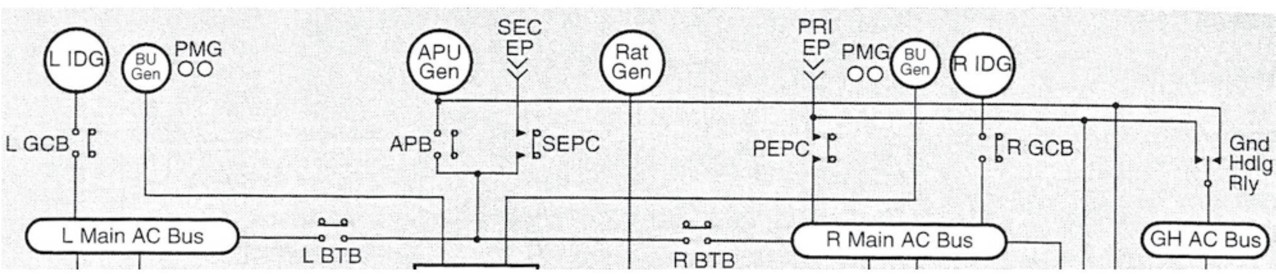

Figure 1

Boeing 777 electrical power distribution schematic

Figure 2

Fire damage to P200 panel, showing burnt-out RGCB and RBTB contactors
(panel cover has been removed in this photograph)

and the Primary External Power Contactor (PEPC). These previous events all involved Boeing 777 aircraft fitted with ELMS II power panel, which is a modified version of the ELMS I power panel fitted to N786UA, although many components including the contactors are the same. As a result of these incidents the aircraft manufacturer published details of preventative action that operators could take, in its 777 Fleet Team Digest No 777-FTD-24-06005.

Further investigation

The AAIB is working with the US National Transportation Safety Board (NTSB), the aircraft manufacturer, the aircraft operator, the power panel manufacturer and the contactor manufacturer to try and determine the cause of the failures within the electrical power system. Further investigation is also being carried out into understanding how the fire spread and how to improve fire protection within the MEC. The AAIB will publish a full report on this accident when the investigation has been completed.

Figure 3

Burnt aircraft structure and insulation blankets located directly below P200 panel (viewed looking aft with floor panel removed)

Published April 2007

INCIDENT

Aircraft Type and Registration:	Avro 146-RJ100, G-CFAA
No & Type of Engines:	4 Lycoming LF507-1F turbofan engines
Year of Manufacture:	2000
Date & Time (UTC):	20 September 2006 at 2037 hrs
Location:	40 miles south of Edinburgh
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 51
Injuries:	Crew - None Passengers - None
Nature of Damage:	Internal damage to No 2 engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	7,500 hours (of which 600 were on type) Last 90 days - 154 hours Last 28 days - 66 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, and further AAIB enquiries

Synopsis

During the descent into Edinburgh, smoke began to fill the flight deck. The No 2 engine was identified as defective and was shut down. The aircraft landed safely and was then ferried to a maintenance base where the defective engine was changed but, on the first flight afterwards, smoke again filled the flight deck.

It was concluded that, on the first occasion, a bearing failure lead to seal damage and contamination of the air conditioning system. It appeared that residual oil in the system, resulting from the initial failure, had not been eliminated during the rectification and was responsible for the second event.

This AAIB Bulletin reports on both events. AAIB file EW/G2006/09/22 relates to the event which took place on 20 September 2006, and AAIB file EW/G2006/09/26 refers to the second event which occurred on 26 September 2006.

History of the flights and technical actions

The aircraft was descending through FL120 en route to Edinburgh when the crew became aware of fumes on the flight deck. Oxygen masks were donned. A low oil pressure was then noted on the No 2 engine, and the crew shut the engine down. The Quick-Reference Handbook (QRH) actions for engine failure/shutdown and smoke on flight deck/in the passenger cabin were carried out and a 'PAN' call was broadcast. An approach was made to Runway 24 and the aircraft was landed and taxied onto the nearest available stand. A precautionary rapid disembarkation was then carried out.

The aircraft was subsequently ferried to the operator's maintenance base at Birmingham where the No 2 engine was changed and other work carried out. It was confirmed that a bearing failure had occurred. The aircraft was in maintenance for approximately a week before being returned to service on 26 September.

At Birmingham International Airport the crew reviewed the Technical Log in preparation for the first flight following the rectification and accepted the aircraft as fit for service. They noted that, according to the Technical Log, the No 2 engine had been replaced, engine test runs had been carried out and the air-conditioning packs and ducting had been checked for traces of contamination.

The aircraft then took off with the first officer acting as the Pilot Flying (PF). Initial climb was normal and flaps were retracted on schedule. Immediately after the air supply was changed over to 'ENGINE' and the APU was shut down, dense smoke rapidly filled the flight deck. At this time the aircraft was in the climb, passing approx 3,500 feet, climbing towards FL60 and following the Daventry 4D departure. Engine air was quickly turned off and APU air selected. The APU was then re-started and, as the APU air entered the aircraft, the smoke started to clear very slowly.

At this point the cabin crew informed the flight crew by intercom that the cabin was full of smoke; the crew responded that they had stopped the source of the smoke and were in the process of clearing it. Whilst this was happening, the aircraft communication was transferred to the London Control frequency, which was selected but not contacted. The aircraft had by then levelled at FL60 and was following the Standard Instrument Departure. Both pilots then carried out the QRH memory items for smoke, fumes or fire on the flight deck and donned oxygen masks. They then carried out the After Take-Off check-list and part of the QRH to the extent that time permitted. In accordance with guidance in the QRH, they made a decision to land as soon as possible.

London Control then called, as they had yet to hear from the aircraft. The crew requested an immediate return to Birmingham Airport. They then called Birmingham on the Approach/Radar/VDF frequency, transmitted a 'PAN' call and requested vectors to the ILS of Runway 33 to land. In view of the fact that the smoke was clearing, a 'MAYDAY' call was not made and evacuation using slides was not anticipated. The cabin air control was selected to 'FRESH' to help with smoke removal. The cabin crew were informed by intercom that the aircraft was returning to Birmingham as this was an emergency but that the landing was expected to be normal and use of evacuation slides was not expected.

The Purser in charge made calls on the Public Address (PA) system to the passengers and informed them that the crew had the situation under control and they were returning to Birmingham. Passengers were advised to keep their heads low to avoid smoke. The calls were made by the purser, since the flight crew were wearing oxygen masks and it was felt that the passengers might not understand them and might be alarmed by the unusual sound of the pilot's voices created by the wearing of the masks. Use of oxygen or smoke hoods by the cabin crew was briefly discussed but it was left to their discretion and in the end none were used and passenger oxygen masks were not deployed.

Birmingham Tower enquired of the passenger and crew numbers and whether the aircraft was overweight. An approach was made by the first officer, remaining as PF, whilst an uneventful manual landing was carried out by the captain. The runway was vacated and the aircraft taxied to the terminal with fire trucks following, brief radio discussion with the fire service having taken place. Both pilots removed masks and the captain made a PA call to inform the passengers that they would be disembarking normally at the gate using the aircraft front steps.

Technical investigation

The No 2 engine, which had been removed after the first event, was forwarded to its manufacturer's overhaul base for defect investigation and repair. Considerable internal damage was identified but the failure of its No 1 bearing appeared to have been the main event in the failure sequence. Little oil remained in the engine system and damage to the bearing sealing accounted for the loss of oil and its entrainment in the bleed air flow. This then contaminated the air-conditioning system with oil and allowed smoke to enter the cabin.

The operator concluded that the oil contamination of the ducting and internal components of the packs, which occurred just before the engine was shut down on approach to Edinburgh, remained present thereafter. Its removal had not been carried out successfully during the maintenance activities at Birmingham. Although ground running was carried out following the replacement of the engine, it appears that this did not involve full functioning of the air-conditioning system and consequently oil contamination remained in the packs and ducting and was neither identified nor effectively eliminated.

On removal from service following the second event, the aircraft was subjected to extensive ground running and functioning of the air conditioning. This did not produce smoke in the cabin. It was therefore concluded that all the residual oil in the air-conditioning components had been eliminated during the brief period when the engines were supplying air to the packs. This occurred after the air-conditioning supply was selected from 'APU' to 'ENGINE', early in the climb.

The aircraft was returned to service and no reports of further flight-deck/cabin smoke have been received.

INCIDENT

Aircraft Type and Registration:	BAe 146-300, G-OINV
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines
Year of Manufacture:	1990
Date & Time (UTC):	8 November 2006 at 2100 hrs
Location:	Descent into Inverness
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 71
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	10,566 hours (of which 4,800 were on type) Last 90 days - 153 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and analysis by the aircraft manufacturer

Synopsis

During the descent into Inverness the APU was started and subsequently there was a loss of electrical power to all the Primary Flying Displays, Navigation Displays, and cockpit lighting with no warnings being shown. The commander managed to regain electrical power about 15 seconds later. The subsequent investigation, which involved the manufacturer, was inconclusive.

History of the flight

The aircraft was inbound to Inverness from London Gatwick at FL70 and was above cloud. The APU was started as part of the approach checks when, approximately five seconds into the APU start procedure, there was a loss of electrical power to all the Primary Flying Displays, Navigation Displays, and cockpit lighting, with no warnings being shown. A 'MAYDAY' call was made to Inverness to report the loss of electrics, and the reply from ATC was heard by both pilots. The aircraft was maintained above cloud in Visual Meteorological Conditions.

The commander then 'worked backwards' and switched the APU off. Generator 1 (GEN 1) and Generator 4 (GEN 4) were then reset and electrical power to all the flight deck displays returned to normal. The cabin crew confirmed that the cabin lighting had remained illuminated but that galley power had been temporarily lost. It was estimated that the electrical power was lost for around 15 seconds. The approach to Inverness was continued and, once the aircraft was established on the ILS and the airfield was in sight, the 'MAYDAY' was cancelled. After landing a Ground Power Unit (GPU) was requested and there was no attempt to start the APU. At no stage were any circuit breakers found to be tripped.

Aircraft information

The BAe 146 has three electrical generators; GEN 1 and GEN 4 are mounted on engine No 1 and engine No 4, and these supply the AC1 and AC2 busbars respectively. There is also a generator on the APU (APU GEN). The two AC busbars can be linked by two bus tie contactors, and there are also contactors which can link the APU GEN to the AC1 and AC2 busbars. The captain's displays are supplied from busbars fed from GEN 1, and the co-pilot's displays are supplied from busbars fed from GEN 2.

Each of the three generators has a Generator Control Unit (GCU), which is designed to lock out if a fault is detected. There is also a daily check carried out by the flight crew to ensure that a dormant lock-out has not already occurred.

Subsequent maintenance activity

On the ground, the only fault which could be identified was a possible problem on the ground service bus, and hence the operator replaced the No 1 bus tie contactor. This contactor allows the APU, the GPU or GEN 4 to supply power to the AC1 busbar. This did not rectify the fault. Attention was therefore focussed on the No 1 GCU as potentially being the cause of the failure, and this was replaced. This resulted in the fault being cleared and the aircraft was returned to service, from which time it has continued to operate without any recurrence.

Both the contactor and the GCU were sent for a strip inspection. No fault was found with the GCU. The contacts in the contactor were found to be worn to varying levels, and there was an out-of-limit voltage drop across all three sets of contacts. However, there was no evidence of the contacts melting or fusing. Tests were also carried out under hot and cold conditions in an attempt to find an intermittent fault, but no such fault was found.

Bus bar faults - Service Information Leaflet (SIL) 24/47

The aircraft manufacturer has issued SIL 24/47 to assist operators in troubleshooting AC1 and AC2 busbar faults. In SIL 24/47 it is noted that typical causes are an open phase in the contactor or wiring chafes in the generator circuit (from the engine to the electrical bay).

Previous incident

On 18 August 2006 this aircraft suffered a failure of the No 1 Generator at FL240, and this resulted in the AC1 busbar tripping off-line and hence the loss of the captain's displays. An air turnback was made and the fault was attributed to the No 1 GCU, which was replaced.

Subsequent analysis

The AAIB and the manufacturer undertook an analysis of the electrical system and this included comparison of the reported events with the electrical wiring diagrams. The most likely explanation for the incident is that GEN 1 dropped off-line, in part because of the current supplied for the APU start. Either coincidentally or beforehand, the bus fail relay on GCU 1 locked out the bus transfer. It is believed that, prior to the recovery actions, the Battery, Emergency DC and AC2 busbars were all powered; however Essential DC, DC1, DC2, the warning lights bus bar and AC1 busbars were all unpowered.

Safety actions

In view of the inconclusive outcome of the investigation, the manufacturer has recommended that the operator carries out a series of more detailed tests on the system including the requirements of SIL 24/47. These are scheduled for the aircraft's next deep maintenance check.

ACCIDENT

Aircraft Type and Registration:	Beech B200 King Air G-PCOP
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-42 turbo-prop engines
Year of Manufacture:	2004
Date & Time (UTC):	28 March 2006 at 0832 hrs
Location:	Within the Scottish Terminal Manoeuvring Area
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Overstress damage to outer wings and engines
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	6,524 hours (of which 180 were on type) Last 90 days - 131 hours Last 28 days - 34 hours
Information Source:	AAIB Field Investigation

Synopsis

After takeoff and whilst in IMC, the commander noticed a gradual and progressive loss of information on his flight instruments, followed by a loss of radio communications. The commander concluded that the aircraft had suffered a major avionics failure. When ATC became aware of the loss of communications, they arranged for an RAF Tornado aircraft to intercept G-PCOP. While attempting to guide the aircraft below cloud, the RAF crew saw it enter cloud in an apparently uncontrolled fashion and they transmitted a 'MAYDAY RELAY' message. However G-PCOP re-appeared from the cloud. Eventually G-PCOP descended to VMC below cloud and landed at RAF Leuchars.

On the ground, with an electrical source attached to the aircraft, the instruments and radios worked correctly. The next day, after inspection, the aircraft was ferried by another pilot to Blackbushe for further examination. This revealed damage to the outer wing skins and wing leading edges. The damage to the aircraft was characteristic of it having been subjected to abnormally high flight loads and the outer wing panels had to be replaced. Despite extensive investigation, no defects were found with the electrical generation and distribution systems of the aircraft. Recommendations were made relating to information in the Airplane Flight Manual and to the certification standards of the aircraft.

Aircraft description

The aircraft, manufacturer's serial number BB-1860, was manufactured in 2004 and granted an EASA Standard Certificate of Airworthiness. It was fitted with Rockwell Collins 'Pro Line 21' avionics systems and cockpit displays. The Pro Line 21 system comprised a fully-integrated avionics suite and an Electronic Flight Instrumentation System (EFIS). The cockpit instrumentation consisted of two electronic Primary Flight Displays (PFD) and a single electronic Multi Function Display (MFD). Standby instrumentation was provided by a Goodrich Electronic Standby Instrument System (ESIS) which displayed attitude, altitude, airspeed and heading on a single display. An annotated photograph of the instrument panel is shown at Figure 1.

Background to the flight

The pilot involved in the accident was the Chief Pilot of a charter company and normally flew the Cessna 310 and the Beech 200 version fitted with electromechanical instruments. He had also agreed to deputise as necessary for the professional pilot of G-PCOP, a commercially owned Beech 200 equipped with Pro-Line 21 avionics and cockpit displays. There was no requirement for a conversion course to fly the Pro-Line 21 equipped aircraft but the accident pilot stated that he had flown

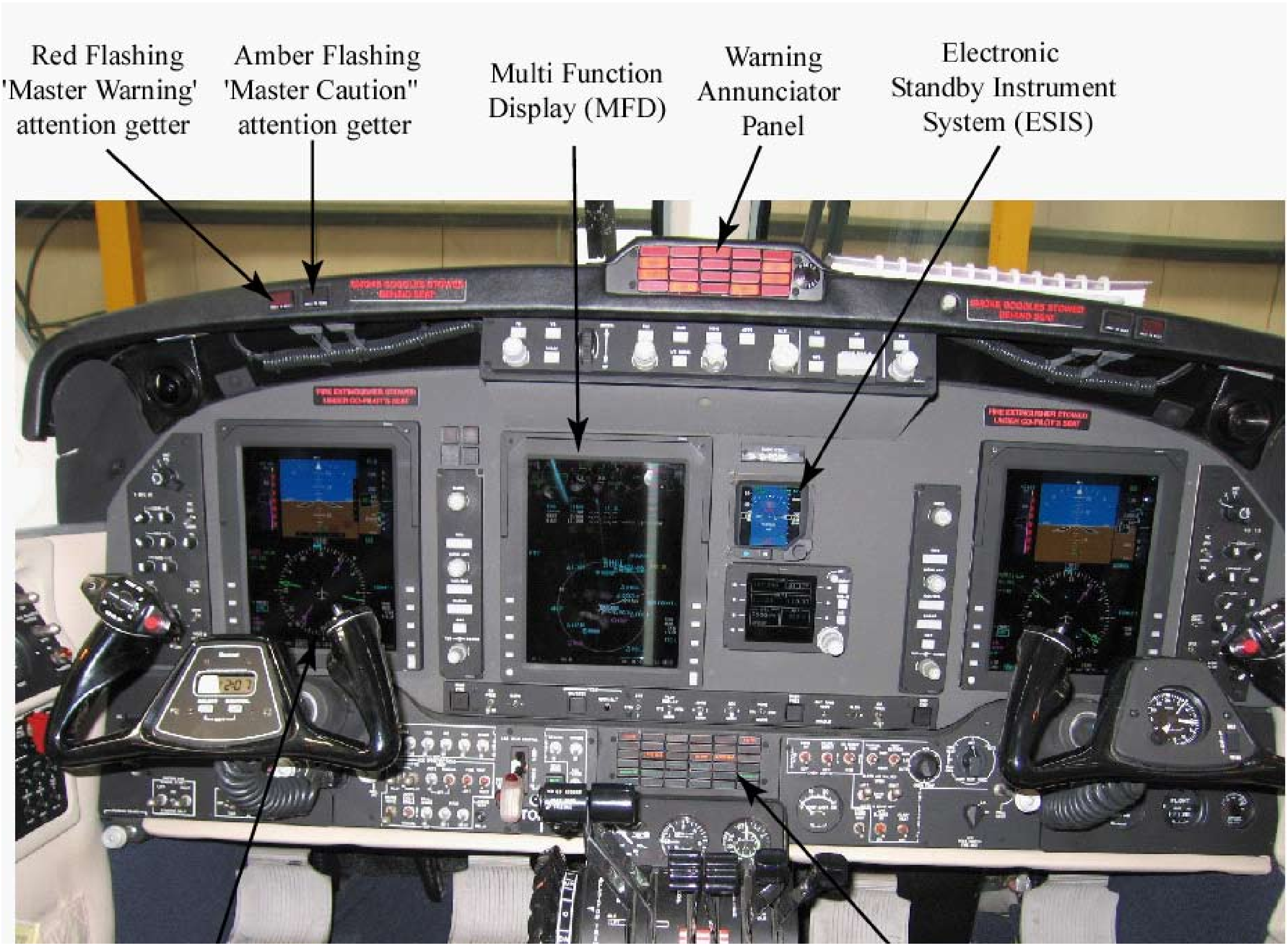

Figure 1

G-PCOP's instrument panel

some 10 flights in the aircraft before the accident. He had flown four sectors in the right hand seat with a commander from a TRTO[1] followed by six sectors with G-PCOP's customary commander during which the two pilots shared the P1 duties.

History of the flight

The commander planned a flight from Glasgow Airport to Peterborough (Conington) Aerodrome. There was one defect recorded in the aircraft's Technical Log indicating that the heading function of the ESIS was inoperative.

The commander began starting the engines using battery power at 0815 hrs; the right engine was started first and both engine starts were uneventful. He subsequently stated that all after-start checks were normal, including voltage checks of the battery and generators, and that the generator loadmeters were within 10% of each other. By 0818 hrs, the aircraft was cleared to taxi and by 0831 hrs it had been cleared for takeoff. The commander stated that before takeoff he selected both ENG AUTO IGN switches to ARM and both ENGINE ANTI-ICE switches to ON. He also recalled checking both the warning and caption panels and seeing no red or amber lights. To confirm that the correct checks were completed he used the Airplane Flight Manual positioned on the right pilot's seat.

After takeoff, the aircraft was transferred to Glasgow Approach control at 0832 hrs. By 0835 hrs control had been transferred to Scottish Radar and the aircraft was cleared to climb to FL100 on a heading of 150º. At 0836 hrs, the controller cleared G-PCOP for a further climb to FL150; this message was correctly acknowledged by the commander. One minute later, the controller noted a loss of secondary radar and made a radio check with the aircraft. There was no response and there was no further radio contact by any agency with G-PCOP throughout the remainder of the flight.

Shortly after takeoff, the commander noted that the left EFIS display indicated a failure of the Flight Management System (FMS) which had been selected as the primary navigation source. He had then selected VOR as the primary source but shortly afterwards all three EFIS displays became intermittent and then went blank. By then, the aircraft was with Scottish Radar and the commander decided to return to Glasgow Airport. However, he then became aware that the radio was not operating. He assumed that he had a major avionics failure and concentrated on the ESIS display indications until the aircraft had climbed clear of cloud and was level at FL150. Whilst he was considering his options, he became aware of an RAF Tornado aircraft on his left side.

The RAF crew had been on a training flight and had received a request from ATC at 0858 hrs to assist a small aircraft that was in distress. By 0910 hrs, the Tornado was alongside G-PCOP. In accordance with the advice given in the CAA Publication '*Safety Sense Leaflet 11: Interception Procedures*', the RAF pilot rocked his aircraft's wings to indicate that the crew wanted G-PCOP to follow them. Seeing the same manoeuvre in response from G-PCOP's pilot, the RAF crew were confident that he would follow them and they started turning towards Prestwick. However, the RAF crew lost sight of G-PCOP as it moved towards the rear of the Tornado. The commander of G-PCOP subsequently commented that he had not been fully aware of the meaning of the signals from the RAF aircraft and had started heading in a north-easterly direction where the weather was forecast to be better.

Footnote

[1] Type Rating Training Organisation.

Subsequently, the commander of G-PCOP saw the Tornado in various positions around the aircraft and eventually was aware that the RAF crew were indicating that he should descend. The ESIS was still operative so the commander initiated a descent. However, as his aircraft entered cloud, the ESIS display started to "flash on and off" and the commander could only make out the horizon indication on the display. By then G-PCOP was in a steep descent in cloud and the commander had great difficulty in recovering the aircraft into a climb. He eventually achieved straight and level flight above cloud but he had been aware of some slight negative 'g' during the recovery manoeuvres. His ESIS display was, by then, inoperative.

The Tornado crew saw G-PCOP enter cloud in an attitude that they considered was uncontrolled and so they had declared a 'MAYDAY'. However shortly afterwards, G-PCOP re-appeared from the cloud in a steeply banked climb and entered another layer of cloud. The RAF crew reported the situation to ATC and were eventually informed that radar contact with G-PCOP had been achieved. Shortly afterwards, they were alongside the aircraft but between cloud layers.

During the subsequent period of straight and level flight, one passenger in G-PCOP used his mobile telephone to contact Edinburgh ATC to inform them of the situation. They arranged for Leuchars ATC to telephone the passenger to advise him that RAF Leuchars was the planned landing airfield. In company with the RAF aircraft, the commander eventually found sufficient gaps in the cloud and descended to VMC below cloud. He then identified his geographical position and, after manually pumping down the landing gear, made a flypast over the runway at RAF Leuchars before landing at 1025 hrs. The aircraft had been airborne for almost two hours and had been without electrical power for at least 90 minutes.

Throughout the flight, the commander considered that the workload involved in maintaining controlled flight had made fault finding "almost impossible". After the flight he stated that he had seen no warning or caution lights illuminate during the flight and he could not recall whether he had checked the voltage/loadmeter gauges or the battery ammeter gauge during the flight. He did recall looking at the battery and generator switches and that they appeared to be ON. He also confirmed that before landing at Leuchars he had attempted, unsuccessfully, to reset both generators.

Subsequent flight

Once on the ground, the commander checked the battery voltage and noted that it was very low. He also reset the passenger oxygen masks which had deployed during the flight. The commander telephoned the aircraft's maintenance organisation for advice. At their suggestion he arranged for electrical power to be applied to the aircraft and this resulted in all the aircraft's systems appearing to work normally.

Engineering support arrived at RAF Leuchars the next day and the pilot returned to Leuchars to liaise with the engineers but, according to them, he did not mention any unusual 'g' excursions. The only entry in the aircraft's Technical Log described a total electrical failure so the engineers carried out a detailed examination of the aircraft's electrical systems. Both aircraft batteries were replaced and a full and successful check was made of the aircraft electrical system. Then, with no further indications of unserviceability, it was decided that the aircraft would be positioned to Blackbushe Airport for more detailed examination. The incident pilot was unavailable on the day so another pilot flew the aircraft to Blackbushe on 31 March. The incident pilot was unable to brief the positioning pilot about his in-flight experiences and when the latter pilot carried out a pre-flight inspection, he did not notice any external signs of airframe damage. However, at Blackbushe it was found that the aircraft's outer wing panels had some wrinkling and there was bulging in the wing skins. The engines were also removed for examination.

Weather information

The synoptic situation at 0600 hrs showed low pressure over northern parts of the British Isles with an occluded front moving across Scotland during the morning. In the area around Glasgow, Prestwick and towards Edinburgh, the cloud structure was: FEW/SCT (few or scattered) stratus base 200 to 600 ft with tops at 1,200 ft; BKN/OVC (broken or overcast) strato-cumulus and/or nimbo-stratus base 1,500 ft with tops between 15,000 and 19,000 ft; and further layers above. There were forecast breaks in the cloud from the east of Edinburgh towards Leuchars. The freezing level was at 3,000 ft.

The METAR for Glasgow at 0820 hrs was as follows: surface wind 340º/ 02 kt; visibility 9,000 metres in rain; cloud FEW at 600 ft and BKN at 1,000 ft; air temperature +8ºC and dew point +7ºC; QNH 981 mb.

Recorded information

There was no requirement for a Flight Data Recorder (FDR) to be fitted to the aircraft and none was fitted. Although not required by regulation, a 30-minute Cockpit Voice Recorder (CVR) was fitted. However, the CVR circuit breaker was not pulled after the landing at RAF Leuchars and so the CVR data from the accident flight was overwritten before it could be downloaded.

A radio recording was available of the Glasgow and Scottish Radar frequencies. The recording confirmed that G-PCOP's commander requested engines start at 0815:20 hrs and requested taxi clearance at 0818:30 hrs. At 0821:20 hrs, G-PCOP was transferred to 'Tower' and was cleared for departure at 0831:05 hrs. By 0835 hrs, the aircraft was identified by 'Scottish Radar' and cleared to climb to FL100 on a heading of 150º. At 0836:10 hrs, the aircraft was further cleared to FL150 and this clearance was correctly acknowledged by G-PCOP's commander. This was the last transmission received by the aircraft and at 0837:20 hrs, 'Scottish Radar' made a check call following the loss of secondary radar.

Electrical generation and warnings

All the aircraft's systems were powered electrically. Electrical generation was provided by a 28V DC starter-generator on each engine with emergency standby power provided by a single nickel-cadmium battery. The generators were controlled by a pair of switches beneath a guard labelled MASTER SWITCH to the left of the control column, as shown in Figure 2. If the generators drop off-line, the switches do not move and must be moved to the GEN RESET position to bring the generators back into operation. Unguarded ENG AUTO IGN, ENGINE ANTI-ICE and IGNITION AND ENGINE START switches were clustered near the generator and battery master switches.

The overhead panel was fitted with two DC load and voltage meters together with a battery ammeter. This could be used to confirm the voltages on both electrical buses and to establish whether the battery was being charged or discharged.

In the event of complete DC generation failure, the aircraft battery was certified to provide power for 30 minutes; this duration depends on the pilot recognising the problem and shedding non-essential electrical loads. All of the non-essential components of the Pro Line 21 system would lose power automatically. If load-shedding was not actioned and both the landing gear and flaps were

Figure 2

Lower left instrument panel switches

operated, the manufacturer estimated that the aircraft battery would be capable of powering the aircraft's systems for approximately 10 minutes. The ESIS had its own independent battery supply in the event of a loss of electrical generation. The ESIS battery was certified to provide sufficient power for a minimum of 30 minutes.

The aircraft was fitted with an un-dimmable multi-caption warning panel on the top of the instrument panel glare shield, together with a red master warning light in front of each pilot. An additional and dimmable caution/advisory annunciator panel was installed centrally below the MFD, see Figure 3. This panel contained amber caution captions, linked to a master caution light next to the master warning light, and green advisory captions.

If a problem occurred with an aircraft system, dependent on the severity of the defect, either a warning or caution caption would illuminate together with the associated master warning or caution lights. The master warning and master caution lights could be extinguished but the captions would remain illuminated until the affected system was restored. A failure of either or both generators would illuminate the master caution light together with an associated L GEN and/or R GEN amber caution caption(s).

United Kingdom Generic Requirement (GR) No 4

Generic Requirement No 4 was contained within CAP 747, '*Mandatory Requirements for Airworthiness*'. Its purpose was to ensure that 'certain aircraft' under 5,700kg maximum authorised weight provided the pilot with a clear and unmistakable warning in the event of a loss of electrical generation. The requirement stated:

Figure 3

Caution/Advisory annunciator panel

> *'2.2 Clear visual warning shall be provided, within the pilot's normal line of sight, to give indication of, either:*
>
> *a. reduction of the generating system voltage to a level where the battery commences to support any part of the main electrical load of the aircraft, or*
>
> *b. loss of output of each engine driven generator at the main distribution point or busbars'*

EASA Certification Standard CS 23.1322 defined a warning indication as '*red and non dimmable*'.

Initial investigation

After landing, the aircraft was connected to a ground power supply and all the electrical systems came back on-line. An inspection of the aircraft was carried out at RAF Leuchars by staff from the aircraft's maintenance organisation in conjunction with the aircraft manufacturer's technical representative. The inspection was conducted in the open and after rainfall. Despite extensive troubleshooting, no defects were identified with the electrical generation and distribution systems of the aircraft.

After the ferry flight to Blackbushe, additional airframe inspections in a hangar revealed damage to the outer wing skins and leading edges, characteristic of the aircraft being subjected to high flight loads. Externally this damage was difficult to detect without the use of a high-intensity mobile light source and it would probably have been masked by raindrops on the wings at Leuchars.

Subsequent investigation

The outer wing sections were disassembled and both outer wing spars showed clear evidence of overstress, which required replacement of the outer wings. No evidence of overstress was found elsewhere on the airframe. Due to the loss of engine indications and the damage identified in the outer wings, both engines and their propellers were removed for disassembly and inspection by their respective manufacturers.

Further tests of the aircraft's electrical system, carried out in conjunction with the AAIB, failed to identify any defects which could have resulted in the loss of electrical power. Subsequent tests were designed to evaluate the aircraft systems under degraded electrical power as reported by the commander during the accident. These tests were delayed until November 2006 when the engines had been re-installed after inspection, and after replacement outer wings had been fitted.

Test 1:
In the first test, the ESIS was switched on and external electrical power was then removed from the aircraft. Although the ESIS battery was only certified for 30 minutes of operation, the ESIS continued to operate on battery power for in excess of 85 minutes. The battery used for the test was new.

Test 2:
The second test was carried out, using a new main battery, to determine the probable order and timing of system failures on the flight and to verify whether it was possible to reset the generators with a fully depleted battery. A new battery was used to provide optimum electrical storage and charging conditions. It was not possible to determine accurately the condition of the aircraft's main battery at the time of the accident.

Using information from the commander and the aircraft's checklists, both engines were started without using external power and the aircraft was configured to replicate, as closely as possible, the electrical loads during the accident flight. The pitot heat system was not activated and the electrical load from raising the landing gear could not be accurately reproduced. Both generators were taken 'off-line' which illuminated the associated L GEN and R GEN captions, together with the flashing master caution lights. Resetting the generators extinguished the lights and captions. After allowing the battery to recharge for a period of five minutes, both generators were 'tripped' again and the aircraft's systems monitored. The battery ammeter indicated that the battery was being discharged but the deflection of the gauge needle was small. Also, from the pilot's seat, it was difficult to determine whether the reading was positive or negative. After five minutes, the battery voltage had dropped from 24 V to 20 V and the illuminated L GEN and R GEN captions had dimmed such that it was not possible to confirm that they were illuminated. Nine minutes into the test, with a battery voltage of 14 V, the FMS and the right PFD shut down, displaying a red FMS caption on the left PFD. After nine and a half minutes, the FD, GPWS, RA, and WS captions illuminated on the left PFD and the single MFD began to flicker. At 13 minutes, with a battery voltage of 6 V, the MFD and the left PFD shut down and all radio communications were lost. After 35 minutes of operation on battery power, with both DC buses indicating 0 V, both generator switches were moved to GEN RESET and then to ON; all aircraft electrical systems came back on line and both DC buses indicated 29 V. It was noted that there was no information contained in the aircraft Flight Manual to advise operators that the generator switches were self-powered and required no battery voltage for activation. Discussions with other Beech 200 operators indicated a general lack of awareness of this information.

Associated switch layout

On the pilot's left subpanel there were two switches that control the auto ignition system. These were surrounded by a white border line and labelled ENG AUTO IGN (see Figure 2). Below and to the left of these switches were two other switches, again surrounded by a white border and labelled IGNITION AND ENG START. Both sets of switches were of similar design and operated in the same sense. The auto ignition switches were normally selected to the ARM position immediately before takeoff. With the engines running, operation of the IGNITION AND ENG START switches would engage the starter circuit and would also trip both DC generators off-line, illuminating the flashing master caution light and the respective caution captions.

Aircraft manufacturer's information

Activation of the engine start switches with the engines running will not cause the starter to engage the engine but, in addition to tripping off the generators, it will have two more highly undesirable effects: the starters draw a heavy current which drains the main battery very quickly and the generators cannot be reset until the switches are returned to the OFF position. The aircraft manufacturer estimated that, if the ignition and engine start switches were inadvertently switched to the ON position just before takeoff, the battery would be unable to support the aircraft's systems within six to seven minutes.

The avionics manufacturer confirmed that if the aircraft had suffered a progressive failure of its electrical supply, this should have been recorded on both the Maintenance Diagnostic Computer (MDC) and Flight Management Computer (FMC). Both were removed and their non-volatile memories were downloaded by the manufacturer in the presence of the AAIB.

In the event of a complete electrical generation failure, power to the MDC would be lost immediately preventing fault recording. To record a flight log, the MDC logic required an airspeed of 80 kt and a signal from the weight-on-wheels switch indicating that the aircraft was airborne. The MDC contained 100 recorded flight logs. The logs were not date or time 'stamped' so it could not be determined if the MDC logic had been satisfied and a log recorded for the accident flight. The only fault data recorded was related to the troubleshooting carried out after the accident flight. This data included when an individual engine generator had been 'tripped'. The FMC contained no data relevant to the accident flight.

Analysis

Because the aircraft's outer wing panels had to be replaced, this serious incident subsequently became an accident as defined in the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. However, the extensive engineering investigation could not identify a malfunction within the aircraft's systems that would explain the situation experienced by the commander.

The fact that the MDC failed to record any fault information for the accident flight suggested that the aircraft had suffered a simultaneous loss of both DC generation systems early in the flight, or that the aircraft's systems were being supported by battery power before the MDC flight log logic had been satisfied. Although a transient fault could not be eliminated, an examination of the circumstances of the accident indicated that inadvertent switch selections by the commander could explain the scenario.

There is no doubt that both generators went off-line at some stage and did not come back on-line. In the absence of any identified technical malfunction, the possibilities were that neither generator had been switched ON or that they had both been inadvertently switched OFF.

It was considered highly unlikely that neither generator had been switched ON after engine start. Firstly, the commander stated that he had checked the generator loads after engine start and that they were within the required parameters. Secondly, a check of the timings showed that the radios stopped working in the accident some 21 minutes after engine start. During tests, it was noted that with a new battery the radios stopped working after 13 minutes.

However, if during the pre-takeoff checks, the IGNITION AND ENGINE START switches had been selected to 'ON' rather than the ENG AUTO IGN switches, the result would have been that the generators would have been tripped off-line. This action would have resulted in the battery being unable to support the aircraft systems within about six to seven minutes. Examination of the radio recording indicates that the aircraft radios were inoperative some five minutes after takeoff. Although this timing would support the hypothesis, the inadvertent tripping of the generators would still have illuminated the master caution lights on the glareshield and the associated L GEN and R GEN amber annunciator lights. However, depending on when any incorrect switch selection was made, the illumination of amber caution lights would not cause the same concern as the illumination of red warning lights. It was possible that the commander may have cancelled the caution as a reflex action and then did not critically examine the lights on the caution panel. Tests indicated that these lights would have dimmed within about five minutes of the generators going off-line.

The initial problem noted by the commander occurred shortly after takeoff when his workload was high, partly due to the weather conditions. In that situation, it was sensible to concentrate on flying the aircraft accurately until it was at a safe altitude and in steady flight. The commander achieved these conditions but when he attempted to inform ATC of his decision to return to Glasgow, he became aware that his radio was not operating. Subsequently, the commander commented that his workload was so high that he found fault finding "almost impossible". However, at one stage he was clear of cloud and at FL150 and this would have been an opportune time to evaluate his situation and at least attempt to reset the generators. Subsequent tests indicated that resetting the generators should have fully recovered all the aircraft's systems.

The commander stated that he attempted to reset the generators just prior to landing at Leuchars. If the problem was caused by having the start switches in the ON position, then he would have been unable to reset the generators until he noticed his mistake and selected the start switches to the OFF position. This factor lends further credence to the scenario that the generators were tripped off-line just before takeoff by the pilot inadvertently operating the IGNITION AND ENGINE START switches instead of the ENG AUTO IGN switches.

The Flight Manual did not include any information to the effect that the generators could be activated with zero battery voltage and several Beech 200 pilots thought that a minimum battery voltage was required to activate a generator. Moreover, it did not make clear that the generators could not be reset if the IGNITION AND ENGINE START switches were in the ON position. Although most pilots would attempt to reset generators regardless of battery voltage, it would be appropriate for the aircraft manufacturer to include this information in the Flight Manual because if a pilot had inadvertently operated the wrong pair of switches, a generator reset would be impossible until the mistake was corrected. Accordingly it was recommended that:

Safety Recommendation 2007-022

The Raytheon Aircraft Company should amplify the information in the Beech 200 series Airplane Flight Manuals to reflect that the generators can be reset regardless of battery voltage but they cannot be reset if the IGNITION AND ENGINE START switches are in the ON position.

When the RAF aircraft came alongside, its crew provided full assistance to the commander of G-PCOP. Unfortunately, he was not fully aware of the meaning of the signals from the RAF crew. Safety Sense Leaflet 11 detailed the procedures in the event of an interception, and because interception was a fundamental part of the RAF crew's daily job, they were intimately aware of the signals and responses. However, the commander of G-PCOP was much less familiar and, as a single pilot operating with an emergency, he could not have been expected to consult any available document during the accident. Nevertheless, it was clear that the RAF crew persevered with attempts to assist the commander of G-PCOP and they played an important part in ensuring that the aircraft landed safely.

Irrespective of the causal factors in this accident, other aspects raised legitimate concerns. Firstly, the aircraft did not meet the CAA and EASA airworthiness requirements with respect to generator warning systems. After being briefed by the AAIB shortly after the accident, in June 2006 the CAA made a safety recommendation to the EASA. The Authority recommended that the EASA should release an Airworthiness Directive to ensure that the aircraft type complies with the requirements of EASA CS 23.1309(b)(3) and 23.1353(h) by providing red warning annunciations when both generators are off-line, and a 'low volts' warning when the aircraft battery is supporting any part of the aircraft's electrical load. The AAIB fully supports this recommendation which is being actively considered by the EASA.

Secondly, in the event of double generator failure the main instrument display should continue to operate for an estimated 30 minutes, with appropriate load shedding. At the same time, the ESIS display would be powered from its dedicated battery for the specified 30 minutes (although in tests it lasted for longer than the specified time). If the pilot is aware of reversion to battery power, 30 minutes should usually be sufficient time in which to take appropriate action. However, if the pilot is unaware that both generators are off-line, in this aircraft variant both the main and standby instruments could fail in succession. Consequently, this eventuality lends further weight to the safety recommendation made by the CAA to the EASA.

With the aircraft safely on the ground at RAF Leuchars, it was checked for the reported electrical problem but not for any possible overstress, primarily because no 'g' excursions were reported to the engineers by the incident pilot. This resulted in a flight in an aircraft with damaged outer wings and potentially damaged engines.

ACCIDENT

Aircraft Type and Registration:	Boeing 737-436, G-DOCT
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1992
Date & Time (UTC):	8 July 2005 at 1006 hrs
Location:	Aberdeen Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 149
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to tailplane and elevator
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	8,500 hours (of which 3,965 were on type) Last 90 days - 185 hours Last 28 days - 67 hours
Information Source:	AAIB Field Investigation

Synopsis

On takeoff, sections of a blast pad positioned at the runway threshold lifted and broke up, causing damage to the aircraft's tailplane and elevator. The crew were unaware of the damage to the aircraft and completed the takeoff and flight to their destination without further incident. The investigation identified issues concerning the construction and marking of the blast pad and other factors concerning the conduct of the takeoff. 10 safety recommendations were made.

History of the flight

The crew were operating their final sector of the day, from Aberdeen to Gatwick, with the commander acting as handling pilot. Prior to start, the flight crew had received the aircraft performance figures for their predicted departure weight. These were calculated for a reduced thrust takeoff at FLAP 15, rather than the more usual FLAP 5, due to performance limitations. The commander stated he briefed the co-pilot that, due to the short runway length, he would hold the aircraft on the brakes whilst setting takeoff power.

The aircraft was pushed back at 0956 hrs and, after engine start, was taxied to Runway 16, via Taxiway W, for departure. ATC cleared the aircraft to line up and take off on Runway 16. The commander taxied onto the runway, ensuring that the aircraft was positioned close to the threshold, to make maximum use of the runway length available. This was witnessed by the crew of a following aircraft, the commander of which stated that

G-DOCT had turned slightly left as it crossed holding point W5 (Figure 1) before turning sharply to the right to line up on the runway centreline. He further stated that this turn was through more than 90° and appeared to be done "gently". This commander also stated that the wheels of the aircraft had remained on the runway throughout the manoeuvre and that, once lined up, G-DOCT was brought to a halt with the tail "just in front of the threshold lights".

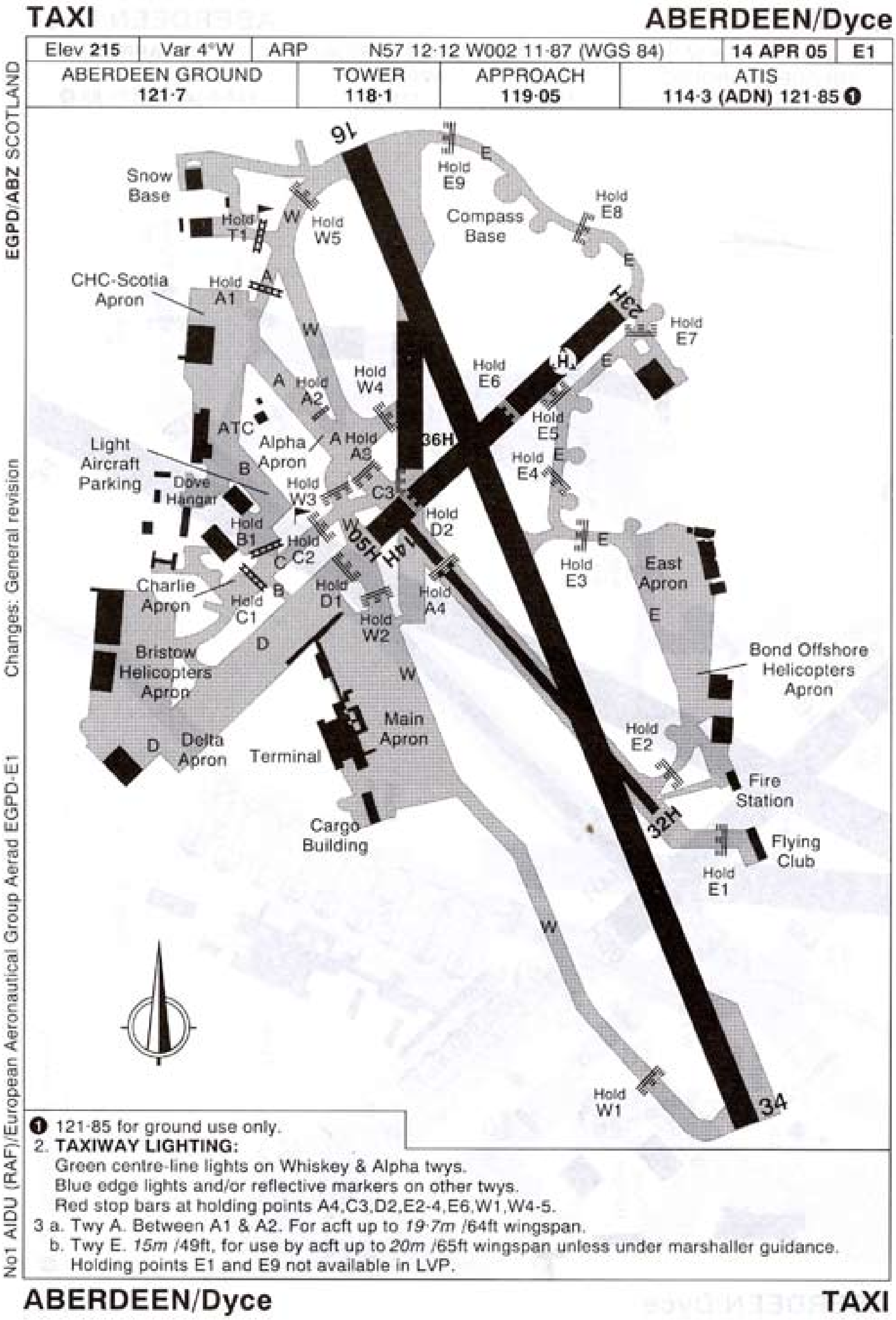

Figure 1

Aberdeen Airport taxi chart

The commander of G-DOCT stated that, on being cleared for takeoff, he had held the aircraft on the brakes as briefed. He stated that he set the thrust levers to 40% N_1[1] and waited for the engines to stabilise at this power before selecting takeoff power by pressing the TO/GA (takeoff or go-around) button. The commander recalls that takeoff power had been about 92% N_1 and that, once the thrust had reached about 90% N_1, he released the brakes. The aircraft began to move forward and almost immediately he felt a jolt as if the nosewheel had run over a small bump. Neither pilot was unduly concerned and the commander continued the takeoff. The takeoff time was 1006 hrs.

The flight crew of the following aircraft had watched G-DOCT take off and saw two large sections of asphalt, the largest section estimated to be 2 m by 3 m, slowly lift and disintegrate as the aircraft started its takeoff roll. They reported what they had seen to ATC, and this was heard by the crew of the aircraft taking off, just as they became airborne. Once they had completed their 'after takeoff' checks the departing commander asked over the radio if the crew who had witnessed the surface break-up had seen any damage to the aircraft. This crew replied that no damage to the aircraft had been seen and, in light of this reply, and the fact that the aircraft appeared to be handling normally, the commander of G-DOCT decided to continue with the flight.

The commander stated that the rest of the flight was uneventful and the aircraft landed at Gatwick at 1114 hrs. After shutdown, believing there had been no damage to the aircraft, the crew returned to the crew room, only to learn shortly afterwards that a routine engineering inspection had revealed considerable damage to the tail of the aircraft.

Footnote

[1] N_1 is the rotational speed of the engine fan, expressed as a percentage of maximum rpm.

Aircraft damage

The aircraft sustained damage to its left tailplane and left elevator. There was a dent 2.4 metres long on the underside of the left tailplane as depicted in Figure 2. The dent contained pieces of black bitumen from the asphalt section that had struck it. Some of the tailplane skin within the dent had torn and some ribs had buckled. A section of the elevator, approximately 0.9 m by 0.6 m, had completely detached, causing a separation between the outboard section of the elevator (containing the balance weights) and the remainder of the elevator – see Figure 3. The elevator underside was peppered with pieces of black bitumen. The damaged sections of elevator were found in the grass area behind the Runway 16 threshold, close to the extended runway centreline. The farthest pieces were found 132 metres behind the threshold.

Blast pad damage

The blast pad (also known as an erosion strip) at the Runway 16 threshold at Aberdeen Airport was a paved area 8.4 m long and 72 m wide, extending beyond both sides of the 45 metre-wide runway (area shown in yellow in Figure 4). The asphalt surface of the central section of this blast pad, approximately 6.5 m either side of the runway centreline, had completely detached. Most sections of asphalt had been blown aft into a grass area – some were found 20 metres behind the end of the blast pad. The remainder of the asphalt sections were piled up in the damaged area of the blast pad (see Figure 5), the largest of which was approximately 1.8 m by 1.5 m and 6 cm thick, weighing approximately 340 kg. The exposed surface below the removed asphalt consisted of stones and dirt with almost no bitumen residue. Some of the stones from this surface were found on the runway. The majority of the bitumen overband sealing (designed to create a flush surface, without cracks, between the runway and blast pad) had detached with the asphalt.

Figure 2

Damage to left tailplane and left elevator on G-DOCT

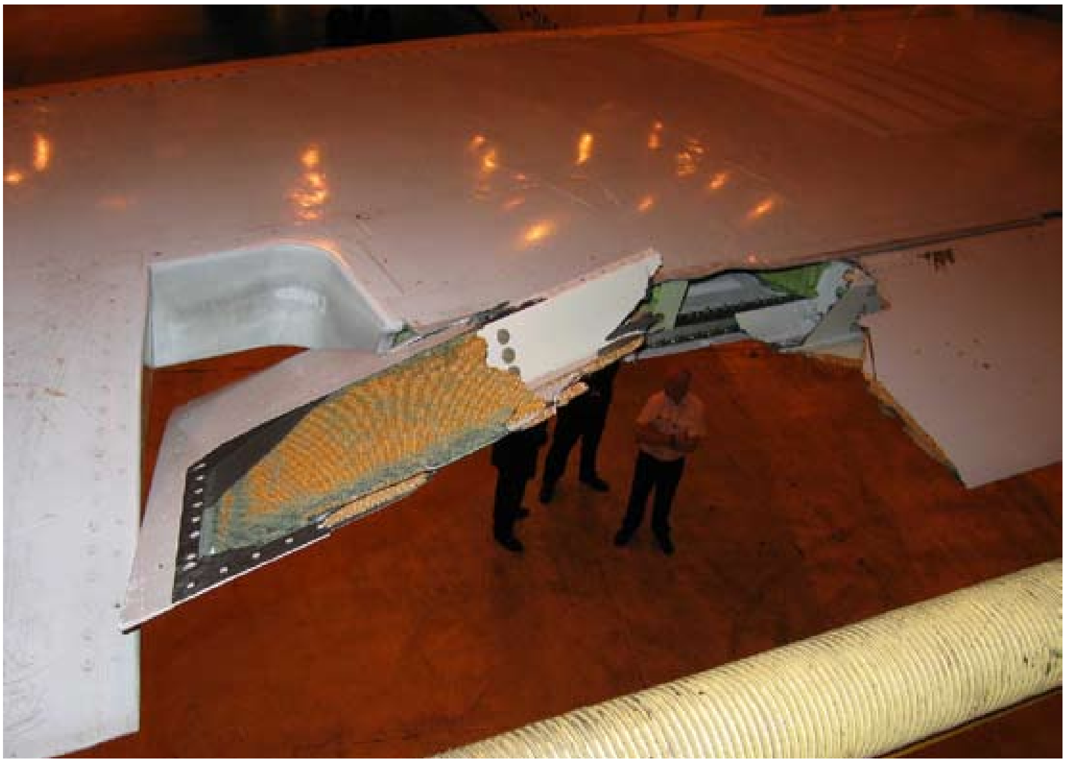

Figure 3

Damage to left elevator of G-DOCT, showing separation of outboard section

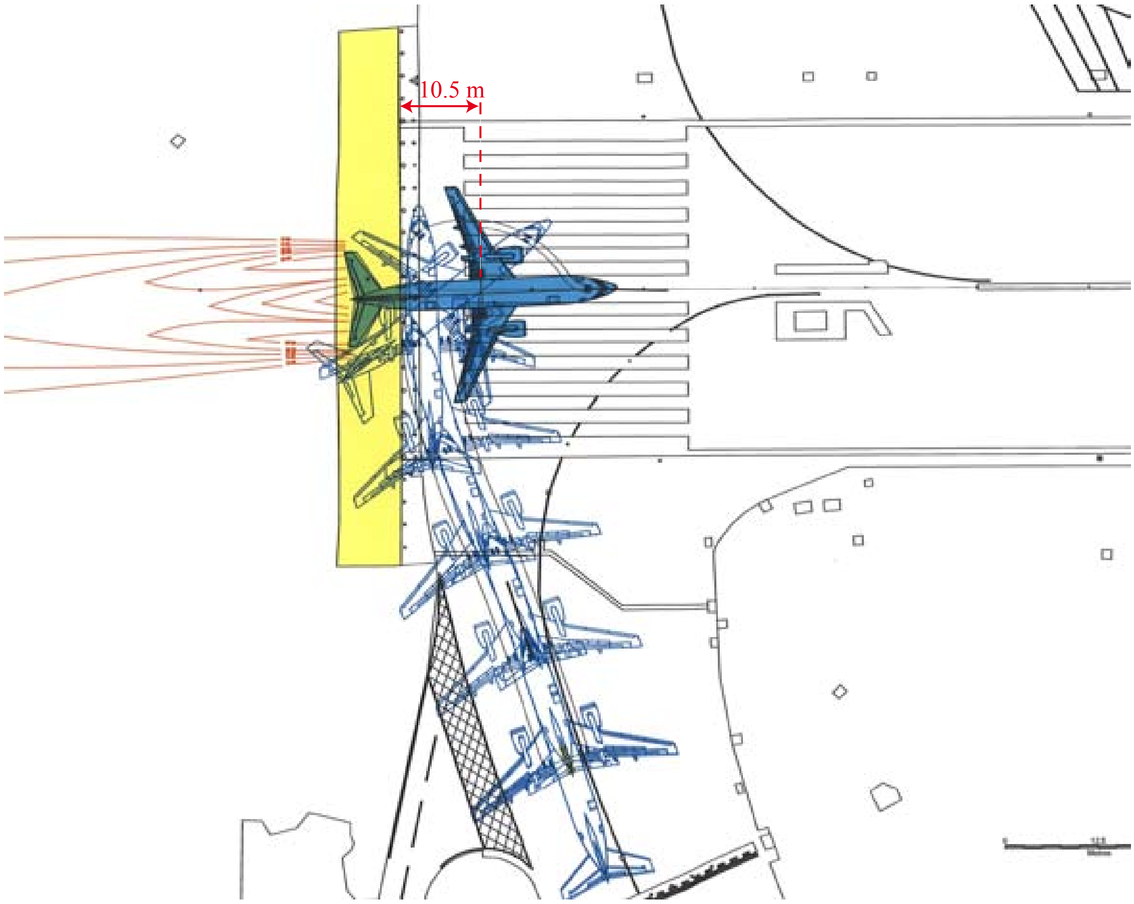

Figure 4

Predicted line-up path for a 737-400 trying to maximize takeoff distance available without running over the blast pad (blast pad shown in yellow)

Flight recorders

The aircraft was fitted with a Flight Data Recorder (FDR) that recorded a range of flight parameters and a Cockpit Voice Recorder (CVR) which recorded 30 minutes of crew speech and area microphone inputs. Both the FDR and CVR were downloaded at the AAIB where 25 hours of data from the FDR, including the accident at Aberdeen and subsequent flight to Gatwick, were recovered. Audio recordings from the CVR for the accident at Aberdeen were overwritten with more recent information.

A time-history plot of the relevant parameters during the accident at Aberdeen is given at Figure 6. The data presented at Figure 6 starts just before G-DOCT came to a halt at holding point W5 for Runway 16, where the aircraft remained for eight seconds with brakes applied.

As the brakes were released, the aircraft began moving, turning through 40º to the right over a period of 40 seconds (at a maximum turn rate of 2º/second), on to a heading of 075º(M). The ground speed peaked at eight knots during this turn. The aircraft remained on this heading for five seconds before turning to the right through a further 85º, over 16 seconds, onto the runway heading of 160º(M). Left-engine thrust, up to 40% N_1, was applied during the turn and the aircraft's turn rate reached a maximum of 8.6º/sec while the ground speed peaked at two knots. Once on the runway heading, the brakes were applied and the aircraft came to a stop.

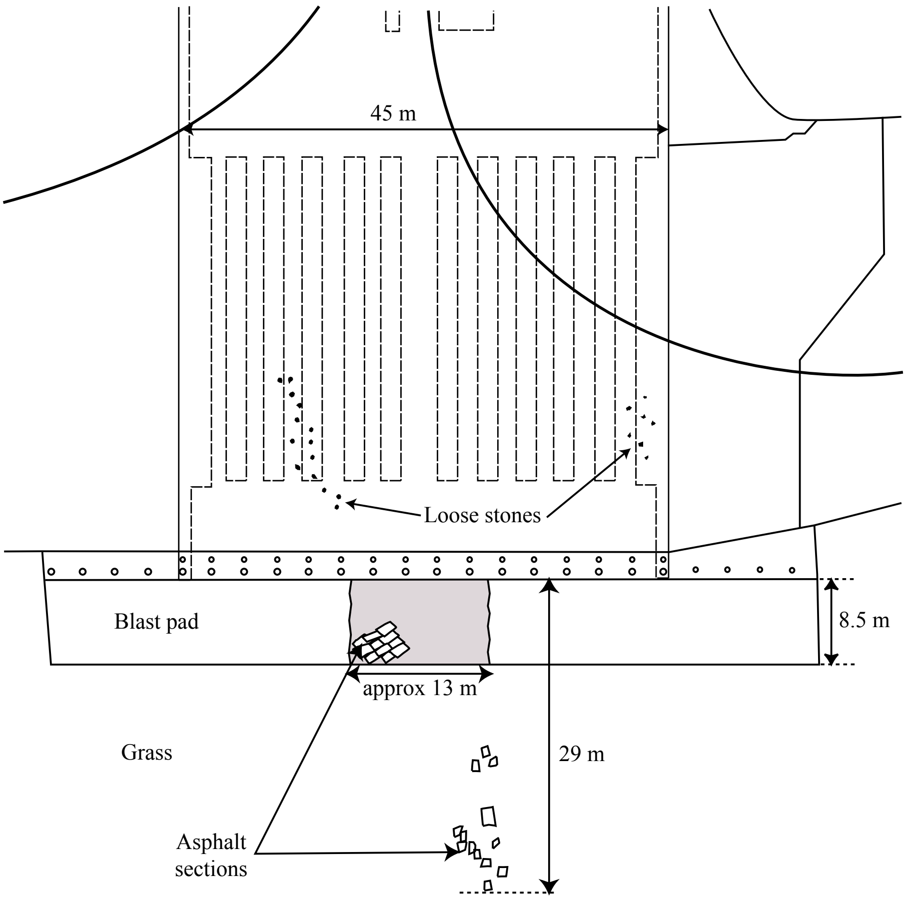

Figure 5

Blast pad debris following accident to G-DOCT.
Grey area denotes delaminated portion of blast pad

The aircraft remained lined up on the runway with brakes applied for one minute. After 38 seconds (ie 22 seconds before brake release), the thrust on both engines started to increase from 25% N_1 to 45% on the left engine, and to 49% on the right engine, where they remained for three seconds. The thrust then continued to increase, at a slightly faster rate, reaching 95% N_1 five seconds before the brakes were released. The thrust remained at 95% N_1 for about two seconds before again increasing, reaching 100% N_1 two seconds before brake release. From brake release, it took a further two seconds for the brake pressure to drop to zero by which time the aircraft was already moving forward and accelerating through seven knots.

During the flight to Gatwick no anomalies in the flight data were found to indicate an asymmetric flight configuration that might have been a result of damage to the aircraft.

Aberdeen Airport

Aberdeen Airport has three short runways for helicopter use and one main long runway for fixed-wing aircraft. The main Runway 16/34 has a declared Takeoff Run Available (TORA) of 1,829 m in both directions and a declared Accelerate Stop Distance Available (ASDA), also of 1,829 m, in both directions. The largest aircraft that operate out of Aberdeen are Boeing 767 aircraft.

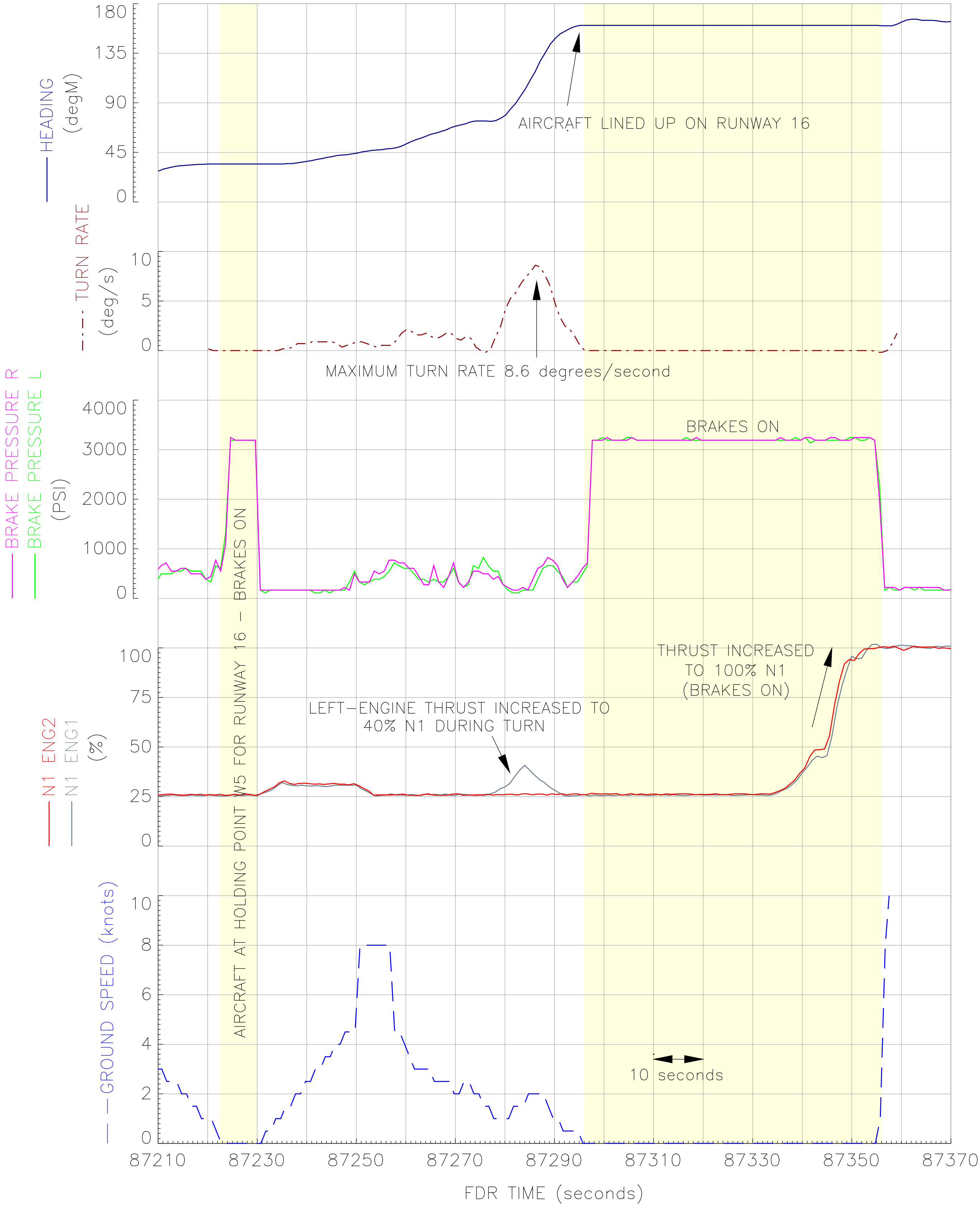

Figure 6

Salient FDR parameters

Blast pad history and construction

Runway 16/34 at Aberdeen Airport was originally constructed in 1952 to its current length without blast pads at the runway ends. The runway has since been re-surfaced many times. The airport authority did not have records detailing when the blast pads at both runway ends were constructed nor did they have records detailing the specification of the blast pads. No blast pads were shown in drawings of the runway created in 1986. The first time the blast pads were noted in documentation was following a survey carried out in January 1996. The airport authority believes the blast pads were probably constructed during the early 1990s to prevent erosion from the existing areas of grass at the runway ends. The central section of the blast pad, approximately 30 m wide, had been re-surfaced some time after the blast pad's original construction. On 31 March 1992 a BAe 146 aircraft (G-UKHP)[2] over-ran the end of Runway 34 (ie went into the grass off the Runway 16 end) and airport staff believe that the central section of the blast pad may have been repaired after that occurrence.

Following the accident to G-DOCT it was determined that the damaged blast pad surface probably consisted of Hot Rolled Asphalt (HRA) laid on a Type 1 Sub base (a mix of stone material which aids load distribution). The sections of damaged asphalt had varying thicknesses of between 4.5 cm and 6.5 cm. The depth of the asphalt where the blast pad joined the runway surface was measured at 6.5 cm. It was not possible to determine if there were any defects in the construction of the central section of the blast pad but the airport authority believed that it was possible that this repair was not up to the same standard as the surrounding blast pad. In any case, the blast pad was not designed to take the weight of the large airliners operating out of Aberdeen Airport, and although it was behind the runway threshold lights it was not marked as being unusable.

Design standards for blast pad construction

The CAA's design guidelines for runways are laid out in Civil Air Publication (CAP) 168 *Licensing of Aerodromes* but, this publication does not contain any guidelines or references to blast pads or erosion strips. It includes requirements regarding stopways which can serve as blast pads but stopways are different from blast pads in that they form part of the runway's ASDA and can be used for performance calculations. Stopways are therefore required to accommodate the occasional passage of the heaviest aircraft in the event of an aborted takeoff.

The international requirements and guidelines for runways are set out in the International Civil Aviation Organisation (ICAO) document '*Annex 14*'. This document does not include any references to blast pads or erosion strips. However, ICAO also publishes an *Aerodrome Design Manual* which states:

> *'The thickness of runway shoulders, taxiway shoulders and blast pads should be able to accommodate an occasional passage of the critical aircraft for runway pavement design, and the critical axle load of emergency or maintenance vehicles which may pass over the area.'*

It further recommends that for aircraft such as the Boeing 707, or smaller, the minimum surface thickness of the asphalt on blast pads should be 7.5 cm. For aircraft such as the Boeing 747, a 10 cm layer should be used. The manual also recommends that blast pads should be as wide as the runway plus shoulders and should be at least 60 m long. It cautions that:

Footnote

[2] This occurrence was reported in AAIB Formal Report 4/93 but it was not possible to determine from the report whether the blast pad had been in place.

> *'high-energy jet exhaust from turbine-engined aircraft, at 10.5 m behind the exhaust nozzle of an engine operating at maximum thrust, can raise boulders 0.6 m in diameter completely off the ground.'*

The US Federal Aviation Administration (FAA) published an Advisory Circular on Airport Design (AC 150/5300-13) which stated that:

> *'blast pad pavement needs to support the occasional passage of the most demanding airplane'.*

It also stated that the minimum asphalt surface thickness should be 7.6 cm for blast pads designed to handle aircraft in Design Groups III and IV. The Design Groups are based on wing span and the 737-400 is a Group III aircraft.

The airports authority responsible for Aberdeen Airport had its own guidelines for runway design published in their *Airside Planning Standards* document. It stated that:

> *'For runways used extensively by jet aircraft, runway end blast pads shall be provided as an anti-erosion measure… A minimum length of 30 m shall be provided'.*

Furthermore, the document stated the following regarding runway end blast pads:

> *'For its primary anti-erosion purpose there are no particular strength requirements, only that the surface be sealed to prevent flying debris. However, for practical purposes it needs to be able to support the passage of airport vehicles, including snow clearing and rescue and fire fighting vehicles.'*

Temporary blast pad repair

Following the accident to G-DOCT the remaining asphalt from the central section of the blast pad was dug up and the sub base was compacted. Then a 4.5 cm to 6.5 cm thick layer of stone mastic asphalt (SMA) was laid down to serve as a temporary repair. This repair was completed at 0130 hrs on 9 July 2005, the day after the accident. Between 15 and 16 July 2005 yellow diagonal line markings were painted on the surfaces of both the Runway 16 end blast pad and the Runway 34 end blast pad to warn pilots that the surfaces were not suitable for taxiing.

Permanent blast pad repair

Some time after the accident the decision was taken by the airport authority, in consultation with the CAA, to remove completely both the Runway 16 end blast pad and the Runway 34 end blast pad, and replace each with a new thicker surface that could accommodate the occasional passage of a Boeing 767. The new blast pads consisted of four layers. The bottom layer was a thin geotextile material. Above this was a 35 cm thick Granular Sub Base (GSB) Type 1 stone material. The next layer was a 5 cm thick section of Heavy Duty McAdam (HDM) and the top layer was a 5 cm thick section of SMA. The total asphalt thickness was therefore 10 cm. To reduce further the possibility of jet blast penetrating beneath the blast pad the final surface was finished at a level 2.5 cm below the runway level. However, this 2.5 cm vertical step caused problems when the runway edge surface began to break off as a result of airport vehicle traffic. Subsequently a small asphalt filler ramp was added to protect the vertical surface.

Following the new blast pad construction a new paint marking scheme was applied to alert pilots that the surface was not part of the runway. The paint marks consisted of diagonal yellow lines, joining at the centre to form small chevrons as depicted in Figure 7.

Taxiway and runway markings

ICAO Annex 14 Chapter 5 refers to taxiway and runway markings. Civil Aviation Authority document CAP 637, '*A compendium of Visual Aids intended for the guidance of Pilots and Personnel engaged in the handling of aircraft*', is derived from this document.

The centreline of Taxiway W was marked as a single continuous yellow line. This line continued beyond the end of the taxiway, curving in the direction of takeoff on Runway 16 to meet the nearside of the centreline marking. This line is variously described colloquially as the 'lead on' or 'lead off' line depending on whether an aircraft is entering or vacating a runway.

CAP 637, Section 2.1.2 states:

> *'Taxiway centrelines are located so as to provide safe clearance between the largest aircraft that the taxiway is designed to accommodate and fixed objects such as buildings, aircraft stands etc., provided that the pilot of the taxiing aircraft keeps the **'Cockpit'** of the aircraft on the centreline and that aircraft on stand are properly parked.'*

Note 1 of the same section states the following:

> *'At runway/taxiway intersections, where the taxiway centreline is curved onto the nearside of the runway centreline pilots should take account, where appropriate, of any loss of Runway Declared Distances incurred in following the lead-on line whilst lining up for take-off.'*

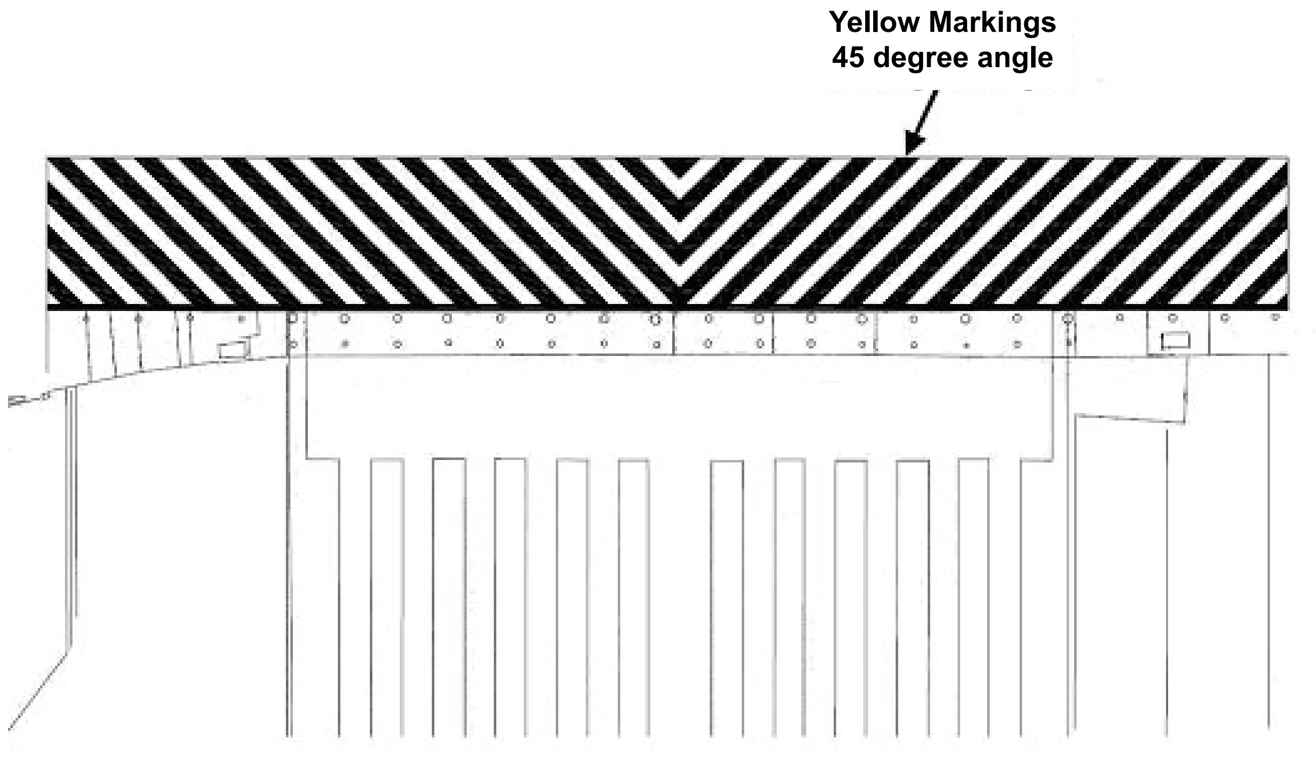

Figure 7

Paint marking scheme applied to the 'permanent repair' blast pads at both ends of Aberdeen Runway 16/34, after the accident to G-DOCT

No mention is made of any requirement for pilots actually to follow the centreline marking although it states that they are:

> *'responsible for taking all possible measures to avoid collisions with other aircraft and vehicles'.*

Section 2 of CAP 637 (Figure 8) describes runway threshold markings and, where a threshold is displaced, the bearing strength of the pre-threshold markings is indicated. The marking described for a pre-threshold area unfit for the movement of aircraft is in the shape of a white 'X'.

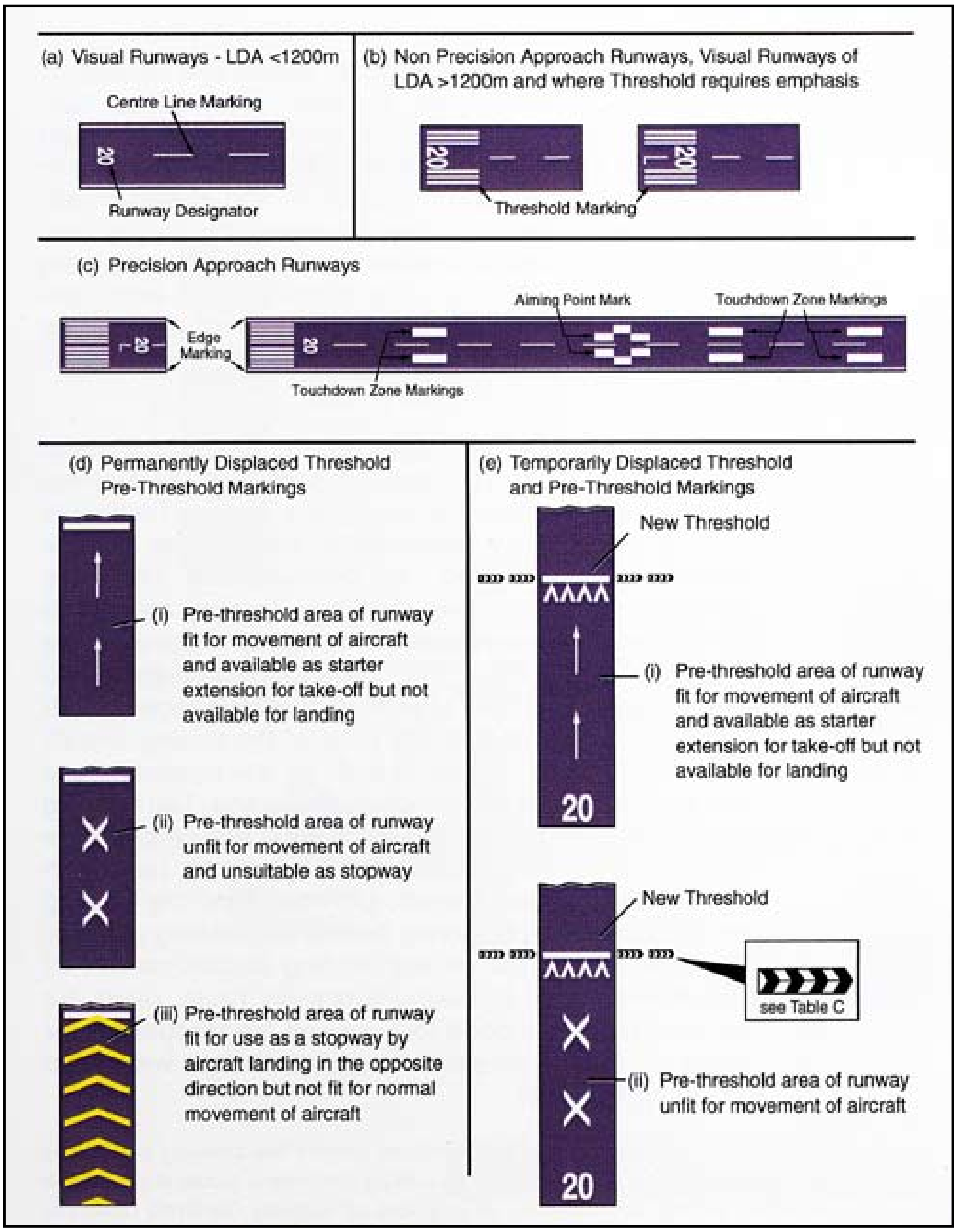

Figure 8

CAP 637 Paved runway markings

The threshold markings of Runway 16 did not extend onto the blast pad, nor was the threshold marked as being displaced. A runway threshold is normally located 6 m behind the 'piano key' markings but at Aberdeen the Runway 16 threshold is located 8.5 m behind the piano keys, behind two rows of runway lights fitted into the surface. There were no markings on the blast pad denoting its bearing strength.

Runway inspections

The Aberdeen Airport authority had a runway inspection process involving the following three levels:

- Level 1: routine daily inspections of the runway surface, carried out by airfield operations staff in vehicles
- Level 2: monthly detailed inspections of the Movement Area, carried out by airfield operations staff on foot
- Level 3: biannual detailed inspections of the Movement Area, carried out by the management team on foot (the last level 3 inspection before the accident was carried out in April 2005)

The Level 1 inspections consisted of 'Full Runway Inspections' and 'FOD[3]/Bird Runs'. During a 'Full Runway Inspection' a detailed inspection of the runway surface was carried out by one vehicle making two slow runs down the runway (once each side) or by two vehicles making a single run (each vehicle doing one side). Four of these inspections were required to be carried out each day and the last 'Full Runway Inspection' before the accident was carried out between the hours of 0300 and 0415 hrs with no anomalies noted. The 'FOD/Bird Runs' were carried out more regularly and at a higher speed in order simply to check for birds and FOD on the runway. The last 'FOD/Bird Run' was completed just two minutes before G-DOCT's departure. According to the officer who carried out this last inspection he did not see any damage to the blast pad surface or notice any damage to the overband sealing at the threshold of Runway 16.

Takeoff performance requirements

Aircraft takeoff performance requirements are calculated taking into account various limiting factors, included in which are runway measurements such as the takeoff run available (TORA), the takeoff distance available (TODA) and the accelerate-stop distance available (ASDA). Whilst the runway dimensions are fixed, allowance must be made for the distance taken by an aircraft to line up with the centreline. This distance depends on the aircraft geometry, the alignment of the access taxiway with the runway centreline and the steering angle used. As the aircraft geometry is known, manufacturers often supply alignment distances for common types of runway access, such as taxiways at 90° to the runway. Where these figures are not published they may be calculated using the method given in JAR-OPS 1 Subpart G, Section 2. This relies on any wheel passing no closer than 3.0 metres (for a B737) to the end of the runway (the 'edge safety margin').

Taxiway W at Aberdeen Airport required a turn through slightly more than 90º to line up with the centreline of Runway 16. The operator's performance calculations for the Boeing 737-400 were based on alignment distances provided by the manufacturer of 10 metres for a 90º turn onto the runway and of 18 metres for a turn on through 180º (these distances incorporate the 3 metre 'edge safety margin'). These figures relate to the distance from the edge of the threshold to the aircraft's main wheels, when the aircraft is aligned with the runway, and conformed to the JAR-OPS method of calculation.

Footnote

[3] FOD refers to foreign object debris.

Modelling used by the AAIB (Figure 4) indicated the minimum alignment distance attainable would leave the aircraft's main wheels about 10.5 metres from the threshold. To achieve this the aircraft would have to enter the runway and run its left main wheel along the edge of the threshold before turning around the right main wheel onto the runway centreline. Once lined up in this manner the aircraft's main wheels are positioned 10.5 m in from the runway threshold and the aircraft's tailplane is directly over the blast pad. The modelling further indicated that, if the aircraft had followed the 'lead on' lines onto the runway, its main wheels would have been about 66 metres from the threshold when aligned with the centreline.

The operator published information to its crews on the takeoff run available and that alignment distances are incorporated into the takeoff performance calculation. However, it did not make clear the exact point from which the aircraft is assumed to start its takeoff run.

Line-up technique

Observations of aircraft operating from Runway 16 indicated that other aircraft were also lined up using a similar technique to that described in this accident: the aircraft were taxied close to the edge of the threshold, without following the 'lead on' line, before braking the inner set of mainwheels and increasing the thrust on the outer engine to turn the aircraft in the shortest possible distance. This resulted in the outer engine passing over the blast pad with above-idle power applied. Evidence from ground marks on the temporary repair to the blast pad indicated that, on occasion, this resulted in aircraft wheels passing over the surface of the blast pad.

Jet-blast pressure study

The aircraft manufacturer publishes velocity profiles for the jet blast behind the tailplane of a 737-400. However, for this accident it was considered important to know the velocity profile and the pressure profile of the jet blast directly below the tailplane at ground level, so the engine manufacturer was contacted to carry out a study using their computational fluid dynamics (CFD) tools. The study revealed that with the engines set to 90% N_1 the jet blast velocity on the ground, aft of the engines and directly below the tailplane, would have been approximately 190 kt. The difference in velocity between the position directly below the leading edge of the tailplane and the trailing edge was minimal. At 100% N_1 the velocity at ground level was slightly lower than at 90% N_1, due to the jet exhaust's slightly narrower profile. The jet-blast pressure study also revealed that the static pressure of the air within the jet exhaust directly below the tailplane at ground level was equal to the ambient static pressure. Thus, the jet blast was not generating suction above the ground.

A further study was then conducted to examine the suction effects from the engine inlet. As G-DOCT made its tight final right turn, to line up with the runway, its left engine was spooled up to 40% N_1 and the path of the left engine probably passed over the blast pad surface. The study was therefore carried out at 40% N_1. The results indicated that in 'nil wind' conditions the static pressure on the ground, in front of the engine inlet, was equal to ambient pressure. However, when a 5 kt cross-wind was introduced into the model, a vortex was generated in front of the engine inlet which applied a suction force of 0.2 psi to the ground. The cross-wind induced flow asymmetry and this triggered the vortex formation. Figure 9 shows the vortex and the pressure contours for a power setting of 40% N_1.

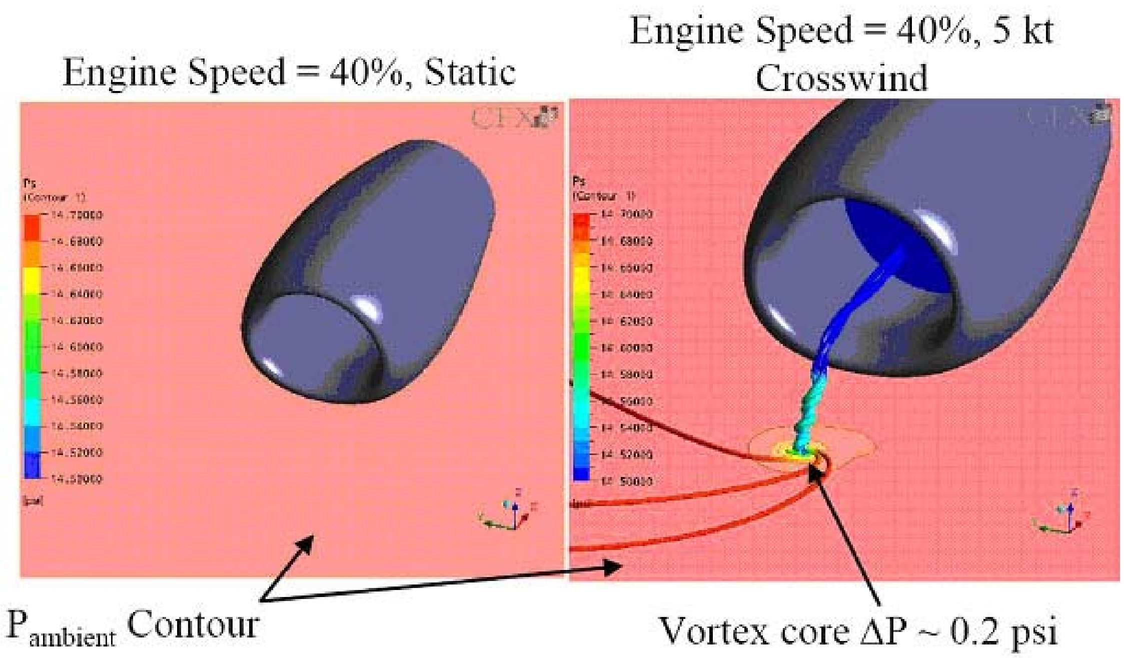

Figure 9

Results from the engine manufacturer's engine inlet study which revealed a 0.2 psi suction force at ground level with a power setting of 40% N_1 and a 5 kt cross-wind

The wind at the time of the accident was 7 kt from 140°(M). Therefore, as the aircraft began its final 85º turn to the right to line up on Runway 16, the aircraft would have been exposed to a cross-wind of approximately 6 kt.

The density of the asphalt from the blast pad was 2,100 kg/m^3 (or 0.0759 lb/in^3). A section of this asphalt, 6 cm thick, would have a weight per surface area of 126 kg/m^2 (or 0.18 psi). Therefore, if any adhesive force between the asphalt and the sub base is ignored, this simple calculation suggests that a suction force of 0.2 psi might be sufficient to start to lift a layer of asphalt 6 cm thick.

Normal takeoff technique

The operator's Operations Manual and Training Manual describe the same normal takeoff technique. This requires releasing the brakes before setting approximately 40% N_1, allowing the engines to stabilise at that power setting momentarily and then pressing the TO/GA switch. Pressing this switch when the autothrust is engaged automatically sets the remainder of the takeoff thrust. Should the autothrust be disengaged, the increase in thrust to takeoff power is achieved by manually setting the thrust levers.

In addition the Operations Manual states:

> *'02-NP-40-6*
> *The rolling take off procedure is recommended for setting takeoff thrust. This expedites takeoff and reduces risk of foreign object damage.'*

No other takeoff technique is described in either the Operations or Training Manual. The commander stated, however, that during his 'in-house' type conversion training on the Boeing 737 he had been taught that on limiting runways the correct technique was to hold the aircraft on the brakes whilst setting takeoff power, in order to ensure maximum takeoff performance was achieved. When asked, the commander described a limiting runway as a runway where, due to its length, the aircraft's maximum achievable takeoff weight was below its normal certified maximum and that the aircraft was at, or close to, this reduced maximum weight.

The commander had previously flown the Boeing 757/767 and Boeing 747-100/200 as a co-pilot with the same company and had seen this technique used on both fleets, although he could not recall it being included as part of the training on these types.

The Boeing Flight Crew Training Manual expands on the guidance offered in the operator's own manuals as follows:

> *'High thrust settings from jet engine blast over unpaved surfaces or thin asphalt pavement can cause structural blast damage from dislodged asphalt pieces and other foreign objects. Ensure run ups and take-offs are only conducted over well maintained paved surfaces and runways.*
>
> *A rolling take-off procedure is recommended for setting take-off thrust. It expedites take-off and reduces the risk of foreign object damage. Flight test and analysis prove that the change in take-off roll distance due to the rolling take-off procedure is negligible when compared to a standing take-off.*
>
> *Brakes are not normally held with thrust above idle unless a static run-up is required in icing conditions. A standing take-off procedure may be accomplished by holding the brakes until the engines are stabilised, then release the brakes and promptly advance the thrust levers to take-off thrust (autothrottle TO/GA).'*

Previous accidents involving jet-blast damage to runway surfaces and aircraft

A review of the CAA's Mandatory Occurrence Report (MOR) database revealed records of nine previous accidents involving jet airliners that had been damaged by blown sections of runway or taxiway, dating back to 1986. A review of the ICAO's accident database revealed an additional six accidents involving jet airliners that had been damaged by blown sections of runway or taxiway, dating back to 2001. Out of the 15 accidents, 11 occurred during the takeoff phase and at least eight involved aircraft becoming airborne after the damage had occurred. Most of the damage in these accidents was to the tailplane, elevator and flaps. Three of the aircraft that became airborne suffered from vibration or a control problem, as follows:

On *8 April 1988* a Boeing 737 on approach to Berlin airport experienced an immediate right roll when the first level of flap was selected at 2,300 ft. Control was maintained with 2º left rudder trim and a normal landing was carried out. The investigation revealed that the right inboard flap mechanism clutch had disengaged and a lump of tar was found jammed between the aft and mid flap surfaces. No further information could be found on the source of the tar.

On *7 February 1991* an Airbus A320 in France experienced vibration at 237 kt and 4,000 ft during the climb so the aircraft returned to land. The investigation revealed that large sections of asphalt had been thrown up by the jet blast and struck the tailplane and elevators. Part of the right tailplane and parts of the right and left elevators were missing.

On *10 September 2002* a Boeing 737 departing Warsaw experienced a slight left roll after liftoff. Right rudder trim was used to maintain wings level. After landing it was found that sections of asphalt had struck the left tailplane causing damage to its leading edge and three dents on its underside.

Very little information is available about what caused the asphalt surfaces to delaminate in these accidents because no formal investigation by an accident investigation body was undertaken. The AAIB investigated an accident to a Boeing 737 that occurred at Luton Airport on 22 September 1992 (AAIB Bulletin 12/92) where paving blocks from the turnpad area were blown up by the 737's jet blast, causing damage to its tailplane (see Figure 10). The paving blocks had not been bonded to the sand bedding beneath and the paved area was not marked. The aircraft departed normally and the damage was only revealed during a turnaround inspection.

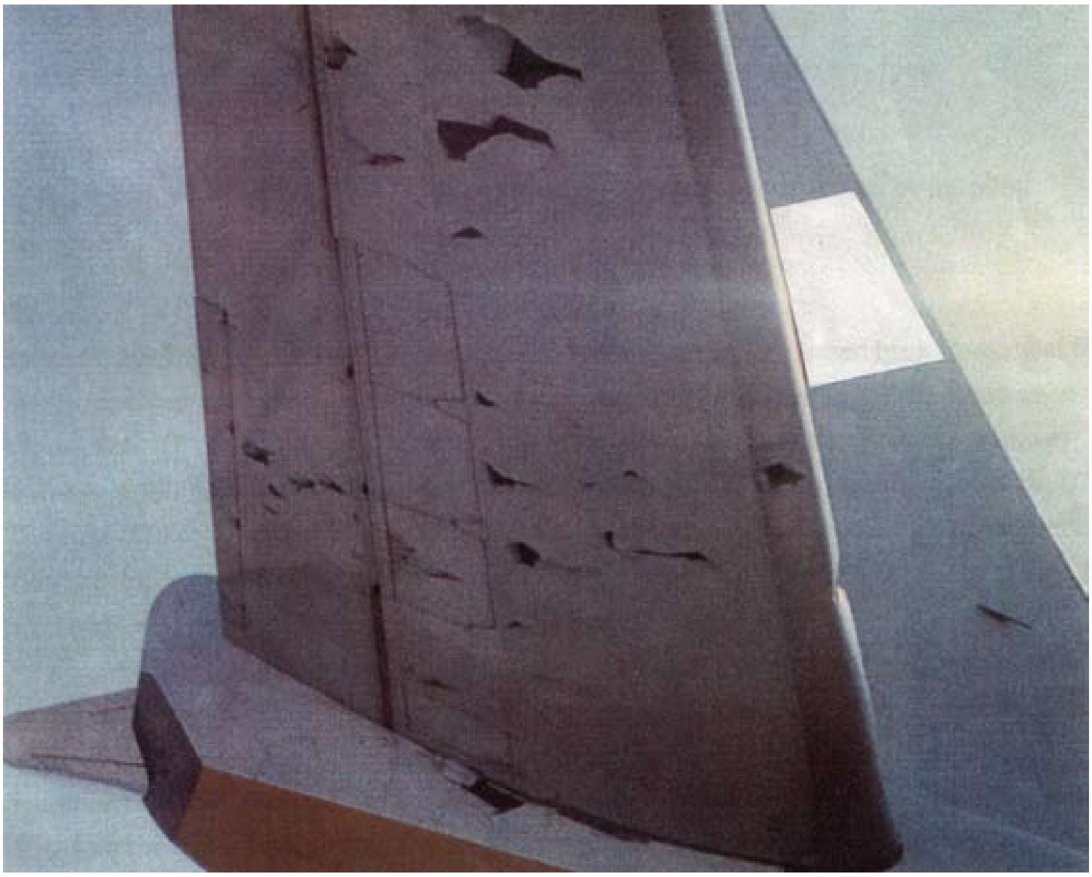

Figure 10

Damage to right tailplane underside of Boeing 737, G-MONM, at Luton Airport on 22 September 1992, following strikes by paving blocks from the turnpad area

The Italian air safety agency, ANSV[4], published a report on an accident very similar to that of G-DOCT, which involved an Airbus A320 at Treviso S. Angelo airport in Italy on 6 August 2002. After backtracking along Runway 07/25 the aircraft turned to line up for a takeoff from Runway 07. When takeoff power was applied the commander felt a jolt and noticed a blue hydraulic system loss so he aborted the takeoff run. Sections of asphalt from the stopway aft of the 07 threshold had been blown up by the jet blast and struck the aircraft's tailplane – the damage is shown in Figure 11. The stopway had been painted with a white arrow rather than with yellow chevrons and the ANSV report questioned the surface's ability to meet the structural requirements of a stopway.

Footnote

[4] Agenzia Nazionale Per La Sicurezza Del Volo.

Figure 11

Damage to left tailplane leading edge of Airbus A320
at Treviso S. Angelo airport in Italy on 6 August 2002,
following a strike by a large section of asphalt from the stopway

Analysis

Aircraft damage and potential consequences

The damage to G-DOCT's left tailplane and left elevator was caused by one or more strikes from large sections of asphalt that had been lifted from the blast pad by the force of the aircraft's jet blast. The largest section of dislodged asphalt found was approximately 1.8 m by 1.5 m, but the 2.4 m dent on the underside of the tailplane indicated that it had been struck by a larger section which had then split. The flight crew of the following aircraft, who had observed the lifting of the asphalt sections, estimated the largest to be 2 m by 3 m, and such a section, 6 cm thick, would have weighed approximately 756 kg. It was not possible to determine accurately where the tailplane was located relative to the blast pad at the time of the strikes, but it would have been positioned approximately where it is depicted in Figure 4.

The damage to the tailplane would have had minimal aerodynamic effect, but the elevator was missing a section almost 1 metre long and this would have reduced the elevator's effectiveness. In the event, the flight crew did not have any difficulty rotating the aircraft to takeoff attitude and did not report any control difficulties during the flight. However, further elevator surface loss could have prevented rotation and resulted in an aborted takeoff beyond V_1[5] speed and a potential runway over-run. A more severe outcome could have resulted if the elevator's structure had been compromised to the point where the aerodynamic loads in flight caused further elevator damage and possible separation. The change in the elevator's aerodynamic and mass properties could also have made the elevator more susceptible to flutter.

The review of previous accidents and incidents involving jet airliners damaged by blown sections of asphalt revealed instances of in-flight control problems and vibrations. The lifting of paved runway surfaces and surrounding areas as a result of jet blast therefore presents a clear hazard to the safety of flight.

Cause of the blast pad break-up

The jet-blast pressure study revealed that the aircraft's jet blast, even at takeoff power, would not have generated any suction at ground level below the tailplane. However, if the jet blast had been able to penetrate between the asphalt surface and the Type 1 Sub base, the dynamic pressure of the jet blast, at a speed of approximately 190 kt, would have been capable of peeling the surface away. In the case of G-DOCT it appears that such penetration and peeling by the jet blast occurred. Once the asphalt started to peel away, the exposed surface would have deflected the jet blast around it and created sufficient lift for the detached asphalt to rise 14 ft and strike the tailplane.

The important question, therefore, is what enabled the jet blast to penetrate between the asphalt surface and the sub base. A bitumen overband sealing was laid along the length of the joint between the blast pad surface and the runway surface and this sealing is designed to create a flush surface, without cracks, between the runway and blast pad. A deterioration of this seal would have made it easier for the jet blast to penetrate. However, no deterioration of the overband sealing was noted during the runway inspections that were carried out on the morning of the accident and just prior to the aircraft's departure.

It is possible that, while the flight crew were trying to position the aircraft, the left main gear wheels passed over the blast pad surface and caused some surface

Footnote

[5] V_1 is the decision speed below which a takeoff can be safely aborted with sufficient runway remaining to stop. The rotation speed (V_R) is always greater than or equal to V_1.

damage because the pad was not designed to withstand the taxiing loads of aircraft. From the modelling shown in Figure 4 it was determined that the left gear would have passed very close to, and possibly directly over, the blast pad in order to place the tailplane in a position to be struck by blown sections of the pad. On this occasion, both the flight crew of G-DOCT and that of the following aircraft stated that no wheel passed over the blast pad. It is probable, however, that in the past other aircraft had taxied over the blast pad surface because aircraft had been observed manoeuvring close to the runway end and an aircraft tyre mark was seen on the re-surfaced blast pad. The cumulative effect of these occasional aircraft taxiing loads could have weakened the blast pad surface.

Another possible cause of blast pad damage is as a result of suction from the engine inlet. While manoeuvring to position a Boeing 737 close to the end of the runway, the engine inlet from one of the engines may pass over the blast pad even without the main gear passing over it. There is no prohibition against allowing an engine to pass over a non-load-bearing surface. The pressure study carried out by the engine manufacturer revealed that, in conditions of light cross-wind, a vortex can form forward of the engine inlet. In the case of G-DOCT, with 40% N_1 power set on the left engine and a cross-wind of approximately 6 kt, a suction force of approximately 0.2 psi would have been applied at ground level. Based on the density of the asphalt surface, this suction force might have been sufficient to start to lift the asphalt surface and cause blistering or cracks. However, this would have been dependent upon the strength of the bond between the asphalt surface and the sub base and the adhesive strength between the asphalt surface and the surrounding material. The results are not conclusive but suggest that further research should be carried out to examine the effects of engine inlet suction on paved surfaces.

The damaged blast pad surface was quickly dug up after the accident and resurfaced overnight. It was, therefore, not possible to determine the strength of the bond between the asphalt surface and the sub base. However, the lack of residual bitumen residue on the stone sub base indicated that the bond may have been inadequate and contributed to the jet blast's ability to peel the surface away. The asphalt's surface thickness, of between 4.5 and 6.5 cm, was significantly less than the 7.5 cm recommended by ICAO's *Aerodrome Design Manual* and the 7.6 cm recommended by the FAA's Advisory Circular. If the asphalt surface had been thicker it would have been more difficult for the jet blast to penetrate beneath it. Neither the CAA nor the airport authority had published any guidelines on the surface thickness of paved blast pads.

In order to prevent future recurrences of these types of accidents, blast pads need to be designed so that they are of sufficient strength, sufficient thickness and have adequate bonding and sealing to ensure that they cannot be damaged or uplifted by the engine inlet suction or engine jet blast of the most critical aircraft. Furthermore, since aircraft are permitted to use the full length of the runway, right to the edge of a blast pad, it must be expected that occasionally an aircraft will accidentally taxi over a blast pad. Therefore, blast pads should also be designed to accommodate the occasional passage of the most critical aircraft.

In light of these findings, the AAIB recommends that:

Safety Recommendation 2007-023

The International Civil Aviation Organisation (ICAO) should consider amending Annex 14 to include requirements for paved blast pads that will ensure that they cannot be damaged by the engine inlet suction, the engine jet blast or the taxiing loads of the most critical aircraft.

Safety Recommendation 2007-024

The International Civil Aviation Organisation (ICAO) should review the requirements of Annex 14 to ensure that runway surfaces, stopways and other adjacent areas susceptible to high-power jet blast cannot be damaged by the engine inlet suction or the engine jet blast of the most critical aircraft.

Safety Recommendation 2007-025

The Civil Aviation Authority (CAA) should consider amending Civil Air Publication (CAP) 168 to include design requirements for paved blast pads that will ensure that they cannot be damaged by the engine inlet suction, the engine jet blast or the taxiing loads of the most critical aircraft.

Safety Recommendation 2007-026

The Civil Aviation Authority (CAA) should ensure that paved blast pad surfaces, stopways and turnpads at all licensed UK airports are constructed such that they cannot be damaged by the engine inlet suction, the engine jet blast or the taxiing loads of the most critical aircraft.

Blast pad markings

At the time of the accident there were no markings on the blast pads at either end of the runway. The only delineation between the runway surface and the blast pad surface was the strip of runway threshold and runway end lights. By international convention, in the absence of a line across the runway denoting a displaced threshold, the known load-carrying extent of the runway would have extended back 6.5 metres from the 'piano key' markings. Performance calculations are based on the aircraft wheels not passing closer than 4.5 metres to the end of the runway surface. Therefore, a pilot should aim to keep the aircraft wheels close to the edge of the 'piano key' markings irrespective of the extent of any surface beyond it. The short extent of the blast pad, together with an absence of any markings, meant that it may not have been apparent to all flight crew that the surface did not form part of the runway and was not designed to withstand taxiing loads.

Following the accident, a temporary asphalt surface was laid down and a row of parallel yellow diagonal lines was painted on it. These markings did not conform to any national or international standard. After the permanent repair was installed, a different paint scheme was developed by the airport authority in consultation with the CAA. This new paint scheme, consisting of yellow diagonal lines and mini chevrons (see Figure 7), shared a degree of similarity with the internationally standardised marking for a stopway (yellow chevrons). However, a stopway is designed to be used as an overrun area in the event of an aborted takeoff and is therefore strong enough to cater for the taxiing loads of the most critical aircraft. Blast pads should be similarly designed but if they are not as strong as stopways then a different marking scheme should be used to avoid confusion. The AAIB therefore recommends that:

Safety Recommendation 2007-027

The International Civil Aviation Organisation (ICAO) should establish standardised markings for paved blast pads and amend Annex 14 accordingly.

Safety Recommendation 2007-028

The Civil Aviation Authority (CAA) should, in consultation with the International Civil Aviation Organisation (ICAO), establish standardised markings for paved blast pads and amend Civil Air Publications (CAPs) 168 and 637 accordingly.

BAA and CAA safety action

As a result of this accident the airport operator, BAA, installed a new blast pad at both ends of the runway at Aberdeen Airport. The new blast pads are 10 cm thick and are designed to accommodate the occasional passage of a Boeing 767 (the most critical aircraft). This safety action should prevent a recurrence at Aberdeen. BAA also determined that no action needed to be taken at their other airports because similar issues did not exist.

The CAA Aerodrome Standards Department took some safety action shortly after the accident by publishing information about the accident in its *Reference Point* leaflet (Issue 8 – August 2005). The publication stated that all Licensees should ensure that all hard surfaces are in good condition and should determine where surfaces are not capable of bearing the weight of the largest aircraft. The leaflet states:

> *'If it cannot* [bear the weight of the largest aircraft]*, or if there is any doubt, a suitable marking should be placed on the surface to warn crews of this possibility.'*

It also stated that if Licensees decided to replace blast pads they should take into account the recommended design thickness in ICAO's *Aerodrome Design Manual.* The CAA also tasked all CAA aerodrome inspectors to establish the integrity of all known blast pads at UK airports.

In 2006 the CAA carried out a more detailed survey of blast pads, turn pads and other similar surfaces. It has identified eight UK airports at which closer attention is going to be paid and potential redesigns considered.

Commander's actions

It is apparent that the commander believed, in the absence of any information to the contrary, that the performance restrictions imposed on the aircraft's takeoff were due to runway length. In the event, the restriction was actually due to obstacle clearance requirements during the climb out. Regardless of the cause of the performance limitation, any restrictions are reflected in the maximum weight allowed for takeoff. Therefore, as long as the aircraft remains at or below this weight, there is no requirement to alter the takeoff technique in order to achieve a safe departure.

The commander employed a technique which did not comply with the standard technique laid down in either the manufacturer's or the operator's manuals. Whilst there was nothing in the operator's manuals specifically prohibiting the technique, the manufacturer had published warnings advising against it. These warnings were, however, not readily accessible to the operator's line pilots. Having witnessed others employing the same or similar technique within the company, and having been trained to do so on his type conversion course, it appeared to the commander a legitimate procedure to use on this occasion. It ensured, in his mind, an adequate margin over the performance limitations imposed, he believed, by the length of the runway.

In addition to holding the aircraft on the brakes whilst setting the calculated takeoff power the commander also continued to increase the power above this level until the maximum power available was set. The aircraft remained stationary with high power set whilst this was achieved for some five seconds and it is possible that this contributed to the surface of the blast pad breaking up. It is also possible that, had the commander carried out a rolling takeoff, the tail would have been clear of the affected area of blast pad before sufficient power had been achieved to lift the surface.

As a result of this accident, the operator's 737 Fleet Management issued a Fleet Technical News entitled '*Rolling Take-off Procedure*', outlining the recommended takeoff procedures from the Boeing Flight Crew Training Manual. The commander stated that the takeoff technique he had used on G-DOCT was the same technique he had used on other fleets within the same company: this suggests that the issue would benefit from wider promulgation than the Boeing 737 fleet alone. The AAIB therefore recommends that:

Safety Recommendation 2007-029

British Airways should review the training of takeoff techniques across all fleets to ensure that it is consistent with the operator's intended procedures.

Safety Recommendation 2007-030

British Airways should incorporate information on appropriate takeoff techniques in relevant flight crew documentation for all fleets.

Aircraft performance

The performance figures were correctly calculated for the aircraft, runway and ambient conditions at the time of takeoff. The performance figures relied, however, upon the aircraft lining up 10 metres from the runway threshold in order to be valid. This was slightly less than the minimum line-up allowance in the computer modelling used by the AAIB and 56 metres less than the line-up allowance had the commander chosen to follow the line linking the taxiway centre line to the runway centre line. On this occasion, in order to maximise performance, the crew had ignored the taxi guidance provided. This potentially presents a problem when operating at night or under low visibility conditions.

In order to calculate performance data for airports used by its aircraft, an operator needs to be able to rely on known runway parameters. As these do not normally include the position of 'lead on' lines, they cannot be taken into account when defining the start of the takeoff run in calculating performance. This results in a possible conflict between maximising performance whilst ensuring aircraft safety is not compromised by ignoring runway markings designed to ensure appropriate guidance to aircraft whilst lining up. As the extent of this problem is not fully understood the AAIB makes the following recommendation:

Safety Recommendation 2007-031

The Civil Aviation Authority should review the implementation of current performance requirements for 'Performance A' aeroplanes, to ensure that they adequately reflect desired line-up techniques, in particular following ground markings provided for taxi guidance.

In order for the flight crew to be able to comply with the calculated performance requirements, they must be informed of the reference point used and be able to identify its position so that the aircraft does not commence its takeoff beyond that point. Prior to this accident the operator did not provide this information to its crews. This has now been reviewed and, as a result, additional guidance notes have been provided for use with the operator's computerised performance system on all fleets. The investigation did not extend to analysing how other operators ensure the actual takeoff point complies with that used in the performance calculations. In view of this the AAIB recommends that:

Safety Recommendation 2007-032

The Civil Aviation Authority should, during routine audits of operators of 'Performance A' aeroplanes, ensure that operators' takeoff performance calculations are consistent with the operation of their aircraft, specifically with respect to the line-up position.

INCIDENT

Aircraft Type and Registration:	Cessna 404 Titan, G-OOSI
No & Type of Engines:	2 Continental GTSIO-520-M piston engines
Year of Manufacture:	1981
Date & Time (UTC):	16 December 2006 at approximately 1930 hrs
Location:	En-route from San Pedro Airport, Cape Verde Islands, to Dakar Airport, Senegal
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence with Instrument Rating
Commander's Age:	32 years
Commander's Flying Experience:	504 hours (of which 35 were on type) Last 90 days - 85 hours Last 28 days - 35 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, a company report and enquiries by the AAIB

Introduction

The incident occurred over international waters and, in agreement with the Portuguese Authorities the AAIB, representing the State of Registration, took responsibility for the investigation.

Synopsis

When flying above 10,000 ft, the commander did not use continuous oxygen. He was probably suffering from hypoxia when he attempted to adjust his engine controls and this resulted in vibration and an uncontrolled descent. He recovered full control at a lower altitude and made a successful diversion.

The operating company is implementing changes to their operating procedures to prevent a similar occurrence.

History of the flight

The aircraft had been operating in the area since the end of November 2006 and was being used for map survey operations. During this time there were no reports of any significant aircraft unserviceability. The aircraft was usually operated on survey flights with two people on board: a pilot (the commander) and a camera operator (the passenger).

Prior to the incident flight, the commander had noted that his intended route from San Pedro Airport to Dakar Airport included a portion with a minimum notified altitude of FL195. He therefore planned a cruise altitude of FL210 but intended to descend below FL100 when within the Dakar FIR. The aircraft oxygen pressure indicator was showing 1,200 psi before the flight which would allow just over four hours oxygen use for two people at FL220. The commander subsequently stated that the aircraft occupants would need oxygen for approximately 45 minutes.

There were three pilot-style oxygen masks for the two occupants. Each had a rubber restraining strap and a microphone. However, the commander was aware that the microphone on at least one of the masks was "crackly" and he didn't intend to use it for radio transmissions. Additionally, the mask provided to the passenger had a broken strap held together with adhesive tape.

The passenger stated that a week before this flight, he was advised (by a different commander) that he should only use oxygen "as and when he needed it" to avoid any possibility of draining the system. However, the operator's representative stated that no such instruction was necessary for the incident flight and the commander stated that he had intended the passenger to use "as much oxygen as they felt necessary". The operator also stated that the oxygen system was serviceable and had been used on recent flights. There had been no noticeable leakage from the system and there was more than sufficient oxygen remaining for the planned flight.

For the takeoff at 1855 hrs, the passenger was seated immediately behind the commander in a seat facing aft. As the aircraft climbed through 10,000 ft, the passenger was instructed to move to the rear of the cabin, to optimise the aircraft's CG position, and to activate the oxygen system. When seated at the rear of the cabin, the oxygen and intercom leads were too short to allow him to connect both simultaneously.

During the climb, the commander used his oxygen mask intermittently, albeit more frequently as altitude increased. When not using the mask, he placed it on his lap. Once level at FL210 in the cruise, he engaged the autopilot. During the subsequent cruise, the passenger had the impression that the commander's voice was "a little slurred" when transmitting to ATC. When asked, the commander confirmed that he was using oxygen and shortly afterwards he was seen to be adjusting the engine controls. The commander subsequently confirmed that he took off his oxygen mask to adjust the controls in response to a perceived engine problem. Soon after, the passenger heard a change in engine noise and was aware of vibration together with the sensation that he was being pushed into his seat. Attempts to contact the commander by intercom were unsuccessful and, with the aircraft descending at high speed and in a spiral, the passenger called twice for the commander to transmit a 'MAYDAY'. The commander responded to the second call and declared an emergency. The aircraft was still descending and, at around 5,000 feet altitude the passenger opened the emergency escape hatch in preparation for a possible sea ditching. However, the commander then regained control of the aircraft and once it was fully stable, he requested a diversion to Amilcar Cabral Airport on the Cape Verde Islands. A safe landing was made there at 2005 hrs.

Post landing actions

After landing, the commander checked the aircraft and considered that it was fully serviceable. He was confident that the aircraft had remained within normal operating parameters during the incident and that no negative 'g' manoeuvres had occurred. On reflection, he considered that he had started suffering from hypoxia during the climb. The perceived engine problem probably resulted from him not correctly adjusting the engine controls at altitude.

The commander contacted his company engineer in UK to advise him of the incident and also carried out uneventful engine ground runs the next day before flying the aircraft to Dakar Airport in daylight. At Dakar, the company engineer, who had flown out from the UK, checked the aircraft and assessed it as fully serviceable. The aircraft's oxygen contents gauge was reading 600 psi.

Cessna 404 oxygen system

If an oxygen system is factory-fitted to a Cessna 404, the storage cylinder(s) are normally carried in the nose compartment. It is activated by the pilot pulling the oxygen control knob to the ON position allowing oxygen to flow from the regulator to all cabin outlets. However, the cabin of G-OOSI had been significantly modified for survey tasks and an oxygen cylinder was installed at the rear of the fuselage. The oxygen control knob was located at the rear of the aircraft cabin. Consequently, the commander had either to activate the oxygen system before takeoff or instruct passengers to activate it in the air when oxygen was required.

A normally closed valve in each oxygen outlet is opened by inserting the connector of a mask and hose assembly. The front-seat oxygen outlet was under the armrest beside the commander's seat, adjacent to the headphone and microphone jack sockets. The passengers' oxygen connector at the rear of the cabin was above his head within a small panel containing lights and a ventilation outlet. This panel did not have adjacent headphone and microphone jack sockets.

The Pilot's Operating Handbook contains an aircraft altitude operating limitation of 30,000 ft with oxygen equipment.

Regulations

All aircraft must fly at an altitude less than 10,000 ft unless the aircraft has a pressurised cabin or the pilot uses an individual oxygen source supplied by a personal mask. Additionally, it is recommended that oxygen be used at a lower altitude when flying at night.

Pilot's assessment

After the incident, the pilot stated that although he was aware of the insidious nature of hypoxia, and despite his attempts to recognise the symptoms during the flight, he under-estimated the risks of becoming hypoxic through not wearing the oxygen mask continuously.

Company actions

The company concluded that the main contributing factor to the incident was the commander not using his oxygen mask continuously above 10,000 ft. Another contributing factor was that at least one of the oxygen masks on the aircraft may have had a defective microphone; this would have required the user to remove the mask when communicating with ATC.

The company intends to implement more stringent hypoxia training and is also making the following changes to their procedures:

1. Future annual flight checks for all company pilots will include a briefing on the use of the aircraft oxygen system.
2. When operating abroad, crews will be required to inform the Chief Pilot or Company Safety Pilot whenever equipment is unserviceable.
3. Camera operators will be required to attend initial company CRM courses.
4. Night flights in unpressurised aircraft will be prohibited above 10,000 ft.

In view of these actions, the AAIB did not make any safety recommendations.

INCIDENT

Aircraft Type and Registration:	Piper PA-31-350 Navajo Chieftain, G-BBNT
No & Type of Engines:	2 Lycoming LTIO-540-J2BD piston engines
Year of Manufacture:	1973
Date & Time (UTC):	16 August 2006 at 1552 hrs
Location:	Sandown Aerodrome, Isle of Wight
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	8,396 hours (of which 61 were on type) Last 90 days - 43 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB

Synopsis

After touching down on Runway 23 the pilot continued the landing roll onto the runway overrun to avoid a motor vehicle.

History of the flight

At the end of a flight from London (City Airport), the pilot made a visual approach for a landing on Runway 23 at Sandown Aerodrome. The runway had a dry grass surface and an LDA of 884 m. The exit to the northern taxiway is at the end of the runway. Beyond the end of the runway there is an overrun of approximately 100 m which crosses an uncontrolled minor public road. For the landing the weather was good with an estimated surface wind of 180º/5 kt and an air temperature of 18ºC.

The pilot reported that he made a normal touch-down and commenced gentle braking. Towards the end of his landing run, he was preparing to vacate the runway to the right when he became aware of a vehicle entering the overrun area of the runway from the public road. As the vehicle appeared to be turning left towards the aircraft, the pilot considered that his most prudent action was to continue straight ahead onto the overrun and across the road. This he did and he succeeded in avoiding the vehicle. He then turned G-BBNT around through 180º and vacated the runway onto the northern taxiway. The pilot reported that the vehicle was driven off at high speed.

Performance calculations

The reported weight of G-BBNT on landing was 2,869 kg compared to the maximum landing weight of 3,175 kg. Based on the prevailing conditions, the Airplane Flight Manual required a landing distance from 50 ft of 585 m on dry grass using maximum braking. With the Public Transport factor of 1.43 applied, the LDR (Landing Distance Required) was 837 m which was within the LDA.

Corrective action

After this incident the aerodrome management installed barriers to restrict vehicular movement on the road during certain aircraft movements.

ACCIDENT

Aircraft Type and Registration:	Pierre Robin R2112, G-BIVA
No & Type of Engines:	1 Lycoming O-235-L2A piston engine
Year of Manufacture:	1978
Date & Time (UTC):	24 March 2007 at 1043 hrs
Location:	Truro Airfield, Cornwall
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Several small dents on leading edge, minor damage to propeller and rear strake
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	927 hours (of which 2 were on type) Last 90 days - 22 hours Last 28 days - 17 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot was carrying out a touch-and-go landing at Truro Airfield and the aircraft failed to get airborne.

History of the flight

The flight was planned from Royal Naval Air Station Culdrose to Truro. Prior to takeoff, the pilot called Truro Airfield and requested permission to carry out "a couple of approaches". This was approved and the pilot inquired about the runway length. He was informed that the available length was 500 m, with an additional 30 m unavailable due to water-logging and the fact that the grass needed cutting in preparation for a 'fly-in' the following day. He was also informed that the radio may not be manned.

On arrival at Truro the pilot noted from the windsock that the wind was light and an approach to Runway 23 was carried out. The aircraft was flown down the length of the runway at approximately 20 ft agl. It climbed away normally and entered the circuit pattern at 1,000 ft. The pilot, in consultation with the passenger who was also a pilot, decided that the runway looked suitable to carry out a touch-and-go. Downwind checks were completed and the carburettor heat control selected 'ON' where it remained until 100 ft on the final approach. At this stage the carburettor heat was selected 'OFF' in accordance with normal procedures.

The aircraft touched down 40 m beyond the runway threshold at a speed of around 50 kt, slightly faster than the normal touch-down speed for this aircraft. The pilot stated that the retardation as the aircraft rolled along the surface was noticeable but did not seem excessive. He then applied full power and raised the flaps to the takeoff position. Light back pressure was applied to the control stick, as the aircraft normally becomes airborne in quite a flat attitude due to the presence of a strake on the tail. However, the aircraft did not become airborne. The pilot checked both the flap setting and the carburettor heat selection to ensure it was not selected. A second attempt was made to raise the nose and become airborne without success. The pilot closed the throttle, but re-opened it as he considered that the aircraft would contact a fence beyond the end of the runway if he attempted to stop at this stage. The pilot pulled back on the control column in an attempt to hop over the fence. However, the aircraft went through the fence and came to rest in the field beyond. Both occupants were uninjured and vacated the aircraft normally.

The damage to the aircraft was limited to a number of dents in the leading edge of the left wing and a 'nick' in one propeller blade. The fence was constructed of plastic and was intended to be frangible; however, it had a strand of steel supporting wire which caused the damage. The aircraft was recovered to the airfield boundary and, following an inspection by the repair agency, was flown to their overhaul facility. No problems were reported with engine performance.

Witnesses reported hearing the aircraft make a low go-around followed by a circuit and a very low approach. The engine note was heard to increase initially and then splutter.

Airfield information

Truro is an unlicensed grass airfield at an elevation of 400 ft amsl, with three runways. Runway 14/29 has a length of 531 m, with a 100 m starter extension on Runway 32. Prior permission is required to use the airfield.

Discussion

The pilot considered that the aircraft had suffered a power loss due to carburettor icing. Meteorological observations between 1000 and 1100 hrs in the Truro area estimated a temperature of 10ºC and a dew point of 2ºC, with 58% humidity. The wind was light and variable. Reference to the carburettor icing chart in the CAA General Aviation Safety Sense Leaflet 14A showed that these conditions are just within those conducive to serious icing at any power. The pilot stated that this aircraft type was new to him and therefore, as the takeoff position is flatter than he is used to, he may have let the aircraft remain on the runway for too long. Grass, and in this case long grass, can increase the rolling resistance and therefore the takeoff ground run considerably.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161, G-BPMR
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1984
Date & Time (UTC):	5 April 2007 at 1200 hrs
Location:	Enstone Aerodrome, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left wing damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	254 hours (of which 92 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst backtracking toward the parking area, following an uneventful landing on the asphalt Runway 26, the pilot became distracted by a landing aircraft on the grass Runway 26. He allowed his aircraft to drift to the left and strike a fence, causing damage to the left wing leading edge.

History of the flight

The flight to Enstone from Gloucester was uneventful, as was the landing on the asphalt Runway 26. To reach the parking area the pilot had to backtrack. As there were other aircraft operating in the area and an aircraft was about to land on the grass Runway 26, to the south, the pilot decided to backtrack beside, and to the north of, the marked runway area.

To the north of the asphalt Runway 26, and running in the same direction as the runway, was a six-foot fence consisting of posts with wire strands suspended between them. The fence segregated a northside grass strip used by a maintenance facility, which was a separate operation from that of the aerodrome.

The aircraft was backtracked between the fence line, to the pilot's left, and the northern edge of the asphalt Runway 26, to the pilot's right. Whilst taxiing, the pilot became distracted by the aircraft landing to his right on the grass Runway 26. His aircraft then drifted to the left after which the left wingtip struck one of the fence posts and the aircraft swung further to the left, causing the left wing to contact several additional fence posts.

The aircraft subsequently came to a halt and the pilot and the passengers exited the aircraft normally and were uninjured.

ACCIDENT

Aircraft Type and Registration:	Piper PA-32-300, G-BAXJ
No & Type of Engines:	1 Lycoming IO-540-K1A5 piston engine
Year of Manufacture:	1970
Date & Time (UTC):	25 March 2007 at 1325 hrs
Location:	Old Buckenham Airfield, Norfolk
Type of Flight:	Aerial Work
Persons on Board:	Crew - 1 Passengers - Nil
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear destroyed, propeller blades bent, damage to the wings and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	2,418 hours (of which 1,000 were on type) Last 90 days - 43 hours Last 28 days - 22 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and inspection by an insurance loss adjustor

Synopsis

Commencing a descent after a parachute drop, the pilot became aware, at 500 ft, that the engine had failed. Lacking the height to make it to the airfield, he decided to land in an undershoot field where the impact resulted in substantial damage to the aircraft.

History of the flight

Following a parachute drop the pilot commenced a descent to land on Runway 07. The descent was uneventful and the approach and landing checks were completed. At about 500 feet the pilot applied a small increase of the throttle and became aware that the engine was not responding and had failed. He changed fuel tanks and checked that the auxiliary pumps were still selected ON (part of the approach and landing checks) but there was no response from the engine. He retracted the first stage of flap and thought that he might be able to land on the runway but realising that he did not have sufficient height, he elected to land in an undershoot field. Unfortunately, the intended touch-down area was traversed by a ditch. The pilot raised the aircraft's nose and cleared the ditch but, because the airspeed was low, the aircraft impacted the ground heavily on the other side. The ground was of a heavy clay-type soil and the aircraft came to a halt very rapidly, having collapsed all three landing gear legs.

The accident site was quickly attended by the airfield's fire crew but there was no fire. The pilot asked the fire crew to check the aircraft's fuel state and they found that there was fuel present in both wing tanks. The fuel state was low and the aircraft would have required refuelling prior to the next flight but, in the pilot's estimation, there was a total of approximately 30 litres in the two tanks.

At no time during the aircraft's descent or approach did the pilot notice that the engine had failed; there had been no detectable coughing or spluttering.

Engineering examination

During the recovery of the aircraft an engineer noted that there was fuel present in both tanks, that there was oil in the engine and that the engine appeared to be free to rotate. An insurance loss adjustor inspected the aircraft some days after it had been removed from the accident site and he confirmed that there was fuel in both tanks, oil in the engine and that the engine was free to turn. He saw no evidence of a major engine mechanical failure or major engine oil loss. It was not apparent what had caused the loss of power.

Icing

The engine fitted to this aircraft has a fuel injection system which, for the weather conditions on the day, would not have been affected by icing.

ACCIDENT

Aircraft Type and Registration:	Sukhoi SU-29, HA-YAO
No & Type of Engines:	1 M14 PF piston engine
Year of Manufacture:	1998
Date & Time (UTC):	1 February 2007 at 1649 hrs
Location:	Southend Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the engine and engine compartment
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	950 hours (of which 56 were on type) Last 90 days - 27 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot was attempting to start the engine, which was warm, when a fire broke out in the engine compartment. Both the pilot and the passenger evacuated the aircraft via the normal canopy exit. The fire was extinguished by the airport fire services shortly after their arrival, and nobody was injured in the accident.

History of the flight

The pilot refuelled the aircraft in the self-refuel area, having just completed some circuit flying. He then primed the engine, which was warm, and attempted to start it, which resulted in the engine firing and then stopping twice. The pilot then replenished the air supply for the pneumatic starter. On the next attempt to start the engine, it backfired and a fire broke out in the engine bay.

The pilot and passenger evacuated the aircraft via the normal canopy exit. They attempted to tackle the fire with two fire extinguishers which were located at the self-refuel area, but the size of the fire increased, probably as a result of the fire spreading to the aircraft's oil tank. A fire officer noticed the fire and raised the crash alarms, and the fire was extinguished by the airport fire services shortly after their arrival.

The pilot attributed the accident to a carburettor fire, probably due to over-priming a warm engine.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-OSMS	
No & Type of Engines:	1 Lycoming O-320-B2C piston engine	
Year of Manufacture:	1990	
Date & Time (UTC):	15 January 2007 at 1420 hrs	
Location:	Wolverhampton Airport	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Substantial	
Commander's Licence:	Student pilot	
Commander's Age:	69 years	
Commander's Flying Experience:	56 hours (of which all were on type) Last 90 days - 21 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

As the student pilot was doing a left clearing turn in the hover, the left skid touched the ground and the helicopter rolled to the left onto the ground.

History of the flight

The student had completed a short dual flight with his instructor and then refuelled the helicopter before commencing a solo flight. He had been briefed for a flight in the local area before returning to the threshold of Runway 10 where he was to carry out some takeoffs and landings before hover taxiing to the parking area. The weather was good with a surface wind varying in direction between 170º and 200º and in speed between 8 and 15 kt.

The departure and subsequent flying in the local area was uneventful and the student then made an approach to the grass area beside Runway 16 before hover taxiing to the threshold of Runway 10. Once there, he made three takeoffs and landings, all on a heading of approximately 180º. Then, in preparation for his return to the parking area, he lifted off again and initiated a clearing turn to the left. He estimated that he was at a height of about 5 to 10 feet in the turn when he suddenly realised that the helicopter was left skid low. Almost immediately the skid struck the ground and the helicopter rolled to the left onto the ground. The engine stopped and the pilot had some trouble releasing his harness because he was almost upside down. However, he was able to undo it and crawl clear of the helicopter through the broken windscreen.

The wreckage had come to rest on its left side on a heading of approximately 260º. There were no other witnesses to the accident.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-ROUT
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1989
Date & Time (UTC):	22 January 2007 at 1015 hrs
Location:	Near Romiley, Stockport, Cheshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	355 hours (of which 354 were on type) Last 90 days - 0.8 hours Last 28 days - 0.8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During an approach to a private landing site, the pilot brought the helicopter to a high hover with a strong tailwind. During the subsequent right turn to align the helicopter into wind, G-ROUT started descending and the pilot was unable to prevent the helicopter contacting a wooden fence and rolling onto its side.

Background to the flight

The passenger on the accident flight had flown G-ROUT from his private site near Romiley to another private site near Hawarden. It had been agreed that he would be taken back to the private site as a passenger in the helicopter. The pilot on the return flight had not previously operated a helicopter into the Romiley site but had been in there as a passenger. Dual controls were not fitted to the helicopter during the flights.

The landing site was in a paddock and bounded by a low wooden fence; the altitude of the site was 430 ft amsl. To the east of the landing site were open fields bounded by a row of trees and power lines orientated north/south. The preferred approach path was initially from the east and then turning to the south for the final approach. This procedure avoided built-up areas to the south and was convenient for the predominant surface wind from the west or southwest.

History of the flight

For the flight, the weather was good and the surface wind was reported as 030º/17 kt by Manchester ATC during the return transit. There was no windsock at the Romiley landing site. During the flight, the helicopter appeared fully serviceable.

The passenger provided advice to the pilot on the approach normally used and the pilot established a descent on a north-westerly direction over the power lines and trees to the east of the landing site. He then turned left onto a southerly direction and reduced airspeed until the helicopter was in a high hover at approximately 75 ft agl just to the east of the landing site. To maintain the hover, the pilot was using almost maximum permitted manifold pressure. He then commenced a slow right turn to align the helicopter into wind for the landing. This right turn was initially stable but the pilot was then aware that the helicopter was descending. He was conscious that the situation was conducive to a vortex ring condition but was also aware that the surrounding area limited his fly-away options. He lowered the collective lever with the aim of raising it again to cushion the landing. Close to the ground he raised the collective but the right skid contacted the top of a wooden fence and the helicopter toppled over onto its right side. The pilot turned off the fuel before exiting with his passenger through the left door.

Relevant information

The Robinson R22 Pilot's Operating Handbook included the following information:

1. *'Hover controllability has been substantiated in 17 knot wind from any direction up to 9,800 feet density altitude.'*
2. *'At 75 ft agl, the helicopter should be at a minimum airspeed of 52 kt to remain clear of the avoid area of the Height-Velocity diagram.'*
3. *'Never make takeoffs or landings downwind, especially at high altitude. The resulting loss of translational lift can cause the aircraft to settle into ground obstacles.'*
4. *'A vertical descent or steep approach downwind can result in "settling with power" (vortex ring condition). This happens when the rotor is settling in its own downwash and additional power won't stop the descent. Should this occur, reduce collective and lower the nose to increase airspeed. This can be very dangerous near the ground as the recovery results in a substantial loss of altitude.'*

LASORS Safety Sense 17 General Aviation *Helicopter Airmanship* provides advice on operating into private helicopter sites and on potential problems, and refers the reader to other relevant information on the British Helicopter Advisory Board (BHAB) web site www.bhab.org. It also includes information that conditions likely to result in vortex ring are: power on, low IAS (below 35 kt) and high rate of descent (over 300 ft per min).

Pilot's comments

The pilot assessed that it was likely that the helicopter entered a vortex ring situation and that the proximity of the fence meant that he had no chance of achieving a clear landing.

On reflection, with the unusual wind direction and its associated strength, the pilot considered that it would have been appropriate for him to carry out at least one overflight of the site to assess the situation and the preferred approach path before attempting a landing. He also thought that, with his lack of flying currency, he should have carried out some continuation training before landing at the site.

INCIDENT

Aircraft Type and Registration:	Cameron A-140 Balloon, G-OXBC
No & Type of Engines:	None
Year of Manufacture:	2001
Date & Time (UTC):	18 February 2007 at 1650 hrs
Location:	Hardwick Park, Standlake, Witney, Oxon
Type of Flight:	Positioning
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	1,002 hours (of which 278 were on type) Last 90 days - 10 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While walking the balloon to a more suitable location after landing, a gust of wind blew it towards a row of trees and the balloon envelope collapsed over some power lines.

History of the flight

At the completion of an uneventful flight, the pilot made a safe landing and the six passengers left the basket. The weather was good with a surface wind of 090º/05 kt. To the north of the landing area was a row of trees and power lines orientated approximately east to west.

The immediate area was wet and slippery and the pilot decided to move G-OXBC to a more suitable and drier area before deflating the envelope. He left the basket and began to 'walk' the balloon slowly in an easterly direction. After he had gone some distance, a southerly gust of wind caught the balloon and it started to move towards the trees. On the slippery ground, the pilot was unable to stop the movement and the basket came to rest at the base of the trees. The balloon envelope collapsed over the trees and onto the power lines. There was no damage to the power lines which were insulated but the local fire service had to disentangle the envelope from the power lines and the trees.

ACCIDENT

Aircraft Type and Registration:	X'Air R100, G-CBPU
No & Type of Engines:	1 BMW R100RS piston engine
Year of Manufacture:	2002
Date & Time (UTC):	17 December 2006 at 1335 hrs
Location:	5 miles SE of Wellesbourne, Warwickshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Moderate damage to nose wheel, left mainwheel and pod
Commander's Licence:	Private Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	280 hours (of which 268 were on type) Last 90 days - 18 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following an engine failure, the pilot carried out a forced landing but the aircraft ran into a hedge at the end of the landing roll.

History of the flight

The X'Air R100 is a three-axis microlight type. On the second flight of the day, the pilot took off from Tatenhill Airfield for a flight to Long Marston Airfield. The weather was good with a surface wind of 280º/10 kt.

After approximately an hour, with the aircraft level at 1,800 ft amsl, the engine power suddenly reduced by about 50%. The pilot declared a 'MAYDAY' and selected a suitable field for an emergency landing. His options were limited and the most suitable field was at the top of a hill at an elevation of about 400 ft amsl. The pilot used the engine power available to position G-CBPU for a landing into wind; he did not wish to reduce power to idle as the aircraft has a high sink rate at that power setting. However on finals the engine stopped completely and the pilot then found himself landing short of his target field. He landed in the undershoot field but he was unable to stop the aircraft before it ran into a hedge dividing the two fields.

Shortly afterwards, a helicopter arrived on the scene from a nearby aerodrome followed soon after by a police helicopter.

Subsequent investigation

The pilot stated that the engine relied upon the alternator and battery to maintain correct operation of the engine ignition, timing and fuel pump. During the subsequent investigation, he identified faults with the alternator that led to a low battery voltage which he had noticed in flight shortly before the engine lost power.

BULLETIN RE-ISSUED

In its September 2004 Bulletin, the AAIB published a report into a fatal gyroplane accident. Between publication and completion of the Inquest into the pilot's death, new and significant facts emerged. Principal amongst these facts was that after it was issued with a Permit to Fly, the machine was fitted with a rotor of larger diameter than that specified in the Permit. This change to the machine's configuration had implications relevant to its weight, balance and performance; it also had potential but unquantifiable effects on its handling qualities. Consequently, the Chief Inspector decided that the report should be updated and re-issued in full to incorporate new and revised information.

ACCIDENT

Aircraft Type and Registration:	Ponsford Bensen B8MR (modified), G-BIGU
No & Type of Engines:	1 Rotax 532 piston engine
Year of Manufacture:	2001
Date & Time (UTC):	29 June 2003 at 1250 hrs
Location:	Shipdham Airfield, near Dereham, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence (Aeroplanes) and qualifications for the issue of a Private Pilot's Licence (Gyroplanes)[1]
Commander's Age:	44 years
Commander's Flying Experience:	324 hours (of which 43 were on gyroplanes) Last 90 days - 27 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

The accident occurred on the first unsupervised flight following the pilot's completion of his Private Pilot's Licence (Gyroplanes) course. It resulted from the rotor blades striking the rudder, which rendered the gyroplane uncontrollable. Witness accounts indicated that G-BIGU was flying straight and level at a reasonable speed just before this event, although there were reports of possible 'over-controlling' during the flight. The specific reason for the rotor blades striking the rudder could not be determined but a pilot-induced oscillation appeared to be the probable cause. An examination of the aircraft, and subsequent computer modelling by the University of Glasgow, indicated that the aircraft could have poor longitudinal stability characteristics. The investigation also highlighted the poor safety record of gyroplanes in general compared to other types of recreational aircraft. Accordingly, recommendations have been made concerning the approval of gyroplanes and the training and licensing of gyroplane pilots.

Footnote

[1] The pilot had completed an approved course for the issue of a PPL (Gyroplanes) and had submitted his licence application to the CAA. At the time of the accident the CAA had not processed the application and so had not issued the licence. However, the Authority subsequently confirmed that the pilot met all the requirements for the issue of a PPL (Gyroplanes).

Factual Information

Background to the flight

The pilot had been the holder of a Private Pilot's Licence (PPL) (Aeroplanes) since July 1992 and had started a PPL (Gyroplanes) course in August 2002 at a recognised flight training school. He had bought G-BIGU from the original builder of the aircraft.

He subsequently passed his General Flight Test (GFT) on 17 April 2003 in a twin seat VPM. After a final flight in G-BIGU under supervision at the training school on 21 June 2003, the flight examiner endorsed the pilot's flying logbook with a clearance to fly "*single seat gyroplanes and VPM twin seat*". The pilot then transported his aircraft by road to his home. His intention was to keep the aircraft in a hangar at Shipdham Airfield and to enable him to do so he joined the Shipdham Aero Club.

On 22 June, he brought G-BIGU by trailer to the airfield, parked it in a hangar and was seen to attach the rotor blades to the body of the machine. During the subsequent week, he did not go to Shipdham Airfield but did complete a dual flight in a fixed wing aircraft at another airfield on 23 June.

History of the flight

On the morning of 29 June, the pilot went to Shipdham Airfield with the intention of flying in his gyroplane. One club member spoke to him as he was preparing G-BIGU for flight. During the conversation, the club member informed the pilot that there would be some glider flying using Runway 20 with a right hand circuit, and that powered aircraft normally used a left-hand circuit on that runway. At the time, the surface wind was calm and the pilot asked if there would be any problem with him doing some ground runs in both directions along the runway. The pilot also commented that he had "something to try out". The club member's impression was that the pilot seemed in "good spirits". The weather was good with no cloud and a light and variable surface wind.

Sometime later, the gyroplane was seen taxiing out to a position just short of the threshold of Runway 20. It stopped there for a time with the rotors turning before entering and taxiing along the runway. No other aircraft from Shipdham were airborne at the time and various club members were preparing aircraft for flight. No witness watched G-BIGU during its entire flight so it was not possible to determine exactly what manoeuvres were completed. However, most members were aware of the engine noise remaining constant in the background. G-BIGU appeared to take off from Runway 02 and fly a short distance to the north before turning back towards the airfield. The aircraft was seen to fly along the runway in each direction and some witnesses were aware of G-BIGU gently "porpoising" as it flew along. Estimates of the height of the gyroplane during this time varied between 10 and 20 feet above the runway and also between 400 and 500 feet but displaced to one side of the runway. With the variation in height estimates from the witnesses, who were both pilots, it was possible that this "porpoising" occurred at different times. None of the witnesses were concerned by the manoeuvres. One witness, who saw the last moments of flight, was standing by the airfield hangar looking towards the east. He saw G-BIGU in a downwind position for Runway 20 at about 250 to 300 feet agl and at an estimated speed of about 45 kt. The gyroplane appeared to be stable and in level flight when the witness heard a single "bang" and saw an immediate change in attitude. The aircraft pitched nose down and fell vertically to the ground. This witness also commented that he had heard a "broken" radio transmission sometime prior to the accident sequence; with no other club aircraft flying, he assumed that the pilot of G-BIGU had made this transmission.

One other witness, who was cycling in the local area, stopped to look at the aircraft to the east of the runway, as it flew apparently straight and level in a northerly direction. The gyroplane passed close to him and its pilot waved to him. There was a constant noise from the engine until this witness heard a "clunk" and the engine noise stopped. He watched the aircraft tip nose down and fall to the ground with the rotors stopped; his impression was that the rotors were hanging vertically down each side of the aircraft. This witness was approximately 500 metres away from the crash location.

No other witnesses were watching the aircraft just prior to the unusual noise although all considered that the engine noise was constant up to that point. They were attracted to the location by a noise, variously described as a "pop" or a "bang" and a change in engine noise. The aircraft was seen to pitch slightly nose down but it remained in an upright attitude as it descended rapidly to the ground. The rotors were variously described as turning slowly or stopped and two witnesses had an impression that one rotor blade was bent about halfway along its span. One witness thought that the aircraft turned through about 180° on its longitudinal axis as it descended.

Emergency '999' calls were made while two vehicles set out to locate the crash site. One other club member had already prepared an aircraft for flight and he taxiied this aircraft, G-BPWL onto Runway 20 and took off. Once airborne, he contacted Norwich ATC on 119.35 MHz, declared an emergency and requested assistance for a gyroplane that had crashed near Shipdham Airfield. Norwich ATC recorded the call at 1253 hrs and the controller initiated his emergency procedures. As he was doing so, the crew of an air ambulance helicopter, G-EYNL, called on the frequency and, when informed of the accident, elected to proceed direct to the accident site. The pilot of G-BPWL reported that he would remain over the crash site and did so until the air ambulance reached the crash site at 1303 hrs. Just before then, two club members had reached the accident scene and had found the aircraft lying on its side with the pilot still in his seat. They could not detect any signs of life and this was confirmed when the air ambulance personnel arrived, moved the aircraft clear and checked the pilot.

Aircraft description and history

The aircraft was a light single seat gyroplane with a pusher engine configuration and an open cockpit (see Figure 1). When constructed and flight tested, the aircraft was fitted with 22-foot diameter 'Dragon Wing' rotor blades and a Rotax 532 engine with a three-bladed composite propeller. The engine was not fitted with a carburettor heat system. In common with other Bensen-type

Figure 1

Aircraft prior to the accident (G-BIGU)

gyroplanes, the control stick was of the pump-action type which pivots at a point below the seat and moves vertically during forward and aft movements. This differs from a keel mounted stick that has no significant vertical movement during pitch control changes. The movement of a keel mounted stick would be similar to that encountered in conventional fixed wing aircraft.

During the investigation two people reported that the accident pilot had attempted some wheel balancing on his aircraft without supervision at sometime during the latter half of 2002. During this attempt the aircraft had suffered a 'blade flap' incident on the ground[2] resulting in a rollover and damage to the propeller and rotor. These accounts are supported by the fact that the pilot purchased new rotor blades and a new propeller blade in October 2002. The new rotor blades were of the same type but, at 23 ft diameter, one foot larger than the authorised rotor diameter specified in the machine's Permit to Fly. However, there is no evidence to suggest that any aircraft damage from that accident led to the pilot's subsequent fatal accident.

Other modifications to the B8MR design included the addition of a modified nosecone fairing from the Air Command gyroplane design, the addition of side pod tanks and a seat incorporating a fuel tank, also from the Air Command design. The nosecone fairing and seat tank modifications had been approved by the PFA. The side pod tank modification had not yet been approved due to its potential adverse effect on vertical CG. However, a weight and balance study by the University of Glasgow had determined that the tanks had little effect on the vertical CG. From weight measurements taken with the 23 ft rotor fitted, the vertical position of the CG was calculated to be 4.8 ±1.2 inches below the thrust line. The aircraft's mass with the accident pilot on board and with the seat tank half full was measured at 252 kg. The maximum total authorised weight of the aircraft was 280 kg.

The flight instruments on G-BIGU consisted of an airspeed indicator calibrated in knots, an altimeter and a compass. The instrument panel also included an analogue engine rpm gauge, an analogue engine water temperature gauge, a digital rotor rpm indicator and an ignition ON/OFF switch. At the left side of the pilot's seat there was a short, Air Command-style throttle lever and on the right side there was an engine choke control. The fuel supply could be selected from one of three fuel tanks by means of a fuel selector located behind the pilot's seat.

Accident site examination

The aircraft struck the ground in a wheat field approximately half a mile east of the airfield. The lack of disturbed wheat surrounding the aircraft indicated a near vertical impact with very little forward speed. The aircraft had struck on its left side in a steep left bank. There was no indication of any appreciable rotor speed at impact. One rotor blade had buckled on impact and forced the rotor mast to bend to the right. A large section of the upper portion of the rudder had detached and could not be found near the main wreckage. The missing section of rudder was found in pieces two months later by a farmer harvesting the field. The pieces were located 60 to 120 feet from the main wreckage. The rotor blades had red marks along their leading edge and underside between 4.6 and 6.2 feet from the rotor hub. The location of these marks was consistent with the rotor having struck the red rudder and the distant location of the rudder pieces indicated that the rudder was struck in flight rather than at ground impact.

Footnote

2 Accelerating the gyroplane too rapidly along the ground for the current rotor speed causes this form of blade flap.

The rotor blades also had curved red marks on their underside nearer the root. These marks were consistent with the rotor having made contact with the red propeller tips. One of the three propeller blades had separated at its root and one blade had separated at mid-span; both separated blades were found within 15 feet of the wreckage. The close proximity of the propeller blades to the wreckage indicated that the blades had probably separated at ground impact rather than in flight as a result of a rotor blade strike. The close proximity of the propeller blades also suggested that the propeller shaft was rotating at low power at impact.

The side pod fuel tanks were found empty and had not been punctured. The seat tank was also nearly empty but its fuel cap had been dislodged and any fuel remaining would have drained out whilst the aircraft was lying on its side. The fuel selector was set to the seat tank position. The accident site had a distinct smell of fuel and there was fuel remaining in the carburettor bowl.

Detailed wreckage examination

After the on-site examination the wreckage was recovered to the AAIB facility at Farnborough for a more detailed examination.

The flight controls were checked for continuity and no disconnects were found. The aircraft was fitted with a pre-rotator mechanism which was still operable and there was no evidence to suggest any interference between the pre-rotator mechanism and the rotor. The teeter stop plate was bent downwards on both sides which was consistent with a hard impact between the rotor blades and the teeter stops. This evidence suggested a violent vertical motion of the rotor blades which was consistent with the motion required for the rotor blades to strike the rudder.

The engine was taken to an approved overhaul agency to be tested. A few repairs were required including replacement of the damaged starter casing, exhaust manifold and propeller as well as removal of the damaged radiator. It was then mounted on a test stand and the engine started and operated normally.

All the structural failures were consistent with the rotor blade strikes and ground impact damage. No anomalies or defects that might have contributed to the accident were found in the aircraft's construction.

Aircraft approval process

Most gyroplanes are now built from kits but G-BIGU was built from the plans for a Bensen B8MR with additional modifications. The Popular Flying Association (PFA) was delegated by the CAA to investigate and make recommendations concerning new applications for approval of this gyroplane type. Following build completion, G-BIGU was inspected and then test flown by a pilot accepted by the PFA for this task. Seven test flights were carried out during a period between 29 June and 1 July 2002. These tests were conducted with the 22 ft rotor fitted. After the test flights the pilot submitted a declaration to the PFA stating that he considered that the aircraft complied with the British Civil Airworthiness Requirements (BCAR) Section T. The PFA then recommended to the CAA that G-BIGU be issued with a Permit to Fly. The CAA issued G-BIGU with a Permit to Fly on 19 September 2002. The Permit was concurrently issued with a Certificate of Validity that maintained its currency until 18 September 2003. Before the Permit was issued, the builder sold the aircraft to the accident pilot.

Stability characteristics of gyroplanes

In the same way that a fixed wing aircraft has longitudinal static stability when the CG is forward of the aircraft's lift vector, a gyroplane has longitudinal static stability when the CG is forward of the Rotor Thrust Vector. In this configuration, when a gust causes the gyroplane to pitch up the rotor thrust will increase causing a restoring nose-down pitching moment. A large factor in determining the balance of moments which affects the location of the RTV in steady flight is the vertical location of the propeller thrust line relative to the vertical CG. A simplified diagram showing the two dominant forces, propeller thrust (T_{prop}) and RTV, is shown in Figure 2 (the aerodynamic drag is assumed to be closely in line with the vertical CG). For Case A, the thrust line is below the CG and therefore to establish equilibrium in flight, the RTV lines up aft of the CG (to balance the nose-up pitching moment of the thrust line). When a disturbance such as an upwards gust causes the aircraft to pitch up the RTV will increase and tilt aft (flap back), the net effect being to pitch the aircraft nose-down – a restoring moment. For Case B, the thrust line is above the CG and therefore to establish equilibrium in flight, the RTV lines up forward of the CG. When a disturbance causes the aircraft to pitch up, the RTV will increase and tilt aft, the net effect being to pitch the aircraft nose-up even further – an unstable configuration.

In addition to static longitudinal stability it is also desirable that a gyroplane possesses dynamic longitudinal stability. A gyroplane that has static stability does not necessarily possess dynamic stability. A gyroplane with positive longitudinal static stability but negative longitudinal dynamic stability would pitch down in response to an upwards gust but the restoring moment would be excessive and without pilot input the nose-down pitch attitude would increase with each subsequent overshoot.

The University of Glasgow conducted a study into the stability characteristics of gyroplanes using a simulation model based on both wind tunnel data and flight test data. The computer model verified that aligning the thrust line close to the vertical CG had a favourable

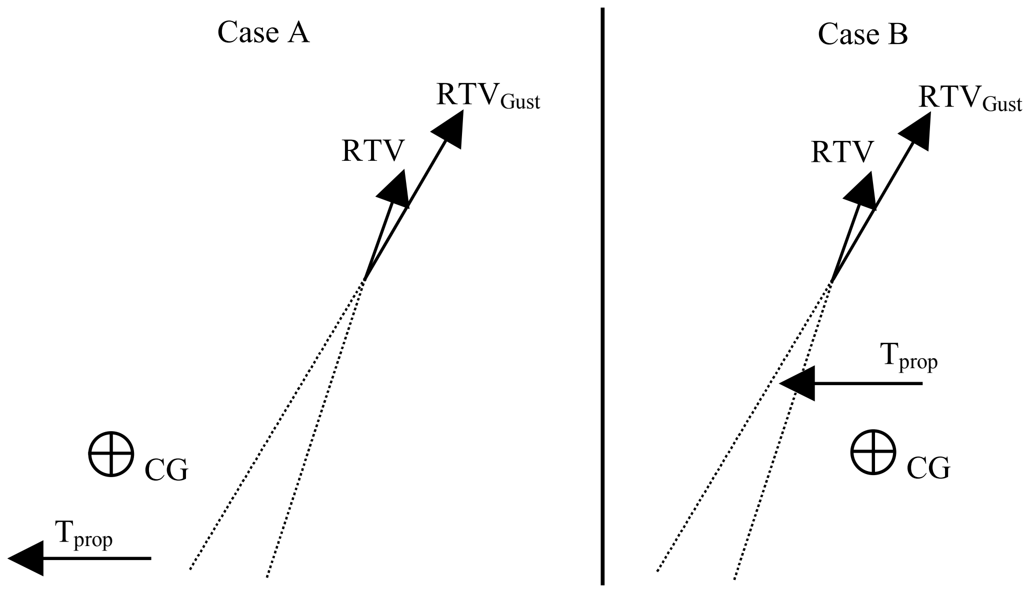

Figure 2

Diagram of Rotor Thrust Vector (RTV) change due to an upwards gust.
Case A: Propeller thrust line passes below CG.
Case B: Propeller thrust line passes above CG

effect on both static and dynamic longitudinal stability characteristics. The study recommended that the CAA revise BCAR Section T to include a limit for vertical CG position that was within ±2 inches of the propeller thrust line. A small amount of instability with a thrust line slightly above the CG was deemed acceptable but a thrust line at or below the CG was deemed desirable. The CAA plans to implement the recommendation by requiring a more rigorous demonstration of acceptable handling qualities if the ±2 inches thrust line to CG relationship is not met. It should be noted, however, that aligning the thrustline close to the vertical CG would be advantageous but will not in itself guarantee that a gyroplane will have good longitudinal stability characteristics.

The aerodynamic drag vector can also affect the stability of a gyroplane if it is not closely aligned with the vertical CG. In this situation, changes in speed will cause drag changes and resulting pitch changes. A drag vector below the vertical CG will result in a speed-unstable configuration because an increase in speed will pitch the aircraft nose-down.

Theoretically the addition of a properly sized and properly located horizontal tail can improve both speed stability and pitch stability. A horizontal tail can provide a restoring pitching moment and it can also act as a pitch damper, reducing the number of overshoots during a pitch oscillation which improves dynamic stability.

The more longitudinally unstable gyroplanes are, the more difficult they are to fly and the more likely the pilot is to enter a pilot-induced-oscillation (PIO) in pitch. In a PIO, the pilot's control inputs are out of phase with the response of the aircraft. A PIO in a gyroplane, if not recognised and stopped immediately by the pilot, can have fatal consequences. The study on gyroplane stability by the University of Glasgow demonstrated that when a gyroplane is pitching up and down, the rotor speed is also oscillating up and down. If a rotor slows down too much, retreating blade stall can occur, also known as in-flight blade flap. During in-flight blade flap the rotor blade becomes unstable and usually strikes some part of the airframe, tail or propeller.

Blade flap can also result from a deliberate unloading of the rotor. If the pilot pushes forward too rapidly on the control stick (bunting) the rotor disk's angle of attack will reduce and the ensuing lift loss will unload the rotor (ie less than 1g). Unloading the rotor causes the rotor to slow down and if it slows down excessively, retreating blade stall can occur and blade flap will follow. The situation is aggravated by a thrust line located above the vertical CG, because as the RTV reduces, the propeller thrust causes the aircraft to pitch further nose-down, further unloading the rotor. For this reason the phenomenon is often referred to as a 'power pushover'.

An additional factor that can affect the aircraft's PIO susceptibility is the type of control stick employed. The pump-action type control stick translates up and down during forward and aft stick movements. In theory, with this type of stick a PIO could be aggravated due to the vertical motion of the aircraft coupling with the vertical motion of the stick as the pilot tries to control the pitch. The keel-mounted stick does not translate up and down and therefore is less likely to couple with the aircraft motion.

In summary, gyroplanes can be designed with inherent longitudinal stability. Aligning the propeller thrust line at or slightly below the vertical CG improves longitudinal stability as may a properly sized and located horizontal tail. Aligning the drag vector with the vertical CG also improves speed stability. The use of a keel-mounted stick as opposed to a pump-action stick may also help alleviate PIO susceptibility.

BCAR Section T requirements

Section T of BCAR covers light gyroplanes. At the time of the accident the current version of Section T was Issue 1, Amendment 1, of August 2001. All new designs of gyroplanes must comply with Section T but G-BIGU did not need to comply with Section T because it was built from the plans of an existing design. Nevertheless, the flight test for the permit issue for G-BIGU was conducted against certain performance and handling criteria from Section T (Issue 1).

Section T includes requirements for static longitudinal stability (T173) and dynamic stability (T181). The static longitudinal stability requirements specify criteria relating to stick force as a function of speed and load factor. The dynamic stability criteria relate to the damping and frequency of any oscillations – important criteria when assessing an aircraft's susceptibility to PIO. The requirement and interpretative material concerning oscillations were as follows:

Requirement: *'Any short-period oscillations occurring under any permissible flight condition must be heavily damped with the primary controls fixed or free.'*

Interpretative Material: *'Longitudinal, lateral or directional oscillations with controls fixed or free and following a single disturbance in smooth air, should at least meet the following criteria:*

(a) Any oscillation having a period of less than 5 seconds should damp to one half amplitude in not more than one cycle. There should be no tendency for undamped small amplitude oscillations to persist.

(b) Any oscillation having a period between 5 and 10 seconds should damp to one half amplitude in not more than two cycles. There should be no tendency for undamped oscillations to persist.

(c) Any oscillation having a period between 10 and 20 seconds should be damped, and in no circumstances should an oscillation having a period greater than 20 seconds achieve more than double amplitude in less than 20 seconds.'

The interpretative material states that any oscillation with a period of less than 20 seconds must be stable, ie damped. Oscillations with a period of more than 20 seconds are more controllable and therefore a certain degree of instability is permitted. These tests can be a challenge to perform as the oscillations can make it difficult to hold the stick fixed.

Stability characteristics of G-BIGU

G-BIGU had a number of characteristics that indicated that it probably would not have met the longitudinal dynamic stability criteria of Section T. The thrust line on G-BIGU was 4.8 ±1.2 inches above the vertical CG. This is in the unstable direction and is outside the 2 inch limit recommended by the University of Glasgow. G-BIGU was not equipped with a horizontal tail designed to improve stability and it was modified with the addition of a nosecone fairing - the drag acting on this fairing could have had a destabilising effect. Moreover, the aircraft had a pump-action stick as opposed to a keel-mounted stick that could have increased the aircraft's susceptibility to PIO. All these features indicate that the aircraft would probably have been difficult to fly, particularly for an inexperienced gyroplane pilot.

G-BIGU was test flown by a very experienced gyroplane pilot as part of the process for the issue of a Permit. The pilot thought that the aircraft flew well and met the criteria of Section T. The flight test report was written in subjective terms and did not contain any data to compare against the longitudinal dynamic stability criteria of Section T. The report stated that the aircraft *"can be flown hands and feet off at cruise speeds of 45 to 50 mph for short periods of time before gently deviating from straight and level flight"*. The phrase "*short periods of time*" was not qualified in the report but the pilot later stated that it was about 5 seconds. The stick-free stability of a gyroplane is generally considerably better than the stick-fixed stability because leaving the stick free allows the rotor hub to move independently of the aircraft, adding a degree of auto-stabilisation.

The University of Glasgow was asked to model the stability of G-BIGU using their RASCAL simulator that had been developed to model gyroplanes. The pod, tailplane and vertical tail aerodynamics were those estimated from a similar looking single-seat Air Command gyroplane. The mass properties, CG, thrust line and geometric data used were those specific to G-BIGU with the 23 ft diameter rotor fitted. The results showed that when the aircraft was excited by a fore and aft stick input, the response was a stable and lightly damped pitch oscillation (see Figure 3) at 45 mph. However, when the speed was increased to 65 mph the model predicted that G-BIGU would have an unstable rapidly divergent pitch response shown by the rapidly increasing pitch angle in Figure 3. The control stick was assumed to be held fixed following

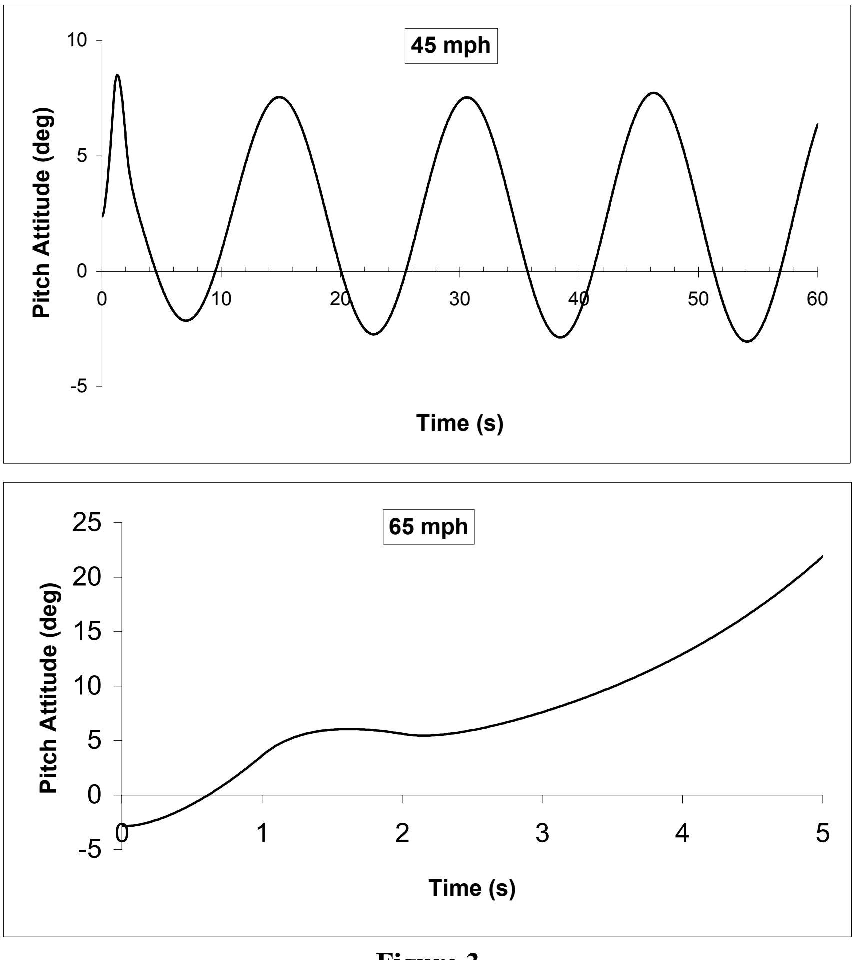

Figure 3

Modelled pitch response of accident aircraft at 45 mph and 65 mph following a fore and aft stick input the initial input. Similar stability results were obtained from the RASCAL simulator when a 22 ft diameter rotor was substituted although the predicted rotor speed was increased by 6%.

Unfortunately, this simulator model for G-BIGU cannot be validated against the real aircraft and therefore these results must be treated with some caution. However, taken together with the design characteristics of G-BIGU, the results indicate that the aircraft could have had an unstable mode in pitch and probably did not meet all the longitudinal stability criteria of BCAR Section T.

The reason for the discrepancy between the flight test assessment and the modelled results could be due to the change in rotor size after the flight tests, the flight test technique, or a combination of both factors. The flight test studies conducted by the University of Glasgow with instrumented gyroplanes revealed that very experienced gyroplane pilots, who have not been trained as test pilots, have a subconscious tendency to correct for instabilities in the aircraft with small stick inputs. The true stability characteristics of an aircraft need to be assessed objectively both stick fixed and stick free.

An additional factor that could have induced or aggravated a PIO in pitch in G-BIGU was the short throttle lever coupled with the 'peaky' nature of the Rotax 532 engine. At high rpm the Rotax 532 engine has a non-linear relationship between power output and throttle position. In the high rpm region small movements of the throttle lever can result in large power changes. Any power changes will affect the pitch response of the aircraft due to the high thrust line above the CG. The Montgomerie B8MR kit-build gyroplane has a longer throttle lever, which partly alleviates this problem.

Finally, the instructor at the training school considered that the high seating position of G-BIGU, coupled with the location of the nosecone, would have resulted in a less favourable airframe reference relative to the horizon.

Stability Characteristics of the VPM M-16

The accident pilot underwent the majority of his flight training on a VPM M-16. The VPM M-16 (shown in Figure 4) is a very different aircraft from G-BIGU. The VPM is a two seat aircraft and has a lower thrust-to-weight ratio than G-BIGU. Unlike G-BIGU, the VPM has a stabilising horizontal tail, a keel mounted stick and its thrust line is closer to the vertical CG than on G-BIGU (between 2.4 and 3.4 inches above CG). The University of Glasgow carried out a flight test programme on an instrumented VPM M-16 with a former military test pilot. Various longitudinal stability tests were carried out, including stick fixed pitch oscillations. The recorded flight test

Figure 4

In foreground, VPM M-16 used by accident pilot for majority of training data was analysed and showed that the aircraft met the longitudinal dynamic stability criteria of Section T. Those who have flown the VPM confirm that the aircraft is considerably more stable and easier to fly than most other gyroplanes.

Operational information

Medical information

A post-mortem examination was carried out on the pilot. He died from severe multiple injuries resulting from a severe vertical force; death would have been instantaneous. There was no evidence of any disease, alcohol, drugs or any toxic substance, which may have caused or contributed to the accident.

Pilot training and licensing

The current requirement for the issue of a UK PPL(G) licence is for the applicant to have completed a course of training to a syllabus recognised by the CAA. The flight training must be completed on an approved 2-seat gyroplane. However, a single seat gyroplane may also be used after specified dual flight instruction. A minimum of 40 hours flying experience as a pilot in a flying machine was required for licence issue, of which 5 hours must be dual flying training, 10 hours must be dual or supervised in gyroplanes and 10 hours must be as pilot-in-command of gyroplanes.

During the gyroplane course, the pilot flew 17 hrs 15 minutes dual instruction in a twin-seat VPM gyroplane before his first training flight in G-BIGU on 16 December 2002. His first three flights in G-BIGU were recorded as 'wheel balancing'. ('Wheel balancing' is one of the early exercises on gyroplanes when the student accelerates the aircraft to a point where the nosewheel is clear of the ground and the machine is balanced on the main wheels.) Thereafter on his course, he flew the VPM, G-BIGU and another B8MR (with a smaller engine than on G-BIGU). All his flights in G-BIGU were recorded in his flying logbook as 'wheel balancing' until 9 April 2003 when he recorded some 'straight and level' flying. Then, on 15 April, his training record showed that he was overcontrolling on G-BIGU and he reverted to 'wheel balancing'. He passed his General Flying Test on the VPM on 17 April. On 18 April, his 'wheel balancing' on G-BIGU was assessed as "*much more confident*" and he was ready for "*high hops and circuits*". After a further 2.5 hours flying in G-BIGU, the flight examiner endorsed his flying logbook with a clearance to fly "*single seat gyroplanes and VPM twin-seat*".

Towards the end of his course, his instructors considered that the pilot appeared more confident. However, comments made by the pilot's partner indicated that he remained somewhat apprehensive of gyroplanes. The pilot had mentioned instances of PIO during the course that had alarmed him and he expressed some anxiety about flying G-BIGU.

Pilot's notes

In common with many other types of gyroplane, G-BIGU did not have any accompanying pilot's handling notes. However, numerous books have been published dealing with the theory and practice of gyroplane flying. In general, specific flight training organisations would recommend publications and provide classroom instruction during a training course. Subsequent to the accident involving G-BIGU, written notes were found belonging to the pilot. These covered subjects such as gyroplane theory, gyroplane safety checks and actions following an engine failure. The current Section T requirement was for type specific handling notes to be available for any new gyroplane build; this requirement was not retrospective.

Safety record of gyroplanes

The safety record for gyroplanes was very poor compared to other types of aircraft. Between 1989 and 2004 there were 15 fatal gyroplane accidents in the UK. In that period there were between 200 and 265 gyroplanes on the UK register. Based on CAA estimates of hours flown, this placed the fatal accident rate for gyroplanes at 27.1 per 100,000 flight hours. This rate compared to just 2 fatal accidents per 100,000 flight hours for microlight aircraft and only 1.1 fatal accidents per 100,000 flight hours for light fixed-wing general aviation aircraft. The fact that the fatal gyroplane accident rate was more than 13 times greater than that for similar weight microlight aircraft raised serious questions over the design of gyroplanes and the training of gyroplane pilots.

A review of the 15 fatal accidents showed that 13 of the pilots involved held a licence for fixed wing aircraft or helicopters. One of the 15 fatalities had a total flying experience on gyroplanes of 170 hours but none of the others had more than 50 hours and 6 had less than 10 hours.

A study of gyroplane accidents in the USA during the 3 year period between 1999 and 2002 by the American Popular Rotorcraft Association revealed that of the 17 fatal gyroplane accidents, 8 listed pitch instability as the primary cause. In these accidents the aircraft was considered to have entered an unstable mode. In 4 of these fatal accidents the rotor had struck the tail in flight. The aircraft in the study were of varying types but it was noted that the fatal accidents as a result of pitch instability all occurred in aircraft without a horizontal tail. Information on each aircraft's thrust line versus CG location was not available. "Deficient Pilot Proficiency" was considered a shared cause when pitch instability was involved.

Previous AAIB investigations and recommendations

An investigation into the fatal accident of G-BXEM, a Cricket Mk IV, on 1 June 2001 (reported in AAIB Bulletin 5/2002) highlighted the possibility that the pilot was experiencing difficulties flying a machine different from that in which he had trained. The CAA addressed this matter in revised requirements for the grant of a UK PPL (Gyroplanes). The revised requirement was to complete differences training so that:

> *'Pilots wishing to fly gyroplanes different from the specific manufactured type that they received flight training on, shall receive appropriate differences training from a gyroplane assistant flight instructor or flight instructor and have their log books endorsed by the instructor.'*

Another investigation involved the fatal accident of G-CBAG, a RAF 2000 GTX-SE, on 17 May 2002 (reported in AAIB Bulletin 9/2003). This investigation highlighted the possibility that the aircraft's stability characteristics contributed to the accident. As a result, the AAIB made the following recommendations to the CAA (listed together with the CAA response):

Recommendation 2003-01: It is recommended that the CAA should review the pitch stability requirements of BCAR Section T in the light of current research, and amend the Requirement as necessary. The CAA should consider the need for an independent qualified pilot assessment of the handling qualities of different gyroplane types currently approved for the issue of a Permit-to-Fly against the standards of BCAR Section T, as amended.

Recommendation 2003-02: It is recommended that the CAA should consider retrospectively assessing all gyroplane types currently on the UK register for acceptable pitch stability characteristics.

CAA Response: The CAA accepted both recommendations and published its proposed response to them in CAA FACTOR F31/2004. This FACTOR is available on the Internet.

Analysis

It was evident from the wreckage examination that the rotor blades had struck the rudder in flight. This evidence is consistent with the loud 'bang' that witnesses reported hearing before they saw the aircraft descend vertically into the field. Following such a rotor to rudder strike, the reduced energy in the rotors would have made a recovery virtually impossible.

There have been other fatal gyroplane accidents that have resulted from the rotor blades striking some part of the airframe - usually the tail or rudder. The cause of these strikes is usually associated with in-flight blade flap following a PIO or a bunt (pushing the nose over and reducing the g appreciably below 1g). Both witnesses who saw G-BIGU at the moment of the 'bang' reported that the aircraft was flying straight and level which suggests that the aircraft was not performing a bunt. The witness evidence would also seem to rule out a PIO but it is possible that a PIO, perhaps leading to a 'power pushover', developed quite rapidly and the distance of the witnesses from the aircraft could have made the oscillation difficult to detect.

The fact that the aircraft was seen to be 'porpoising' earlier in the flight suggests that the pilot was having some difficulty controlling the aircraft in pitch. The aircraft had a number of features that indicated that it could have had poor longitudinal stability characteristics: it did not have a horizontal tail; it had a thrust line to CG relationship outside the ±2 inches recommended by the University of Glasgow; it had a nosecone fairing that could have reduced longitudinal stability; and it had a pump-action control stick. In addition, the aircraft's short throttle lever coupled with the Rotax 532 power characteristics could have induced or aggravated a PIO in pitch. A simplified computer model developed by the University of Glasgow showed that the aircraft might have an unstable mode at 65 mph. Furthermore, the pilot was inexperienced on this aircraft type and had conducted the majority of his flight training on a VPM aircraft, which is reportedly easier to fly and exhibits good longitudinal stability characteristics. For these reasons, it was concluded that a PIO was the most probable cause of the rotor striking the rudder.

No evidence of a technical malfunction was found that might have contributed to the onset of a PIO. The engine was tested and operated normally. There was evidence of fuel at the accident site and all the defects and failures found in the wreckage were related to either rotor blade flapping or to ground impact damage.

Furthermore, there was no evidence of any medical factor which may have resulted in the pilot becoming incapacitated. He was also qualified to fly fixed wing aircraft and he had completed his gyroplane training in accordance with the current CAA requirements. However, there was some indication that he was somewhat apprehensive regarding gyroplane flying in general and G-BIGU in particular.

Throughout the pilot's training, occurrences of overcontrolling had been noted and attempts made to rectify the tendency. At the end of his course, his instructors were satisfied that he had reached an appropriate standard for the issue of a PPL (Gyroplanes).

One aspect that may have been relevant, particularly involving an inexperienced gyroplane pilot, was that he had a dual flight in a fixed wing aircraft in the period between finishing his gyroplane course and the fatal flight. This would have involved different handling techniques in a machine with radically different flying qualities. The accident occurred on the pilot's first unsupervised flight in G-BIGU following completion of his course.

Regardless of the specific cause of the accident to G-BIGU, the investigation highlighted two aspects that were considered highly relevant. Firstly, the current training requirements and secondly compliance with the standards required by BCAR Section T. These were particularly important when associated with the accident rate of gyroplanes.

Safety recommendations

Training requirements

At the time of the accident the requirements for differences training had evolved following a recommendation by the AAIB. It arose from an accident where there was a possibility that the pilot was experiencing difficulties in flying an aircraft different from the one on which he trained. The accident involving G-BIGU had similar indications. Although the pilot of G-BIGU had completed differences training as required by the CAA, his aircraft had a greater power to weight ratio and was less stable than that of the VPM on which he had initially trained. He converted to his own aircraft under supervision but there was evidence that he remained somewhat apprehensive about G-BIGU. The pilot's logbook and training records indicated that a large proportion of his 'flying' on G-BIGU had involved wheel balancing. A review of the training requirements also revealed that there was no minimum hours requirement for the differences training. It was considered appropriate for the CAA to review the training requirements with the aim of establishing a minimum number of supervised flying hours before being qualified for a type of gyroplane different from that on which the preliminary training was completed. Additionally, a minimum number of these required hours should be airborne exercises as opposed to wheel balancing. It was therefore recommended that:

Safety Recommendation 2004-42

The Civil Aviation Authority should differentiate between wheel balancing and airborne exercises when detailing the flying hours required for the issue of a Private Pilot's Licence (Gyroplanes).

Safety Recommendation 2004-43

The Civil Aviation Authority should review the present gyroplane training requirements with the aim of establishing a minimum number of supervised flying hours, discounting wheel balancing, when undertaking differences training on gyroplanes.

CAA Response The CAA accepted these recommendations and published its proposed response to them in CAA FACTOR F31/2004. This FACTOR is available on the Internet.

Assessment of gyroplanes against BCAR Section T

Following the investigation into the fatal accident of the RAF 2000 gyroplane G-CBAG, the AAIB recommended that the CAA should consider retrospectively assessing all gyroplane types currently on the UK register for acceptable pitch stability characteristics (Recommendation 2003-02). Following the accident to G-BIGU in which poor stability characteristics were probably a contributory factor, the AAIB reiterated the importance of carrying out this recommendation. The Civil Aviation Authority has accepted this recommendation and planned to carry out the assessments giving priority to gyroplanes with a poor safety record.

The test flight of G-BIGU that was carried out on behalf of the Popular Flying Association did not appear to have been flown in accordance with the interpretative material of the stability requirements of British Civil Airworthiness Regulations Section T. The flight test report did not include any data to support the opinion that the aircraft met the dynamic stability criteria of Section T. The format of the form used for the flight test report was poor in that it did not include fields for recording the data required by British Civil Airworthiness Regulations Section T. The AAIB therefore made the following recommendations:

Safety Recommendation 2004-44

It is recommended that the Civil Aviation Authority in conjunction with the Popular Flying Association (PFA) ensures that test pilots evaluating the handling qualities of gyroplanes against British Civil Airworthiness Regulations Section T are appropriately trained to make such evaluations.

Safety Recommendation 2004-45

It is recommended that the Popular Flying Association (PFA) in conjunction with the Civil Aviation Authority revises the format of the PFA Gyroplane Flight Test Schedule such that a completed form contains all the data required by British Civil Airworthiness Regulations Section T.

Safety actions taken

On 24 June 2004, the Civil Aviation Authority confirmed that all the recommendations arising from the investigation into the accident to G-BIGU had been accepted.
In respect of recommendation 2004-42 the CAA would make the necessary amendments to the Private Pilot's Licence (Gyroplanes) requirements in the LASORS (Licensing, Adminstration, Standardisation, Operating Requirements and Procedures) publication in time for the next re-print, which was scheduled for January 2005 and completed in 2005.

With regard to Safety Recommendation 2004-43, following a review of the gyroplane training requirements, the CAA would introduce a specified minimum number of supervised flying hours, discounting wheel balancing, for differences training on gyroplanes. The necessary amendments to the Private Pilot's Licence (Gyroplanes) requirements in the LASORS (Licensing, Adminstration, Standardisation, Operating Requirements and Procedures) publication would be made in time for the next re-print, which was scheduled for January 2005. In the meantime, all Gyroplane Flying Instructors would be instructed, by letter, to implement the change to flight training with immediate effect.

In respect of Safety Recommendation 2004-44 the CAA was working with the PFA to define a process which ensures that test pilots evaluating the handling qualities of gryoplanes against BCAR Section T requirements are appropriately trained to make such an evaluation. This work was to be completed by the end of 2004.

In respect of Safety Recommendation 2004-45 the CAA was working with the PFA to define a process which ensures gyroplane flight test schedules include fields for recording all the data required by BCAR Section T. This work was to be completed by the end of 2004.

The Popular Flying Association also endorsed the recommendations and stated: "We are now working with the CAA Projects Department and Flight Department to develop a new gyroplane flight test schedule specifically to investigate ultralight gyroplanes against the Section T handling requirements, and to train selected experienced gyroplane pilots in the test methods and reporting procedures. We are, of course, working with the CAA on the re-evaluation of existing types of gyroplanes against Section T handling requirements which we see as a very positive step towards addressing the high accident rate on this class of aircraft."

FORMAL AIRCRAFT ACCIDENT REPORTS
ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

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.

2/2006 Pilatus Britten-Norman BN2B-26
Islander, G-BOMG, West-north-west of
Campbeltown Airport, Scotland
on 15 March 2005.

Published November 2006.

3/2006 Boeing 737-86N, G-XLAG
at Manchester Airport
on 16 July 2003

Published December 2006.

2007

1/2007 British Aerospace ATP, G-JEMC
10 nm southeast of Isle of Man
(Ronaldsway) Airport
on 23 May 2005.

Published January 2007.

2/2007 Boeing 777-236, G-YMME
on departure from
London Heathrow Airport
on 10 June 2004.

Published March 2007.

3/2007 Piper PA-23-250 Aztec, N444DA
1 nm north of South Caicos Airport,
Turks and Caicos Islands, Caribbean
26 December 2005

Published May 2007.

AAIB Reports are available on the Internet
http://www.aaib.gov.uk