Aircraft Type and Registration:	Falcon 900EX, VP-BMS
No & Type of Engines:	3 Garrett TFE 731-60-1C turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	9 February 2004 at 0130 hrs
Location:	London (Stansted) Airport, Essex
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Extensive damage to right wing and landing gear doors
Commander's Licence:	Airline Transport Pilot's Licence (FAA) with Bermudan validation
Commander's Age:	52 years
Commander's Flying Experience:	20,954 hours (of which 700 were on type) Last 90 days - 105 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft departed from Kilimanjaro en route to London (Luton) Airport with a known hydraulic problem. The crew believed, incorrectly, that this was allowed under the terms of the Minimum Equipment List. During the approach at Luton the crew were unable to obtain indications that the gear was down and locked following selections on both the normal and emergency systems. The crew requested a diversion to Stansted and the aircraft was configured for a full flap landing on Runway 05. During the landing roll the right main landing gear partially retracted and the aircraft veered to the right until it finally left the paved surface, crossed the grass, and came to rest about 139 metres to the right of the runway centreline. Four safety recommendations have been made as a result of the investigation.

History of flight

The aircraft departed Kilimanjaro Airport, Tanzania, at 1515 hrs UTC bound for London (Luton) Airport, UK, with the commander as the handling pilot. The planned flight time was nine hours and thirty minutes and on board were two passengers and the crew, consisting of two pilots. All four had arrived in Kilimanjaro on the same aircraft four days earlier and on this inbound flight the crew had experienced an intermittent HYDR#1 PUMP 3 caution light during the final approach. Engineering facilities at Kilimanjaro were limited and since the crew considered the fault still allowed the aircraft to be dispatched under the limitations imposed by the Minimum Equipment List (MEL) they decided to defer the defect and have the problem investigated on their return to Luton.

The crew stated that shortly after departure on the return flight the HYDR#1 PUMP 3 caution light once again began to illuminate intermittently until finally it remained illuminated. The checklist required confirmation that No 1 hydraulic system pressure and quantity were normal but did not call for any specific actions to be taken and the crew continued the flight, monitoring both hydraulic systems. Some time later, between one or two hours into the flight, the crew reported that the hydraulic quantity in the No 1 hydraulic system began to reduce. The rate of loss was irregular until finally, after about twenty minutes, the quantity gauge indicated that the No 1 hydraulic system was empty; however, the crew reported that the hydraulic pressure continued to indicate the normal pressure of 3,000 psi in the No 1 system.

No other warnings were apparent on the flight deck and the crew was unsure whether they had actually lost the No 1 hydraulic system or not. Whilst continuing the flight they referred to the appropriate checklists to identify systems which would be affected following a subsequent loss of the No 1 hydraulic system. As a result they selected the No 2 braking system and reviewed the procedures for emergency slat selection and emergency gear extension. They also added 5 kt to the planned approach speed and an additional 60% to the landing distance required, as indicated in the checklist, before finally confirming that Luton's runway had sufficient landing distance available.

The flight continued without further incident and the aircraft was positioned onto a long base leg for Runway 26 at Luton. The weather at the airport was good with CAVOK conditions and a surface wind from 300° at 6 kt being reported on the ATIS. The aircraft was slowed to 200 kt and the flap selection lever moved to the Flap 7 position. The crew stated that the flap position indicator showed normal slat movement then Flap 7 extension, with the slat indicator light illuminated steady green. However, the red slat indicator light then illuminated and the emergency slat switch was selected, although the crew was unclear of the order in which these last two events occurred. The co-pilot then went into the aircraft cabin and reported that there was sufficient light looking through the window to determine that the outer slats were extended whilst the inner slats were retracted.

Whilst still on base leg the aircraft was slowed to 175 kt and the crew attempted to lower the landing gear using the Landing Gear Control Lever. This resulted in three red but no green gear position indicating lights; these were the expected indications following the loss of the No 1 hydraulic system. Emergency gear extension was then initiated by pulling the Emergency Hydraulic Extension Gear Pull Handle (referred to in the pilot checklist as the Gear Pull Handle). The two Main Gear Manual Release Handles were then pulled; these are positioned either side of the flight deck centre pedestal and each pilot pulled the handle located on his particular side of the flight deck. The commander then instructed the co-pilot to pull the Nose Gear Manual Release Handle. This is located on the commander's side of the central console and the co-pilot had to leave his seat in order to access and pull the handle. The three gear position indicating lights remained red with no green lights illuminated, and at no point did the crew recall hearing the gear lock down.

At this point the commander notified ATC that they had a problem with the landing gear and he was given permission to orbit whilst attempting to rectify the problem. Meanwhile the co-pilot went back into the cabin to inform the passengers of the situation.

The commander then reported that he side-slipped the aircraft in both directions before accelerating to the gear limiting speed (190 kt) and repeating the manoeuvre. The gear indicating lights continued to indicate that the landing gear remained in an unsafe condition and the crew discussed with ATC options for the most suitable airfield at which to attempt a landing. The crew then requested a diversion to Stansted and the co-pilot went back into the cabin once again to brief the passengers for a possible emergency landing and evacuation. At this point the aircraft had been holding for about thirty minutes and the crew estimated that they had about thirty further minutes flight time remaining with the existing fuel on board.

ATC provided radar vectors to establish the aircraft on an approach to Runway 05 at Stansted and the tower controller suggested to the crew that he turn the runway centreline lights off in an attempt to minimise the risk of fire after touchdown. No emergency was declared by the pilots although they did request full attendance by the emergency services for the landing. The crew decided that on touchdown the co-pilot would turn off the three generators and two batteries to reduce the risk of fire.

The aircraft was configured for a full flap (Flap 40) landing and the commander flew a manual visual approach. Prior to touchdown the co-pilot dumped the cabin pressure to ensure that opening of the cabin door after landing would not be inhibited by any pressure differential. The commander flared the aircraft at the normal height but intentionally selected a slightly higher nose attitude than normal to ensure that if the gear was not down then it would be the rear of the aircraft that would make the initial contact with the ground; however, initially the aircraft seemed to settle onto its landing gear. The co-pilot switched off all the electrics as briefed and the commander applied the brakes; he could not recall whether he had applied reverse thrust. The aircraft maintained the runway centreline initially, but as its speed reduced the right wing began to drop. At around the runway's mid-point the aircraft began to veer to the right until it finally left the paved surface and crossed the grass, coming to rest about 1,900 metres from the runway threshold and 139 metres to the right of the centreline. The co-pilot immediately left his seat and opened the main passenger door, using this exit to get both the passengers and himself out of the aircraft. The commander meanwhile shut down the engines by selecting all three thrust levers to the idle cut-off position. He then selected the three fuel switches to OFF before vacating the aircraft. The emergency services arrived at the aircraft quickly and were able to put down a protective blanket of foam.

Aircraft information

VP-BMS was a Falcon 900EX, Serial No 042, manufactured in 1999 and registered in Bermuda. It was issued with a Private Category Certificate of Airworthiness on 19 June 2003, valid until 21 June 2004. The last maintenance action was a monthly inspection, carried out on 8 March 2004. The last check was an 'A' check carried out on 21 November 2003. There were no Technical Log entries of relevance.

On-site aircraft examination

The aircraft had come to rest on the grass to the right of the runway. Ground marks indicated that, at the time the aircraft reached the grass, the nose and left main landing gears were extended. Tracks were made in the grass by the nose and both main landing gears, and further on by the right wing tip and flaps, and by the inboard main landing gear doors. There were no evident marks on the runway itself.

When examined by the AAIB the following morning, the aircraft was being prepared for jacking in order to recover it from the grass. The left main landing gear and nose landing gear were both fully extended and locked, however the right main landing gear was partially retracted and the aircraft had come to rest on the right wing tip, causing damage to the right hand flap and outboard slat as well as to the wing tip. There was also damage to the right main landing gear outer door and both inboard main landing gear doors, which were open. There was no obvious damage to the left wing or its flaps or slats. On the flight deck, the Gear Manual Release Handles for all three landing gears were pulled, as was the Emergency Hydraulic Extension Gear Pull Handle, the No 2 brake system was selected, the Emergency Slats switch had been operated and the cockpit voice recorder (CVR) circuit breaker was found in the tripped position. The AAIB inspector was advised that none of these items had been touched after the accident, except to pull the CVR circuit breaker. When the aircraft had been raised, the right main landing gear extended and locked down satisfactorily. The aircraft was recovered from the grass, the flight recorders were removed and the aircraft was then towed to a hangar where it was cleaned and where, subsequently, rectification and testing was carried out in preparation for a ferry flight to Paris (Le Bourget) for permanent repairs.

Flight recorders

The aircraft was equipped with a 25-hour duration, solid state flight data recorder (FDR) and a 30 minute duration, solid state CVR. Both flight and audio data was successfully recovered from the FDR and CVR. The FDR recording contained the time history of the flight from Kilimanjaro to Stansted, as well as the preceding approach and landing at Kilimanjaro. The CVR contained the audio recording for the approach and landing phase only of the flight into Stansted.

Twenty minutes prior to landing on the flight into Kilimanjaro the low-pressure warning parameter for the No 3 hydraulic pump, recorded on the FDR, began to alternate between the normal and the warning state: the warning state was recorded on the FDR when the hydraulic pressure dropped below 97 bar (1,400 psi). The landing gear, slats and flaps were in the retracted position when the hydraulic system low-pressure warning was initially recorded. The No 3 hydraulic pump low-pressure warning parameter then alternated between the normal and the warning state on numerous occasions prior to landing. This parameter then remained in a steady warning state for the final three minutes before engine No 3 was shutdown. All other recorded parameters indicated normal aircraft operation.

On the return flight to Luton, the No 3 hydraulic pump low pressure warning parameter was recorded in the warning state for 37 seconds after the No 3 engine was started. This parameter then recommenced alternating between the normal and the warning state. The No 3 hydraulic pump low pressure warning then entered a steady warning state as the aircraft reached FL120, 15 minutes after the No 3 engine had been started, and remained in this state for the rest of the flight. No other warnings were indicated at this time; however, information concerning hydraulic contents, quantity or system pressure, other than pump discrete warnings, were not recorded on the FDR.

On the initial approach to Luton, at 2,500 feet and 185 KIAS and with the autopilot engaged, the flaps were selected to the Flap 7 position. The outboard slats extended first followed seven seconds later by the inboard slats: this was the normal sequence of operation. The FDR inboard and outboard slat parameters indicated that both slats reached the fully extended position.

Nineteen seconds after the inboard slats were indicated to be in the extended position the No 1 hydraulic pump warning was recorded, thereby rendering the No 1 hydraulic system unserviceable, five seconds later the emergency slat system was selected. After a further two seconds the inboard slats extended parameter altered state to indicate that the inboard slats were no longer in the fully extended position.

Following the loss of No 1 hydraulic system the aircraft remained at 2,500 feet and over the next three minutes the airspeed reduced from 176 KIAS to 164 KIAS. During this period various rudder deflections were recorded by the FDR. These occurred in both directions and varied in magnitude and duration. The largest recorded input was a deflection to the left of 6.5 degrees and the longest duration for a sustained rudder deflection was nine seconds.

The CVR indicates that 12 minutes after the loss of the No 1 hydraulic system the crew advised Luton ATC that the landing gear could not be lowered and that the aircraft had 30 minutes of fuel remaining. The commander subsequently requested radar vectors to Stansted and the aircraft touched down 13 minutes 30 seconds later.

Conversation between the two pilots recorded on the CVR indicates that there was concern that the Gear Manual Release Handles were not operating properly and that the gear had not deployed despite the handles being pulled. Three minutes and thirty seconds prior to landing a "GEAR…GEAR" audio warning was recorded on the CVR, this continued until touchdown. Fifty seconds prior to touchdown, at a radio height of 560 feet, an audio warning "TOO LOW GEAR" was recorded on the CVR, this warning also continued until touchdown. Eight seconds prior to touchdown the audio warning "SINK RATE….SINK RATE" was recorded on the CVR, at a radio height of 50 feet and airspeed of 113 KIAS.

The touchdown, as indicated by the transition of the left weight on wheel parameter, occurred at 106 KIAS. The CVR and FDR recordings ended one second after the left gear weight on wheel parameter had activated coincident with recorded switch movements and it is believed that this was the removal of aircraft electrical power from both the FDR and CVR at touchdown.

Hydraulic system description

The aircraft was equipped with two independent main hydraulic systems. The No 1 hydraulic system was normally pressurised by either of two mechanical pumps: No 1 pump driven by No 1 engine and No 3 pump driven by No 3 engine. The No 2 hydraulic system was pressurised by the No 2 engine driven pump and could also be powered by an electric pump. Both hydraulic systems were equipped with accumulators to minimise pressure fluctuations within the system.

The No 1 hydraulic system provided hydraulic power to the three landing gears and landing gear doors, normal brakes, primary flight controls and also powered the leading edge slats. No 2 hydraulic system provided hydraulic power to the flaps, airbrakes, emergency brakes, and primary flight controls, and provided power for the outboard slats when the Emergency Slat Extension was selected.

Hydraulic system examination

Following the accident the system was checked and fluid was observed running from the No 1 hydraulic pump drain: this leak had caused the loss of the No 1 system contents.

At the AAIB's request, the aircraft manufacturer initiated an investigation of both the No 1 and the No 3 hydraulic pumps and returned the pumps to the original equipment manufacturer for analysis. Unfortunately the pumps were repaired rather than subjected to any failure analysis, as requested. As a result further work was carried out to try and establish their condition before rectification, but little additional information was available. It was, however, possible to establish that the general state of the pumps did not reveal any evidence of abnormal wear or mechanical anomaly.

Pumps 1 and 3 operate independently in the No 1 hydraulic system, drawing from the same hydraulic reservoir. A functional pump will deliver the correct output pressure as long as there is hydraulic fluid available from the reservoir. The aircraft manufacturer concluded that the No 3 hydraulic pump might have had either a sticking of its internal mechanism, or a slight offset of its regulation, resulting in reduced delivery pressure. The unrelated leak in the No 1 hydraulic pump was suspected to have been due to damage to a seal or loss of effectiveness of an associated spring washer.

Landing gear description

The landing gear was a conventional retractable tricycle arrangement. Power for gear retraction and normal extension was provided from No 1 hydraulic system. In the event of loss of No 1 hydraulic system pressure or contents, each landing gear had an independent gravity free-fall system.

In normal operation the gear was extended by selecting the Landing Gear Control Lever to the down position. Operation of this lever energised the landing gear and landing gear door solenoid selector valves and initiated the full sequencing of the opening of the doors, uplock release, extension and downlocking of the landing gears and closing of the inboard main landing gear doors.

In the event of failure of the electrical subsystem the landing gear could be extended by manual operation of the Emergency Hydraulic Extension Gear Pull Handle, located on the co-pilot's instrument panel. Operation of this handle positioned the normal/emergency selector valve to the emergency position. It simultaneously unlocked and opened the main landing gear inboard doors and unlocked, lowered and locked down all three landing gears using hydraulic power. In this configuration the main landing gear inboard doors remained open.

If hydraulic power was lost, the Emergency Hydraulic Extension Gear Pull Handle must be operated as above in order to position the normal/emergency selector valve to the emergency position.

However, without hydraulic power the gears and doors would not be released from their uplocks at this stage. To achieve this each landing gear had a Gear Manual Release Handle fitted at the flight deck floor, which must be pulled. Each handle operated its landing gear independently, mechanically releasing the uplock for the associated landing gear and, in the case of the main landing gears, also releasing the inboard door uplocks. When the handles had been pulled the doors would open and each landing gear would extend by gravity, but would not lock down. In order to achieve engagement of the mechanical downlocks it was necessary to apply a sufficient and sustained aerodynamic force to each landing gear. This was achieved for the main landing gears by sustained sideslip until the gear locked down indications were obtained, and for the nose gear by accelerating until its locked down indication was obtained.

Landing gear examination

Tests were conducted on the right main landing gear to establish whether it had failed to lock down as a result of a malfunction. It was not possible to pressurise the whole of the No 1 hydraulic system because of the failure of both the No 1 and No 3 hydraulic pumps, so a hand pump was used to retract the right main landing gear alone. During the initial testing checks were made for any interference or restriction which might have affected normal operation. No such interference or restriction was found.

With the gear retracted and the inboard door open, but with a load simulated on its uplock, the free fall mechanism was operated. The force required to pull the Mechanical Extension Control Handle was measured as 13 DecaNewton (DaN), about 30 lbf, which was less than the allowable maximum of 16 DaN. The gear fell normally, but came to rest a few degrees short of the downlocked position. A sustained force of 62 DaN was required to engage the downlock. The manufacturer provided limits of 60 DaN, +/- 5DaN. Therefore the free-fall operation of the right main landing gear was found to be normal and within production limitations. In addition, the nose landing gear should require 130DaN, +/- 15DaN, to achieve a downlock. The manufacturer was provided with data from the FDR and asked to evaluate the aerodynamic loads generated on the landing gear during the relevant part of the descent and approach. Their investigation concluded that the lateral forces generated on the main landing gears were about 36 DaN, and the drag force on the nose landing gear reached about 127 DaN.

The manufacturer noted that the degree of rudder used to generate sideslip, as observed on the FDR, was insufficient to generate the necessary aerodynamic forces required to engage the main landing gear downlocks. The manufacturer analysed the data with regard to the rudder deflection and believed the deflection was a yaw damper input reacting to the yaw generated by each landing gear door and gear leg whilst extending under gravity.

Previous landing gear gravity extensions

The manufacturer advised that for the entire Falcon aircraft fleet and for the last ten years (1 January 1994 to 1 January 2004), there had been 23 events in which the landing gear gravity extension procedure was carried out, following hydraulic failure or abnormal gear behaviour. It had been successful on 20 occasions and unsuccessful three times, twice because an internal mechanical jam had occurred and once because of a jam caused by a foreign object.

Slat system description

The slat system consisted of inboard and outboard sections on each wing, which were normally powered by the No 1 hydraulic system. In the event of No 1 hydraulic system failure it was possible to select Emergency Slat by operating a guarded switch on the flight deck. When so selected hydraulic power from the No 2 hydraulic system was supplied to the outboard slat sections only and the inboard slats, if extended, would be returned to the stowed position by the aerodynamic loads.

Slat position was normally signalled from sensors which indicated full extension. While the slats were in transit, the red arrow 'slats in transit' indication would be shown. Successful normal deployment would illuminate a single steady green lamp on the flap/slat indicator.

The indications from a normally functioning slat system may be summarised as follows:

- SLATS + FLAPS handle on SLATS (EMERGENCY SLATS switch OFF):
    - Slats in transit:
      Red arrow
    - Outboard and inboard slats extended:
      Steady green slats indicator

- EMERGENCY SLATS switch ON (SLATS + FLAPS handle on CLEAN:
    - Slats in transit:
      Red arrow
    - Outboard slats extended:
      Flashing green indicator

- EMERGENCY SLATS switch ON and SLATS + FLAPS handle on SLATS, with inboard slats not extended (hydraulic #1 failure):
    - Outboard slats extended:
      Red arrow

Slat system operation during the flight

The FDR data indicate that the flaps were selected to the Flap 7 position. The outboard slats extended first followed seven seconds later by the inboard slats: this was the normal sequence of operation. The FDR indicated that both slats reached the fully extended position. Nineteen seconds after the inboard slats were indicated to be in the extended position the No 1 hydraulic system was rendered inoperative by the loss of pressure from the No 1 pump, five seconds later the emergency slat system was selected. Two seconds later the inboard slats extended parameter altered state to indicate that the inboard slats were no longer in the fully extended position and were correctly returning to the stowed position.

The initial indications on the flight deck following normal slat selection should have been a red arrow 'slats in transit' indication. This red light would have extinguished when the slats reached the fully extended position and would then have been replaced by a single steady green light. Extension of the slats would have ended a residual circulation of fluid in the No 1 hydraulic system and caused the loss of pressure from the No 1 hydraulic pump. This resulted in the loss of the No 1 hydraulic system since the No 3 pump had already failed. Hydraulic power would now have been removed from the slats allowing them to be forced back by aerodynamic forces. As soon as one full extension switch was no longer active the red arrow would have appeared prompting the crew to select emergency slats. If the SLAT + FLAP handle were also returned to the CLEAN position, a flashing green indication would then have been expected indicating that the outboard slats were in the extended position. If, however, it was left in the SLATS position, the steady red light should have illuminated.

The crew reported that the flap position indicator showed normal slat movement then Flap 7 extension, with the slat indicator light illuminated steady green. However, the red arrow then illuminated and the emergency slat switch was selected, although the crew was unclear of the order in which these two events occurred. The crew could not recall any flashing green light on the flap position indicator. The co-pilot then went into the aircraft cabin and reported that the outer slats were extended whilst the inner slats were retracted.

The checklist used by the flight crew covered two cases including one where the Slat/Flap handle was at 7° and the red transit light was illuminated, with no green steady or flashing light; these were the indications reported by the crew. This case required selection of the Emergency Slat switch to ON and then describes three further possibilities. One of these is that the outboard slats are extended, the inboard slats are retracted, the red transit light is on and the Flaps are at 7°: again, this was the situation reported by the crew.

Checklists and training

In dealing with the failure of the No 1 hydraulic system, and the subsequent gear and slat problems, the crew referred to a set of checklists produced by their training organisation entitled: "FALCON 900EX EMERGENCY /ABNORMAL PROCEDURES PILOT CHECKLIST Revision 4". The crew reported that they found this easier to use than the approved Flight Manual published by the manufacturer. The approved Flight Manual (AFM) was on board the aircraft, but was not used by the crew.

The checklist used by the flight crew contained the following statement:

> *"These are suggested training procedures only and in no way supersede current procedures outlined in the FAA-approved Flight Manual. In case of conflict, the Flight Manual takes precedence. Checklist procedures represented for USA registered aircraft only. For non-USA registered aircraft, consult AFM for alternate procedures."*

In addition the bottom of each page was marked "FOR TRAINING PURPOSES ONLY".

Study of both the checklist provided by the training organisation and the approved Flight Manual published by the manufacturer revealed several notable differences.

Hydraulics

The checklist used by the crew and the approved Flight Manual had similar procedures for a failure of the No 1 or the No 3 hydraulic pump and a subsequent failure of the No 1 hydraulic system. The checklist stated that failure of a single pump in the No 1 hydraulic system will be indicated by a HYDR#1 PUMP 1 or HYDR#1 PUMP 3 caption (with a master warning and audio warning). Failure of the No 1 hydraulic system, in addition to the above warnings for both pumps, will possibly also result in a PITCH FEEL caption. In addition, the approved Flight Manual also stated that there would be a pressure drop in the No 1 system, and that the fluid quantity indicator may read zero, whereas the checklist simply stated 'Hydraulic pressure and quantity….CHECKED', without providing any guidance on the expected indications.

Landing gear

The checklist for Emergency Gear Extension instructed the pilot to sideslip the aircraft after manually lowering the main gear and stated that the downlock light should illuminate *within* thirty seconds whilst the AFM stated that it will not illuminate until *after at least 30 seconds*. This difference in wording is small but crucial in ensuring sufficient aerodynamic force is applied to the main gear to engage the downlock.

Whilst this difference is noteworthy it did not affect the outcome in this instance as the pilots both stated that they had not referred to this checklist. This is because the procedure for the Loss of No 1 Hydraulic System incorporated a subsidiary procedure for Emergency Gear Extension. This made no reference at all to any time limits associated with sideslipping the aircraft to engage the main gear downlocks. It also failed to direct the user on to study the specific Emergency Gear Extension procedure contained elsewhere in the checklist.

Both the Emergency Gear Extension procedure used by the crew (Revision 4) and that contained within the AFM state that the main gear should be extended first, via the Gear Manual Release Handle, and then locked down with sideslip. Only then should the nose gear be released.

Finally, both pilots reported that when they had conducted training exercises in the flight simulator manually deploying the landing gear only required a minimal use of the rudder pedals to provide sufficient sideslip to lock the main gear. They reported that indications that the main gear was down and locked were virtually instantaneous on applying rudder.

Minimum Equipment List

The aircraft manufacturer supplies a Master Minimum Equipment List (MMEL) from which a Minimum Equipment List (MEL) is derived by the aircraft operator. The item of interest, in this instance, is the section dealing with Hydraulic Power, Section 29. A copy of the first page of this section of the MEL is presented at Figure 1. Identification of the relevant item, the hydraulic pump caution light (Section 29.1) is identical in both the MMEL and the MEL. The format of the MMEL, as an approved document, conforms to the conventions generally used by aircraft manufacturers. In particular capital letters are used throughout the MMEL to emphasise the captions on lights, and the operator's MEL uses the same convention.

DA 900EX — MINIMUM EQUIPMENT LIST — Page 1.29.1, Revision 2, Date 1 May 01

SYSTEM & SEQUENCE NUMBERS	ITEM	1	2 NUMBER INSTALLED	3 NUMBER REQUIRED FOR DISPATCH	4 REMARKS OR EXCEPTIONS	
29	HYDRAULIC POWER					
1.	HYDR#1 PUMP 1, HYDR#2 PUMP 2, HYDR#1 PUMP 3 Caution Lights	C	3	2	(O)	One may be inoperative provided: a) Associated hydraulic system pressure indicator operators normally and is monitored during flight, and b) Standby hydraulic pump is verified to operate normally before engine start. Refer to PM 29-1A for (O).
2.	#1 System Hydraulic Pressure Indicator	C	1	0		May be inoperative provided HYDR#1 PUMP 1 and HYDR#1 PUMP 3 caution lights operate normally.
3.	#2 System Hydraulic Pressure Indicator	C	1	0	(M)	May be inoperative provided: a) HYDR#2 PUMP 2 caution light operates normally, and b) Standby pump is verified to operate normally prior to engine start. Refer to PM 29-3A for (M).
4.	No. 1 or No. 2 Hydraulic Quantity Indications (EID)	C	2	1	(M)	One may be inoperative provided associated reservoir fluid quantity is verified to be adequate prior to departure. Refer to PM 29-4A for (M).

Figure 1 - Minimum Equipment List - Section 29, Hydraulic Power

Having arrived in Kilimanjaro with indications of an intermittent fault to the No 3 hydraulic pump the crew made the decision not to have the fault investigated and repaired at the time since they believed, incorrectly, that the MEL allowed dispatch with only two of the three engine driven hydraulic pumps operating.

Discussion

The crew arrived in Kilimanjaro aware of an indication of an intermittent fault to the No 3 hydraulic pump. They consulted the MEL and believed, incorrectly, they could depart with this pump unserviceable. This, combined with the limited repair facilities available, persuaded them to defer this defect until their return to London (Luton) Airport.

The crew had misinterpreted their MEL. Section 29.1 of the MEL allows dispatch with two of the three caution lights serviceable and not two of the three hydraulic pumps as the crew believed. The MEL also requires that two operational provisions are addressed and these, when read in conjunction with their associated procedures, make it quite clear that this section of the MEL concerns the caution lights. However, the crew appear to have been deceived by the relative unimportance of the term 'Caution Lights' which was printed in lower case and appeared after the listing of the three hydraulic pumps which were printed in capital letters. If the term 'Caution Light' had appeared after each caption ie 'HYDR#1 Pump 1 Caution Light' there would have been less room for misunderstanding. Any MEL must be read in a thorough manner since partial reading of any item can easily lead to misinterpretation. However, the MEL is not a document that is used frequently and should therefore be presented in the most clear and unambiguous manner available.

On their departure four days later the No 3 hydraulic pump continued to indicate an intermittent fault until 15 minutes after engine start when it then failed completely. Loss of this pump should have had minimal impact on the operation of the aircraft; however, there was also a continuing loss of hydraulic fluid, through a leak in the No 1 hydraulic pump although the time at which this leak commenced is unclear. This leak and the failure to the No 3 hydraulic pump were probably independent. Even though it is not known precisely when the leak developed loss of fluid was observed by the crew after a flight time of between one and two hours. The leak resulted in the hydraulic quantity indication reducing to zero during the flight. The zero level in the hydraulic reservoir may have been slightly offset, so that a sufficient minimum quantity of fluid was circulating in the No 1 hydraulic system, thus explaining the normal pressure in the system and the absence of a HYDR#1 PUMP 1 caution light. In cruise conditions, with low requirements for hydraulic power, the duration of this condition would depend on the rate of fluid loss. At the time of flap and slat extension, the increased requirement caused the final loss of the No 1 hydraulic system.

The crew expected that indications of the loss of the No 1 hydraulic system would include a reduction in pressure; however, since this did not occur the crew did not believe that they had lost the system. As a precaution, however, they considered what they would do if the system subsequently failed when configuring the aircraft for landing. This would require lowering the landing gear using the free-fall system, and would deny them the use of normal braking and normal slat extension. They also considered the required adjustments to the planned approach speed and the landing distance required before finally confirming that Luton's runway had sufficient landing distance available. However, during the remainder of the flight to Luton the crew did not consult the AFM but relied on their 'training' checklist.

The complete failure of the No 1 hydraulic system became apparent to the crew when they selected the slats on approach to Luton Airport. The emergency slat system worked correctly although the crew failed to receive the flashing green indication they were expecting; however, this condition was allowed for in the procedure that they were using.

The initial attempt to lower the landing gear resulted in three red but no green gear position indicating lights; these were the expected indications following the loss of the No 1 hydraulic system. When conducting the subsequent Emergency Gear Extension procedure the crew operated both Main Gear Manual Release Handles then the Nose Gear Manual Release Handle and each element of the gear deployed but, as expected, none of them achieved a downlock indication. This sequence was at variance with the Emergency Gear Extension procedure which required that each main gear is locked down, through the application of sustained sideslip, before the Nose Gear Manual Release Handle is pulled. Furthermore, evidence from the FDR indicates that the flight crew did not sideslip the aircraft to a sufficient degree and for sufficient time to provide the necessary aerodynamic loads on the main gear and did not accelerate sufficiently to provide the required aerodynamic loads on the nose gear. The reason for not doing so can be ascribed to the checklist they were using, which failed to clearly define the parameters required to lock the gear. In addition, the training that the crew had experienced in the flight simulator led them to believe that when manually deploying the landing gear only the minimal use of the rudder was required to provide sufficient sideslip to lock the main gear down. Moreover, evidence from the CVR indicates that the crew was concerned by the apparent failure of the emergency deployment handles, which they incorrectly believed was the cause of the gear failing to lower and lock.

It seems most probable that all three gears were just short of entering the downlocks before touchdown. Whilst on the runway, any sideways movement would have had the effect of locking one main gear and retracting the other, and this is consistent with the effect of the slight crosswind reported, causing the left gear to lock. The nose landing gear was probably locked down by the initial drag force whilst making contact, wheel spin-up at first contact or possibly by the slight shock of main landing gear first contact. The point at which the aircraft touched down and two of the gears became locked might well have generated two green indications, however, these would not have been observed as the electrical power had been deliberately removed immediately after the touchdown.

The crew were dealing with a hydraulic failure and were unable to lower the landing gear. They made the decision to divert and were properly guided in their choice of alternate airfield by ATC. Stansted fulfilled their requirements in that it had a long runway, benign weather conditions and, crucially at that time of night, was open. In addition, appropriate emergency services were at hand.

The checklist that the pilots used was clearly marked as being "FOR TRAINING PURPOSES ONLY", moreover, a further caveat noted that the checklist procedures were *"for USA registered aircraft only. For non-USA registered aircraft, consult AFM for alternate procedures".* The approved Flight Manual was on board the aircraft, but was not used by the crew. The crew reported that they found their 'training' checklist easier to use than the AFM published by the manufacturer. It is clearly the operator's responsibility to ensure that each member of the flight crew has access to approved documentation that is up to date; this was provided in the form of the AFM which was on board the aircraft. However, if the manufacturer's publications are considered by the flight crew to be unclear then the operator should discuss suitable amendments with the manufacturer, since these publications are approved documents. Training Organisations will often provide their own documentation "FOR TRAINING PURPOSES ONLY" in an attempt to provide simplified, structured guidance to pilots during training. However, they have an obligation to ensure that this training documentation accurately reflects the information provided in the manufacturer's operations manual. Additionally, the pilots should not have been using a checklist that was clearly identified as inappropriate. The use of such checklists is of particular relevance to this type of operation where pilots may often be from a variety of training backgrounds.

Recommendations

Safety Recommendation 2005-023

After landing at Kilimanjaro with indications of an intermittent fault to the No 3 hydraulic pump the crew consulted the Minimum Equipment List and concluded, incorrectly, that they could depart with an unserviceable hydraulic pump. Whilst it is clear that a Minimum Equipment List must be read in a thorough manner the crew appear to have been deceived by the presentation of the information in this instance. The MEL is not a document that is used frequently, which makes it particularly important that it should be presented in the most clear and unambiguous manner available.

It is therefore recommended that Dassault Aviation should review Section 29, Part 1 of the Master Minimum Equipment List to make it clear that this refers to the pump caution lights and not the pumps.

Safety Recommendation 2005-024

During the flight to London (Luton) Airport, following a failure of the No 3 hydraulic pump, there was a continuing loss of hydraulic fluid through a leak in the No 1 hydraulic pump which resulted in an indication of zero contents in the No 1 hydraulic system. The crew, however, was confused by the fact that the system indicated normal hydraulic pressure despite the apparent total loss of fluid.

It is therefore recommended that Dassault Aviation review the indications likely to be seen following a failure of either hydraulic system and, if necessary, amend the checklist accordingly.

Safety Recommendation 2005-025

Training Organisations will often provide their own documentation "FOR TRAINING PURPOSES ONLY" in an attempt to provide simplified, structured guidance to pilots during training. However, whilst providing clarity they also have an obligation to ensure that this training documentation accurately and thoroughly reflects the information provided in the manufacturer's operations manual. Moreover, the documentation and procedures promoted during training should be those that the flight crew will use in the aircraft.

It is therefore recommended that FlightSafety International should review their process for ensuring the accuracy of the documents used in training and should promote the same procedures used in training that will be used when flying the aircraft.

Safety Recommendation 2005-026

The fidelity of modern flight simulators is such that non-normal training can now be conducted in the flight simulator and need not be completed on the aircraft; indeed, some non-normal drills such as manually lowering the landing gear following the loss of the No 1 hydraulic system can only be safely conducted in the simulator. Notwithstanding the required level of fidelity for the qualification standard of the simulator it is clear that in this case the forces required to lock down each element of the landing gear were not representative of those necessary in the aircraft.

It is therefore recommended that FlightSafety International, in coordination with Dassault Aviation, should review their flight simulators used for Falcon 900 training to ensure they represent with acceptable realism the correct pilot input, as defined in the operations manual, to successfully lock down the landing gear during emergency gear extension.

INCIDENT

Aircraft Type and Registration:	DHC-8-311, G-BRYU
No & Type of Engines:	2 Pratt & Whitney PW123 turboprop engines
Year of Manufacture:	1997
Date & Time (UTC):	21 December 2004 at 0723 hrs
Location:	Edinburgh, Scotland
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 49
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	5,350 hours (of which 3,200 were on type) Last 90 days - 50 hours Last 28 days - 16 hours
Information Source:	Aircraft Accident Report Form submitted by the commander and further inquiries to aircraft manufacturer

Synopsis

On 21 December 2004 at 0723 hrs, the pilot experienced high control forces in pitch when rotating the aircraft to get airborne from Edinburgh Airport. Just as the pilot was considering aborting the takeoff above the rotation speed, the aircraft slowly became airborne. After takeoff the pilot exercised the aircraft pitch controls whereupon the control forces returned to normal. The pilot then decided to continue to Manchester where an uneventful landing was made. The cause of the high control forces in pitch as probably due to frozen spring tabs caused either by incomplete de-icing before flight, or by rehydration of the de-icing fluid residue. The aircraft manufacturer has subsequently issued two All Operators Messages applicable to Dash 8 series 100, 200 and 300 aircraft following two instances of a rejected takeoff in the Dash 8 series 200 aircraft due to the inability to rotate at the appropriate rotate speed. The AOMs cite as a potential cause the restriction of the spring tabs due to freezing of rehydrated de-icing fluid residue, and recommends periodic washing of specific aerodynamically "quiet" areas to remove this residue.

History of the flight

The aircraft was on a sector from Edinburgh to Manchester with 4 crew and 49 passengers on board. The aircraft mass was 18,186 kg (which was close to the maximum take-off mass of 19,000 kg); the centre of gravity was at the forward limit due to an almost full passenger load and a relatively light baggage load. The pitch trim was consequently set towards the aft limit of the take-off range.

The aircraft had been de-iced with de-icing fluid Type II 75/25 at 0400 hrs to remove hoar frost, for a planned departure time from Edinburgh at 0700 hrs. The minimum outside air temperature (OAT) during that period was -2°C, and the maximum OAT -1°C. It was a clear morning with no precipitation. The holdover time was five hours. Inspection of the aircraft prior to departure confirmed that the aircraft had been de-iced, with de-icing fluid evident on all visible surfaces. The commander observed that an excessive amount of fluid appeared to have been applied to the fuselage.

During the take-off roll at 0723 hrs the commander, who was the handling pilot, found that the pitch control force required to rotate at V_R (109 knots) was extremely high, which he initially attributed to the aircraft forward centre of gravity position and relatively high mass. However, continued and increased back pressure on the control column appeared to have no effect, and this resulted in a significantly extended take-off roll. He was on the point of rejecting the takeoff above V_R because he thought that the elevators may have jammed, when a very slow rotation was achieved using sustained and increasing back pressure on the control column. The aircraft then became airborne.

Once stabilised after takeoff, the commander carefully exercised the pitch control, whereupon the pitch control forces returned to normal. Further handling checks were conducted during the climb and the cruise with no recurrence of unusual pitch control forces. It was decided to continue to the destination airport, where the subsequent approach and landing at Manchester was completed without further incident.

A static full and free control check carried out after landing was normal. Post-flight examination of the aircraft also indicated that de-icing fluid was evident on the forward section of the tailplane, whilst the aft section, elevator hinges and spring tabs were completely dry.

The pitch control forces during rotation were well in excess of anything that the commander had experienced on this type of aircraft. He considered that there did not appear to be any aerodynamic assistance to the operation of the pitch control, which could have suggested that the elevator spring tab had been jammed or frozen. This explanation is also supported by the fact that the control forces returned to normal in the climb.

Discussion

There have been previous instances of abnormal pitch control forces either in flight or during takeoff, some of which have been attributed to elevator spring tabs becoming frozen with the rehydrated residues of anti-icing fluid. As a result of a serious incident to a Dash 8 aircraft in flight which was due to a frozen elevator spring tab in flight (fully described and discussed in AAIB Bulletin 12/2003, reference EW/C2003/03/01), two Safety Recommendations were addressed to the CAA. The first (2003-81) addressed the implementation of advice given to operators on airframe inspections and cleaning of aerodynamically "quiet areas" where residues can accumulate, and the second (2003-82) highlighted the need for anti-icing fluid manufacturers to develop gelling agents, with suitable hold-over times, that were not re-hydratable.

The CAA accepted Safety Recommendation 2003-81 in Follow-up Action on Occurrence Report (FACTOR) No F5/2004 dated 12 January 2004, and partially accepted Safety Recommendation 2003-82 in the same document.

It would appear that G-BRYU had been de-iced before flight, and the aircraft was being operated within the permissible holdover time of five hours. Thus one possibility is that the elevator spring tabs had become frozen when the aircraft had been parked overnight, and had remained frozen despite de-icing. A second possibility is that the elevator spring tabs had become frozen with the rehydrated residues of anti-icing fluids, as discussed in the AAIB Bulletin referred to above.

The aircraft manufacturer has recently issued All Operators Message (AOM) 784 on 13 January 2005 (applicable to Dash 8 series 100, 200 and 300 aircraft) following two instances of a rejected takeoff in the Dash 8 series 200 aircraft due to the inability to rotate at the appropriate rotate speed. The AOM cites as a potential cause the restriction of the spring tabs due to freezing of rehydrated de-icing fluid residue, and recommends periodic washing of specific aerodynamically "quiet" areas with Type I de-icing fluid when Type IV de-icing fluid has been regularly used. A further AOM 784A dated 23 March 2005 recommended the same procedures for Type II fluids.

The AAIB concurs with the advice given in the AOMs. A further measure to reduce the possibility of control problems due to frozen spring tabs during takeoff would be for aircrew to pay particular attention to the correct operation of these devices during the flight controls checks before takeoff following any de-icing procedure. According to the aircraft manufacturer, the normal characteristics associated with a slow, deliberate and full control throw in pitch have a very distinct feel, particularly at the maximum elevator trailing edge up position. With a fully functional and free elevator and spring tab control there is a constant pull force as the control column is moved toward the nose up position. At the point where the elevator reaches its maximum travel stop, the continued pull of the column gives the impression of winding up a spring, until the control column reaches its maximum travel. If the spring tab is frozen, this latter force will not be felt, as only the elevator maximum travel stop that would be contacted. The aircraft manufacturer further asserted that there was also the possibility of breaking out the frozen tab, which would have a very distinctive feel, prior to reaching the control column maximum travel. The ability to make this assessment is contingent on the pilot having carried out the control throw checks in non anti-icing conditions in exactly the same manner in order to identify any unusual control feel characteristics. Moving the control column forward would result in similar force characteristics, but it was the manufacturer's view that an anomaly in the elevator circuit was more likely to be noticed by the aware and informed pilot when moving the control column aft.

INCIDENT

Aircraft Type and Registration:	DHC-8-402, G-JEDI
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2001
Date & Time (UTC):	5 January 2005 at 0715 hrs
Location:	Taxiway A, Birmingham International Airport, West Midlands
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 21
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	2,900 hours (of which 1,865 were on type) Last 90 days - 170 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further information from maintenance organisation

History of the event

The flight crew were taxiing the aircraft along Taxiway A towards Runway 15 at Birmingham International Airport. After passing a metal plate in the taxiway, the commander turned the nosewheel steering tiller to the right to centralise the aircraft on the taxiway but this initial control input seemed to have no effect. The commander made a larger input on the tiller but the aircraft still did not turn. He then applied right rudder and right brake pedal pressure and was able to bring the aircraft to a halt, with its left main landing gear on the grass next to the taxiway. The crew noted at this point that the 'nose steering' fault light was illuminated and the co-pilot's airspeed indicator (ASI) had failed. The wind at the time was reported as being from 210º at 11 kt which created a significant crosswind component from the left.

The flight crew recycled the 'nose steering' control and the warning light extinguished but they were unable to taxi forwards with the left main landing gear on the grass. Consequently, the passengers were disembarked onto a bus and the aircraft was pushed to a stand for engineering investigation.

Engineering investigation

Analysis of the flight data recorder (FDR) later showed that the 'weight-on-wheels' (WOW) signal was lost for one second early during the taxiing of G-JEDI to Runway 15 and again at about the point where the crew reported losing control of the nosewheel steering. In this aircraft there are two separate WOW switches (WOW1 and WOW2) on the nose landing gear. The loss of signal from either of these sensors results in the FDR recording a loss of WOW signal and in the Steering Control Unit (SCU) removing steering commands from the hydraulic actuators. The loss of nosewheel steering from tiller and rudder inputs in G-JEDI was entirely consistent, therefore, with the loss of one WOW signal from the nose landing gear while the crew were attempting to steer the aircraft on the ground at low speed.

The following day (6 January 2005) there was another ASI problem on the ground with the same aircraft, at a stand at Glasgow Airport. Investigation showed there was a problem with the wiring harness from the WOW2 sensor and this was repaired.

The FDR data was not available to the maintenance engineers immediately following the incident at Birmingham (5 January 2005) and the aircraft was dispatched following a change of the SCU. This diagnosis was based on a particular fault code registered by the SCU. The engineers did not appreciate that this fault code could be an indication of a loss of WOW1 or WOW2. This information came from the aircraft manufacturer; it was not included in the aircraft's maintenance manual. The airline maintenance organisation has requested that the aircraft manufacturer introduce information of this nature into the manual.

Safety action

On 31 March 2005 the aircraft manufacturer informed the AAIB in writing that, in accordance with the operator's request, the company will be amending its Maintenance Manuals to incorporate the information that the operator requested.

Aircraft Type and Registration:	Beagle B121 Series 1 Pup, G-AXNL
No & Type of Engines:	1 Continental Motors O-200-A piston engine
Year of Manufacture:	1969
Date & Time (UTC):	2 February 2005 at 1047 hrs
Location:	Near Holly Hill Farm, Enfield, London
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Damage to top of fuselage, fin and nose
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	219 hours (of which 58 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft suffered a reduction in power whilst over a densely populated area of North London. The selection of carburettor heat, the electric fuel pump and an alternate fuel tank did not resolve the situation. Realising that the aircraft's continued adequate performance was unpredictable the pilot elected to carry out a precautionary landing in one of the few available fields. After a successful touchdown however, the aircraft pitched inverted as the nose wheel dug into soft ground. No reason could be found, after examination of the aircraft and its systems, for the reduction in performance. The weather conditions however, were conducive to moderate to severe carburettor icing at any power setting and it is possible that the pilot did not apply carburettor heat for the length of time required to clear any intake restriction.

History of the flight

The aircraft was being flown from White Waltham to North Weald on a route that passed over Wycombe Air Park and Elstree Aerodrome; close to substantial urban development. A short distance beyond Potters Bar, approximately 5 nm east-northeast of Elstree, the pilot noticed a drop in engine power and fluctuation of the fuel pressure gauge. He was unable to restore normal operation despite applying carburettor heat, selecting the opposite fuel tank and operating the electric fuel pump. Although the engine did not misfire or produce any unusual vibration, the extent of the power loss was such that the pilot considered he would not be able to reach Elstree, with whom he was in radio contact. Finding himself over an area of open farmland, he transmitted a MAYDAY message, selected a landing site and carried out a precautionary landing in a field approximately 3 nm south-east of Potters Bar.

The engine continued to produce some power throughout the approach, and the pilot switched off the fuel and electrics just before touchdown. The landing, on upward sloping ground, appeared normal at first but, during the ground roll, the nose wheel dug in to the soft ground and the aircraft somersaulted, coming to rest upside down. The aircraft suffered substantial damage to the fuselage, vertical stabiliser and nose, and fuel was leaking from both wings. However, there was no fire and the pilot was able to escape without serious injury. He was assisted by a number of people walking nearby, who also alerted the emergency services.

Engineering investigation

The aircraft was taken by road to a maintenance facility at Sywell Aerodrome, where an inspection was carried out on behalf of the AAIB. No mechanical defects were found in the fuel, ignition or induction systems that would have caused the engine to loose power in the manner described. The carburettor bowl was full of uncontaminated fuel and both wing tanks contained fuel. It was not possible to rule out particle blockage of the carburettor metering passages or otherwise to test the free flow of an adequate fuel/air mixture into the combustion chambers.

Aircraft fuel system

The Beagle Pup is a single engine, low wing monoplane with up to four seats. The Series 1 aircraft has two fuel tanks, one in each wing, with a total capacity of 24 imperial gallons. Fuel is supplied to the carburettor via a selector marked OFF, LEFT, RIGHT and BOTH. Operators have discovered that if both tanks are selected, and one tank is allowed to run completely dry, air will be drawn into the system. If a sufficient head of fuel remains in the opposite tank, the engine may run intermittently, but will eventually stop even before that fuel is exhausted, unless that tank alone is selected. A bulletin on this subject will be issued shortly by De Havilland Support Limited.

Fuel records obtained from White Waltham indicate that a satisfactory fuel sample was taken from the fuel pump at the start of the day and that G-AXNL was the first aircraft to refuel, uplifting 40 litres of Avgas prior to departure. The aircraft was airborne for approximately 35 minutes. Using data provided in the aircraft flight manual, total fuel consumption during the flight should not have been more than 23 litres. If both fuel tanks were nearly empty prior to refuelling, and the entire flight had been conducted with the same tank selected, it is possible that all of the fuel in that tank could have been consumed. Even so, the pilot would then have had to select BOTH tanks in order for the condition described in the preceding paragraph to have been a factor. However, selection of the opposite fuel tank and operation of the electric fuel pump would have been sufficient to restore an adequate fuel supply for normal operation almost immediately. Furthermore, the presence of fuel in the carburettor and both wings suggests that adequate fuel was available at the end of the flight.

Meteorology

An aftercast for Elstree at the time of the accident, provided by the Met Office, estimated the temperature and dew point to be 6°C and -1°C respectively. The pilot reported that there was no significant weather and very little cloud. There would have been a risk of moderate to severe carburettor icing at any power setting in these conditions.

The CAA General Aviation Safety Sense Leaflet 14A *"Piston Engine Icing"*, suggests that full carburettor heat must be applied for at least 15 seconds in order to remove carburettor ice completely and notes that this 'may feel like a very long time'. Many pilots, familiar with short applications of carburettor heat when downwind in the circuit and prior to landing, apply it for no more than five seconds at a time. Moreover, a significant power reduction following ice accumulation results in lower exhaust gas temperature, reducing further the effectiveness of conventional hot air carburettor heat.

Conclusion

No pre-existing mechanical defects could be found which would have caused the engine to loose power in the manner described. It is possible that the pilot did not apply sufficient carburettor heat to prevent continuous ice accumulation. In the circumstances, his decision to carry out a precautionary landing, rather than to divert to Elstree with the possibility of a total power loss over a built up area, was admirable.

Aircraft Type and Registration:	Beech Bonanza C35, N60256	
No & Type of Engines:	1 Continental E180-11 piston engine	
Year of Manufacture:	1951	
Date & Time (UTC):	28 January 2005 at 1437 hrs	
Location:	Southend Airport, Essex	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller, main and nose gear doors and nose gear assembly	
Commander's Licence:	See below	
Commander's Age:	71 years	
Commander's Flying Experience:	2,471 hours (of which 310 were on type) Last 90 days - 4 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by AAIB	

History of the flight

The aircraft was being flown by its owner to assess the effects of adjustments which had been carried out during recent maintenance action, including a check of the landing gear warning system. The flight test proved that the landing gear warning horn, which indicates that the landing gear is not down below a certain throttle position, was sounding at too high a throttle setting. Correctly adjusted, the aural warning would sound when the throttle was retarded below a setting equivalent to a manifold pressure of 12 inches Hg, but on the test flight this figure was approximately 18 inches Hg, having remained substantially unchanged after the adjustments.

The pilot had limited time available for the flight due to other activities later in the day, and it was only 10 minutes after takeoff that the pilot called Southend for instructions to rejoin the circuit. The weather at the time was showery, with a moderate and gusty surface wind. Southend Airport's ATIS reported the surface wind from 360°(M) at 11 kt, with a few clouds at 500 feet, scattered clouds at

1,300 feet and broken cloud cover at 3,000 feet; the visibility was 8,000 metres in light rain. When the aircraft was stabilised on the final approach to Runway 06, the Tower controller reported the wind as being from 350°(M) at 8 kt, gusting to 31 kt and, as the aircraft approached the runway threshold it was reported as 020°(M) at 13 kt gusting to 30 kt. The pilot reported later that the approach was very difficult in the wind conditions, which were close to the aircraft's limits. In view of the weather conditions and time pressure, the pilot flew the approach faster than the recommended speed and delayed selection of full flap until just before touchdown.

Runway 06 at Southend Airport has a threshold displaced by about 180 metres due to a public road and church spire adjacent to the beginning of the actual runway length. The pilot intended to touchdown some 40 metres before the displaced threshold but was not sure of the actual achieved touch down point. Once the aircraft had landed, and still with some difficulty in controlling the aircraft, the pilot intended to raise the flaps with a view to 'dumping' lift and increase the chance of vacating the runway at the next exit. However, he inadvertently selected the landing gear to UP and the gear started to retract. Realising his mistake, the pilot reselected the landing gear DOWN, but the aircraft's landing gear had partially retracted and the aircraft slid to a halt on the downwind side of the runway, about 340 metres from the displaced threshold markings. The aircraft sustained damage to the inner main landing gear doors, the nose gear doors, nose gear leg assembly and propeller.

The Tower controller's view of the accident was hampered by rain on the windows, and partially obstructed by buildings and parked aircraft. A CCTV camera covered the undershoot area, but this too was affected by moisture on the lens. The controller was aware of the aircraft during the landing; it appeared to be in a normal attitude but he could not determine whether the aircraft was on or just above the runway, nor whether the landing gear was down or not. However, he did see the right wing start to drop as the aircraft settled on to the partially extended gear and he activated the crash alarm.

Later examination of the runway revealed propeller strike marks situated on the runway centreline, starting about 105 metres from the aircraft's final position. The distance between strike marks indicated that the aircraft was travelling at about 30 kt when the propeller first contacted the runway surface.

Pilot's licence

The pilot held a UK Private Pilot's Licence, issued in 1977, and was the holder of a FAA Private Pilot's Licence, issued in 1986 on the basis of the continuing validity of his UK licence. The pilot had believed that his class rating for Group A aircraft (now Single Engine Piston - Land) could be revalidated on a self-certification basis, which he had done each year in his flying log book. His log book entries had not been certified by a CAA authorised examiner, nor had he complied with the revised requirements of JAR-FCL which were introduced in 1999, and his class rating was therefore invalid.

Description of the landing gear

The retractable landing gear is connected to an actuator which is driven by an electric motor. The landing gear doors are automatically actuated when the landing gear is extending or retracting. The inboard main landing gear doors, which are connected to the retract gearbox, are closed when the gear is in the extended or retracted position. During the extension sequence, the main legs start to lower when the inner doors are approximately half way open, and the doors start closing again just before the legs are fully extended. During retraction, the inner doors open to allow the main legs to retract, and begin to close again when the main legs are about 30 degrees from the fully retracted position. A landing gear safety switch is incorporated into the gear UP circuit and closes when the strut approaches full extension; its function is to guard against inadvertent UP selection whilst on the ground. A landing gear warning horn alerts the pilot to a 'gear not down' situation at low throttle settings, or to the fact that the landing gear is selected UP with the aircraft on the ground.

Aircraft examination

The aircraft was examined in situ by personnel from the aircraft's maintenance company and later underwent functional tests under the AAIB supervision. The aircraft came to a stop with the main gear wheels resting on top of the inner gear doors. Whilst the inner gear doors had suffered considerable abrasion damage, there was no damage to either gear leg, nor signs of distress on the main wheel tyres. The circuit breaker protecting the system had 'popped'.

The aircraft was placed on jacks to allow the landing gear safety switch to be tested. Located on the right hand strut, the switch should close the UP circuit when the landing gear strut is ¾ inch from the fully extended position. With the strut extending, the switch was found to operate ⅛ inch before the normal setting of ¾ inch. A normal retraction sequence was initiated, which was successful. The safety switch was then placed into an "on ground" condition and an attempt made to raise the landing gear. The gear drive motor did not operate, confirming the integrity of the safety system.

Recorded information

The R/T exchanges between the pilot and the tower controller were recorded and available for replay. At the time of the accident, a five second transmission is made by the pilot, in which the landing gear warning horn can be heard clearly. Prior to this, at about 1 minute 45 seconds prior to the accident, the pilot transmits that he is on finals and the warning horn can be heard in this transmission also. However, there are two further exchanges with ATC regarding the wind, at about 90 seconds and 30 seconds prior to the accident, in which the warning is absent.

Analysis

The accident occurred when the pilot inadvertently selected the landing gear UP after landing. The aircraft examination confirmed that the landing gear system and associated warning were fully serviceable. Although the landing gear safety switch was slightly out of adjustment, with the effect that the UP circuit could be closed at a slightly reduced strut extension, the discrepancy is minimal and unlikely to be a significant factor in the accident. The nature of damage to the inner gear doors and lack of damage to the main gear legs or tyres suggested either that an extension sequence had been initiated late in the landing manoeuvre or that the aircraft was at least partially airborne when the retraction sequence commenced, and that the aircraft subsequently sank down onto the retracting gear.

The pilot was certain that the gear was selected DOWN for the approach and the absence of a gear warning horn on the two transmissions immediately before landing supports this. With the landing gear warning horn switch incorrectly set closer to a cruise power setting, it is very unlikely that the warning would not be sounding during an approach with the gear retracted. However, the possibility exists that the warning may have been intermittent due to occasional high power demands in the gusty conditions and the short sampling rate provided by the brief transmissions.

The pilot initially believed that his inadvertent gear up selection was made at quite a low speed, and the aircraft was certainly at a relatively low speed when the propeller contacted the runway. He had intended to raise the flaps, which were controlled by a switch similar to that which operated the landing gear, and made a simple error in his switch selection. The pilot thought that this may have been influenced by the fact that he had been exercising the gear during the flight, though he would also have been operating the flap switch just before the accident. He subsequently considered it possible that the erroneous selection had occurred earlier in the landing phase, possibly whilst the aircraft was still partially airborne, or whilst he was holding full left aileron which may have unloaded the right main gear which contained the safety switch.

Aircraft Type and Registration:	Bolkow BO 208C Junior, G-ATXZ
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine
Year of Manufacture:	1966
Date & Time (UTC):	16 February 2005 at 1330 hrs
Location:	Tatenhill Aerodrome, Staffordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear collapsed, propeller destroyed, and possible shock damage to engine
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	223 hours (of which 0.5 were on type) Last 90 days - 0.5 hours Last 28 days - 0.5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot, occupying the left seat, was carrying out a series landings in order to familiarise himself with the aircraft. Accompanying him, on the insistence of the aircraft's insurance company, was a passenger who was also a pilot and experienced on type. On the fourth approach, described as being higher than previous approaches, the aircraft encountered sink and landed nose wheel first. The nose landing gear collapsed and, after a ground slide of approximately 100 metres, the aircraft came to a stop with no injuries to either occupant. It is possible that the pilot felt he was 'under supervision' and that a lack of comment from the passenger during the final approach was tacit approval to continue to land. In reality the passenger was not a qualified instructor, had never landed the aircraft from the right seat and therefore was not appropriately qualified to intervene.

History of the flight

The pilot had purchased a share in the aircraft, and was undertaking a familiarisation flight to satisfy the Insurer's requirement that he should accrue 10 hours flying on type with either another group member or a Flying Instructor before flying the aircraft 'solo'. The passenger held a Private Pilot's Licence and had 262 hours experience on type. The passenger briefed the pilot on the aircraft and its characteristics, and the two then departed to fly circuits on Tatenhill's Runway 26. Runway 26 is asphalt, 788 metres long, with a displaced landing threshold 58 metres from the beginning of the tarmac. A further 500 metres of unlicensed asphalt continues to the west of the end of the licensed area.

The pilot flew three satisfactory circuits and landings but on the fourth circuit the approach was high. The pilot reported that, although he might have gone around had he been flying solo, he felt content with the approach because of a lack of criticism from his experienced passenger. Just above the runway the aircraft encountered 'sink' and landed heavily, possibly nose wheel first, about 100 metres from the far end of the licensed runway. The nose landing gear leg collapsed and the propeller struck the runway. The aircraft yawed across the runway and came to rest after approximately 100 metres of ground run. The passenger reported that he was not able to react in time as the aircraft pitched nose down towards the runway.

The pilot's recent experience had been on Cessna and Piper light aircraft, which are flown with the pilot's left hand operating the control column and his right operating the throttle. The Bolkow Junior however, is operated in the opposite sense. The pilot reported that it is possible that lack of familiarity with this layout may have caused him to make an inappropriate control input during the landing.

Although the Insurer's requirement was intended to reduce risk, it created an environment in which the pilot felt that he was under supervision. The passenger was familiar with the aircraft but was not qualified or experienced as a flying instructor and had never carried out a takeoff or landing from the right hand seat. Flying Instructors are trained to fly from the right hand seat of an aircraft and to take control of aircraft when their students make errors in circumstances where rapid and effective action is necessary to ensure safety. Had a Flying Instructor been present on board, it is likely that a timely intervention could have prevented the accident. Final responsibility for the safe conduct of flight however, is always the responsibility of the Pilot in Command.

In a review of reportable accidents, the Civil Aviation Authority's General Aviation Safety Review Working Group identified 'Lack of training or experience' as the most common causal factor, present in 23% of accidents.

Aircraft Type and Registration:	Cessna F177RG Cardinal, G-TOTO
No & Type of Engines:	1 IO-360-A1B6 piston engine
Year of Manufacture:	1971 (Construction number 0049)
Date & Time (UTC):	9 February 2004 at 1205 hrs
Location:	Meppershall Airfield, Shefford, Bedforshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Engine shock loaded. Propeller, nose landing gear doors and exhaust pipe damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	715 hours (of which 215 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was flown to a maintenance organisation for the rectification of a landing gear retraction problem. It was flown with the landing gear extended and the electric circuit breaker for the electrical hydraulic pump 'pulled'. The accident flight was uneventful and the landing very smooth. As the aircraft decelerated, its nose dropped and the propeller struck the ground. Post accident rectification revealed defects in all three landing gears. The nose landing gear overcentre downlock was out of adjustment, and the breakout force was minimal. Both main landing gear downlock latch pivot pins had double fatigue and the left one had failed which was the reason for the original landing gear problem.

History of the flight

Twenty three days prior to the accident it was twice noted upon landing gear up selection following takeoff that the landing gear failed to retract fully. In each case following recycling of the landing gear selector the landing gear retracted. Fifteen days prior to the accident it was found that the landing gear would not retract fully and the fault persisted after recycling the landing gear selector. On the day of the accident the aircraft was flown to a maintenance organisation for rectification of the problem with the landing gear extended and the electric circuit breaker for the landing gear's electrical hydraulic pump 'pulled'.

The accident flight to the grass airfield where the maintenance organisation was based was uneventful. Upon arrival at the destination airfield the pilot self-positioned the aircraft on the downwind leg of the circuit pattern, selected 10° of flap, checked that the landing gear green down and locked light was illuminated and reduced the airspeed to 95 mph. After turning the aircraft onto base leg the pilot selected 20° of flap and reduced the airspeed to 90 mph. On final approach the speed was reduced to 75 mph and 30° of flap selected with the landing flare being carried out at 65 mph. The pilot assessed the aircraft's touchdown as very smooth and he held the nose wheel off the ground as long as possible. As the aircraft decelerated, its nose dropped and the propeller struck the ground. As soon as the pilot realised what was happening he pulled the fuel mixture lever to the idle cut off position, switched off the aircraft's electrics, and shut off the fuel. Once the aircraft had come to a halt, the pilot vacated the aircraft via the pilot's door.

The aircraft's history

The aircraft was first registered in the UK in 1971 as G-AZKH. In July 1979 the aircraft was involved in a take-off accident which resulted in damage to the propeller, engine, nose and left main landing gears, and lower fuselage skin (see AAIB Bulletin 10/79). Following repair in May 1982 the aircraft was re-registered G-OADE. In April 1983 when the landing gear was selected down, no landing gear down and locked green light illuminated in the cockpit. The emergency landing gear lowering system was operated (a hydraulic hand pump) but there was still no down and locked indication. A visual examination from the ground indicated that the landing gear was fully extended. A successful landing was carried out whilst operating the hydraulic pump throughout. An engineering examination revealed that the right main landing gear downlock latch pivot pin had failed in fatigue.

In April 1986 the aircraft was involved in a forced landing accident which resulted in damage to the propeller, nose and left main landing gears, and fuselage (see AAIB Bulletin 10/86). In August 1989 the aircraft was re-registered G-TOTO. In 2002 the aircraft had three maintenance checks carried out. During the first of these checks, at 909 airframe hours, the right main landing gear downlock assembly was replaced. Due to the turnaround in staff and the lack of detail in the paperwork raised by a previous maintenance organisation, which was not located at the accident airfield, the reason for this replacement is not known. During the second check, at 956 airframe hours, the left main landing gear downlock microswitch actuating arm was replaced and during the third check, at 981 airframe hours, the main landing gear was re-rigged.

The landing gear system (Figures 1, 2 & 3)

Retraction and extension of the landing gear is accomplished by a hydraulic system integrated with electrical control and indication circuits. There is one hydraulic actuator for the nose landing gear and one actuator that drives a gear system for both main landing gears. Hydraulic fluid is supplied to the actuators by an electrically-powered reversible pump. The hydraulic reservoir is an integral part of the pump. The electrical pump is controlled by the landing gear selector mounted in the cockpit instrument panel. As the landing gear selector is moved to either the up or down position, the pump directs hydraulic fluid through a power pack control valve assembly to the landing gear actuators. As the hydraulic fluid pressure increases at one side of the actuator pistons, the fluid at the other side of the pistons is directed back through the control valve assembly to the pump. The landing gear extension and retraction pipes serve either as pressure or return lines depending on the rotation of the reversible pump and the position of the landing gear selector in the cockpit. Mechanical overcentre locks provide up and down locks for the nose landing gear. The main landing gears utilise hydraulic pressure for positive uplock and electro-mechanical downlocks. Mounted on the control valve, through which pressurised hydraulic fluid passes during landing gear retraction, is a pressure switch. This pressure switch opens the electrical circuit to the pump solenoid when the main landing gear is fully retracted and the hydraulic pressure has reached approximately 1,500 psi. The pressure switch will hold the electrical circuit open until the hydraulic pressure in the system drops to approximately 1,100 psi at which time the pressure switch closes allowing electrical power to the hydraulic pump. The hydraulic pump will run until the pressure reaches approximately 1,500 psi and the pressure switch opens the electrical circuit. This cycling of the hydraulic pressure maintains the main landing gears in their UP AND LOCKED positions whenever the landing gear selector in the cockpit is in the up position. With the landing gear selector in the down position the pressure switch has no effect on the operation of the hydraulic system. Other valves in the hydraulic system channel fluid to the correct outlets during landing gear extension and retraction, allow return fluid into the reservoir without producing any back pressure and allow for thermal relief. An emergency hand pump, located between the two front seats, is used to extend the landing gear manually in the event of electrical or hydraulic failure.

Mounted in the instrument panel are two landing gear position indicator lights. A single amber light illuminates when the landing gear is up and locked; a single green light illuminates when it is down and locked. Each of the three landing gears has a downlock microswitch and all three microswitches have to be made to complete the electrical circuit to illuminate the green down and locked light in the cockpit. In addition to illuminating the green indicator light, the making of all three downlock microswitches opens the electrical circuit to the hydraulic pump. Mechanically connected to the main landing gear downlock mechanisms are two unlock solenoids on the back of which are mounted sequence switches. These solenoids are mounted on pivots which allow them to pivot through approximately 7°. One of the functions of the sequence switches is to open the electrical circuit to the hydraulic pump when the main landing gears are in their downlock positions. All three downlock microswitches and the two sequence switches have to be operated before electrical power to the hydraulic pump is switched off during the landing gear extension sequence. When the hydraulic pump switches off, the pressure in the down lines slowly dissipates over a period of time which is dependant upon the seal leak rates in the landing gear actuators. The hydraulic pump will switch on when any of the downlock microswitches or sequence switches break, which, providing the landing gear selector is in the DOWN position, will pressurise the down lines. When a correctly adjusted landing gear is in the DOWN AND LOCKED position no hydraulic pressure is required to maintain it in that condition. During the landing gear retraction sequence, only the sequence switches, the pressure switch and the landing gear selector in the cockpit have a controlling function of the electrical power to the hydraulic pump.

Engineering examination

Initial examination of the aircraft following the accident revealed that: no pre accident major failure of the nose landing gear system had occurred; there was adequate fluid in the hydraulic reservoir; and the electrical circuit breaker for the hydraulic pump was in the 'out' position.

The aircraft underwent extensive repairs before being returned to service. During these repairs a detailed examination of the landing gear system was carried out.

The nose landing gear overcentre downlock was considerably out of adjustment which made the breakout force virtually non-existent. This condition had been present for a period of time. With the aircraft mounted on jacks, and the landing gear and nose leg oleo extended, a number of unsuccessful attempts were made to unlock the nose landing gear.

The downlock latch (part number 2041017-8) pivot pin mounted on the left main landing gear downlock support assembly (2041017-3) was found to have failed due to a double fatigue mechanism which had occurred over a considerable number of cycles. This failure would have disrupted the operation of either or both of the left main landing gear downlock microswitch and its sequence switch. Examination of the right main landing gear downlock mechanism found that its downlock latch pivot pin was at the point of final failure due to an almost identical double fatigue mechanism.

Previous similar failure

Enquires with other Cessna 177RG maintenance organisations found that a similar downlock mechanism failure had occurred to another aircraft in the UK. In 1993 the landing gear on a Cessna 177RG only partially retracted after takeoff. The landing gear selector was recycled but the problem recurred. The landing gear was extended, the down and locked green indication light in the cockpit illuminated and the aircraft returned to its departure airfield where it landed without incident. An engineering examination revealed that one of the main landing gear downlock latch pivot pins had failed in double fatigue.

Manufacturer's landing gear modifications

Over the life of the Cessna 177RG Cardinal aircraft, the manufacturer has upgraded the landing gear extension/retraction system including the downlock mechanisms and has produced three Service Kits, SK177-21A, SK177-22A and SK177-21D which allow owner/operators to modify/upgrade the main landing gear downlock mechanisms on their aircraft. All three of these upgrade options had been carried out on G-TOTO. The latest standard of main landing gear downlock mechanism fitted to all aircraft from serial number 0283 onwards replaces the electrical/mechanical unlock solenoid and sequence switch with a single hydraulic unit and removes the downlock latch pivot pin from the original design. This latest standard of main landing gear downlock mechanism has been shown to be relatively trouble free compared to the original electrical/mechanical system. There is no Service Kit available to modify/upgrade aircraft to this latest standard.

Analysis

It is probable that the initial problem that G-TOTO encountered when the landing gear would only partially retract was the result of the left main landing gear downlock latch pivot pin failure not allowing the unlock solenoid to pivot correctly. This in turn did not allow the sequence switch to close the electrical circuit to the electric hydraulic pump and consequently, it did not allow the hydraulic part of the retraction sequence to function. The main landing gears became mechanically unlocked which allowed them to move partially rearwards towards their retracted positions due to their weight and aerodynamic drag. In the landing gear partially retracted position, the downlock microswitches would have been broken allowing the landing gear extension sequence to function normally. When the landing gear was extended it was possible that the geometry of the main landing gear mechanical downlock mechanism, with the left main landing gear downlock latch pivot pin having failed, allowed the downlock microswitch to close and, providing that the other two downlock microswitches were also closed, would give a landing gear down and locked indication in the cockpit.

The nose landing gear collapse was caused by a number of factors. The landing gear overcentre downlock was out of adjustment and the breakout force almost non-existent. There would have been no residual hydraulic pressure in the down lines and, due to the circuit breaker for the electrical hydraulic pump having been 'pulled' prior to the flight, the hydraulic pump did not switch on to pressurise the down lines as the nose landing gear downlock microswitch broke. If there had been hydraulic pressure in the down lines it would have resisted the landing gear's collapse although a correctly adjusted landing gear in the DOWN AND LOCKED position does not require hydraulic pressure to maintain it in that condition. However, the accident airfield has a grass runway which in some areas is undulating. These undulations may have produced oscillations in the nose landing gear oleo which caused the out of adjustment mechanical overcentre downlock to 'flick' into the unlock position.

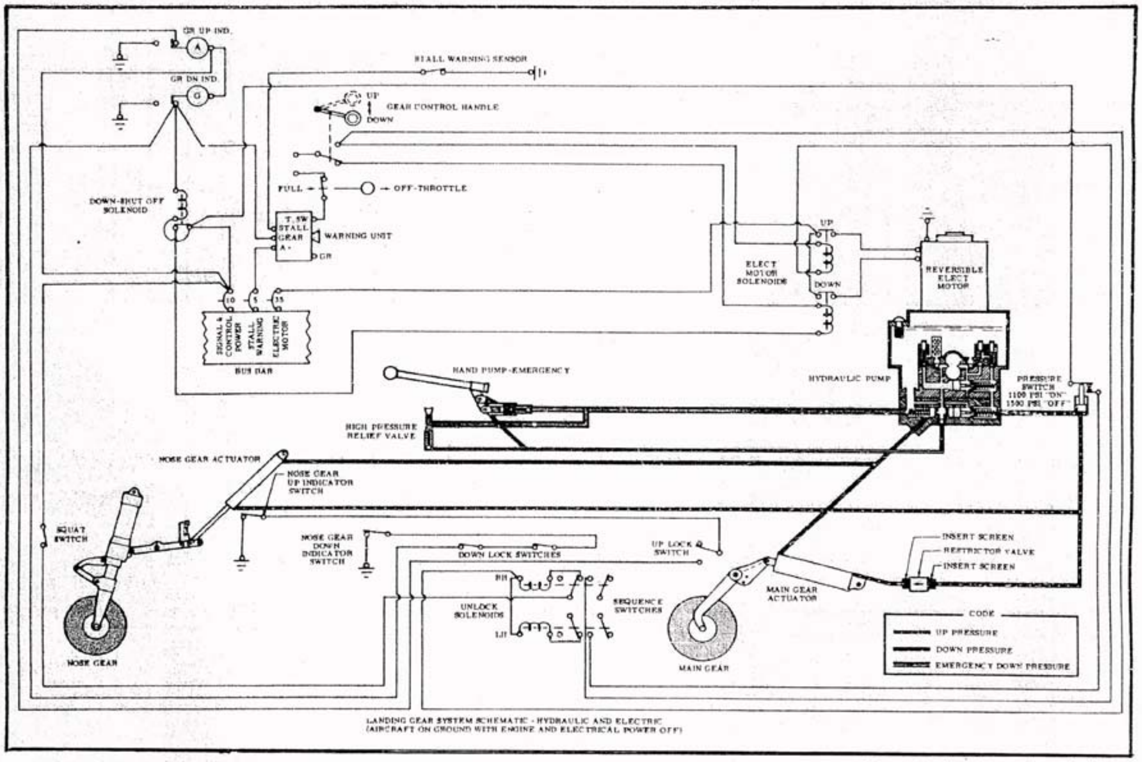
The fatigue of the downlock latch pivot pins had occurred over a period of time. It is likely that this fatigue had been the result of either incorrect rigging of the main landing gears or the rigging having gone out of adjustment in-service, by for example a heavy landing, allowing excessive loads to be placed on the pivot pins.

Safety Recommendation 2005-032

It was recommended to the Cessna Aircraft Company that the Cessna 177RG Maintenance/Service documentation should specify to owners, operators and maintainers that whenever a mechanical failure is found in any part of a main landing gear assembly, the corresponding main landing gear assembly should be examined for a potential similar failure.

Safety Recommendation 2005-056

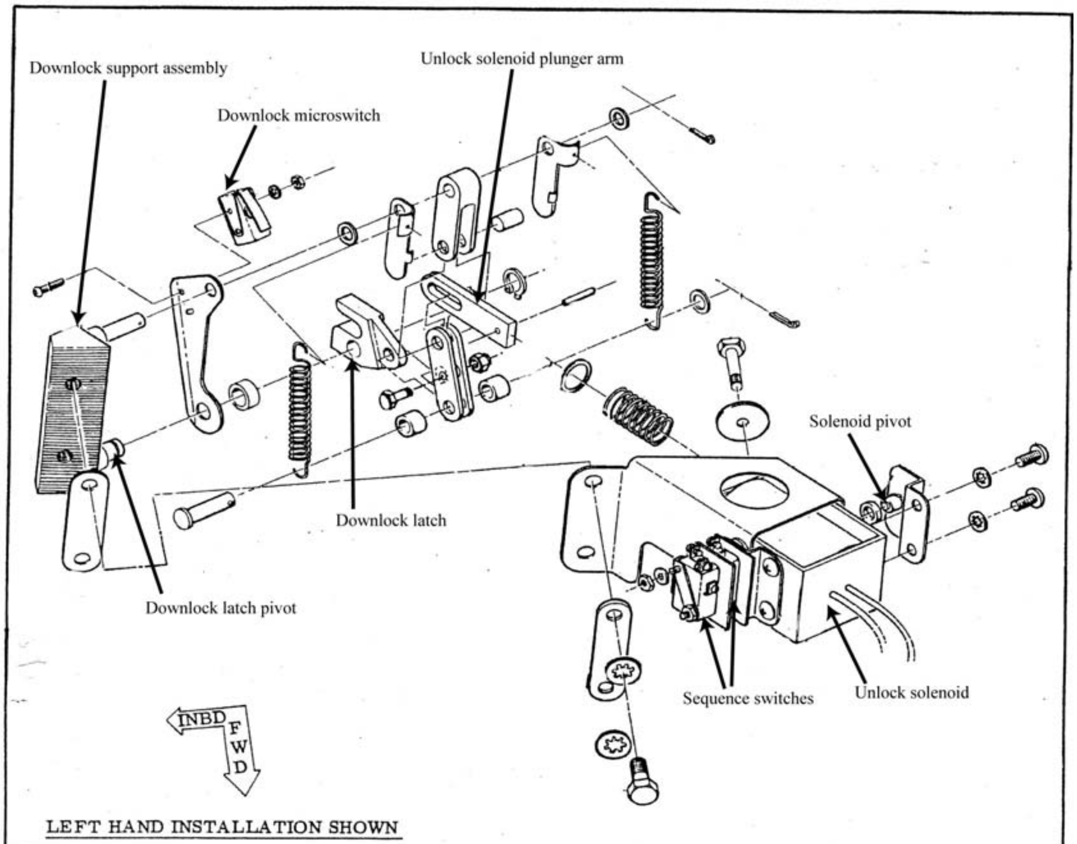
It was recommended to the Cessna Aircraft Company that consideration be given to making available to owners and operators of Cessna 177RG Cardinal aircraft a Service Kit that will enable them to upgrade their aircraft's landing gear extension/retraction system to the standard fitted to aircraft serial number 0283 onwards.



A copy of an aircraft manufacturer's diagram

Figure 1

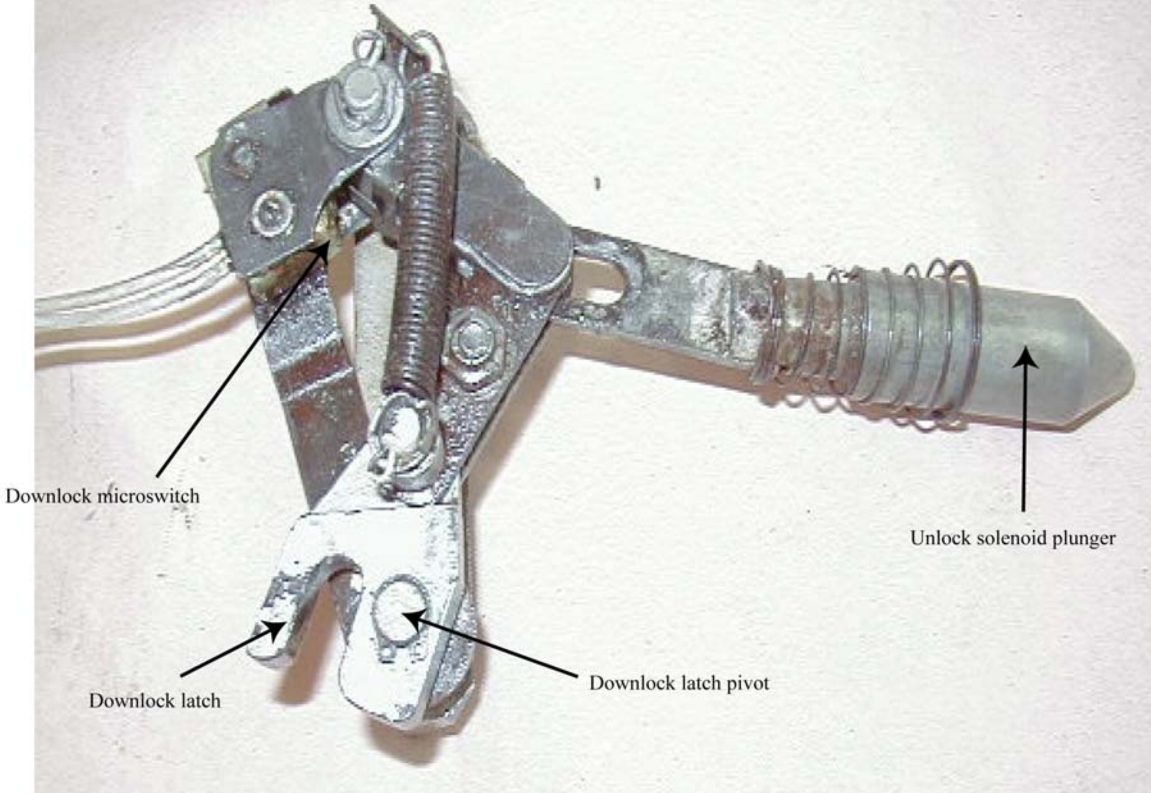
Diagram of the landing gear hydraulic and electrical system



Adapted from an aircraft manufacturer's drawing

Figure 2

Diagram of the left main landing gear downlock mechanism



Courtesy of Brinkley Aircraft Services

Figure 3

Photograph of part of the main landing gear downlock mechanism

Aircraft Type and Registration:	Extra EA 300/L, G-CCPI	
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine	
Year of Manufacture:	2004	
Date & Time (UTC):	21 March 2005 at 1540 hrs	
Location:	Meppershall Airfield, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Extensive damage to the airframe	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	6,500 hours (of which 170 were on type) Last 90 days - 3 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

The pilot was positioning the aircraft from Biggin Hill, Kent to Meppershall, Bedfordshire, for maintenance. The weather conditions were good with a surface wind of 110°/10 kt. Runway 02 was in use and its grass surface was damp.

The approach was flown slightly cross controlled to enable a better view of the strip. The aircraft bounced after touchdown, then the left main landing gear came into contact with soft ground to the left of the mowed strip. The aircraft continued to veer left off the grass strip until both main landing gears sank in the mud at low speed causing the aircraft to nose over and come to rest inverted suffering extensive damage to the propeller, fin, canopy and slight damage to the wings.

Both occupants were uninjured and after an initial difficulty getting out of their harness, due to the fact that they were hanging in them, they vacated the aircraft through the broken canopy. The airfield's local fire tender and first aid qualified personnel were very quickly on the scene and offered assistance.

Aircraft Type and Registration:	Jodel DR1051 (Modified), G-AYGD	
No & Type of Engines:	1 Continental Motors O-200-A piston engine	
Year of Manufacture:	1963	
Date & Time (UTC):	13 March 2005 at 1440 hrs	
Location:	Cardiff International Airport, South Glamorgan, Wales	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Landing gear collapsed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	50 years	
Commander's Flying Experience:	220 hours (of which 14 were on type) Last 90 days - 5 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot had been cleared for an immediate takeoff from Runway 30. The takeoff was initiated from abeam an intersection while a passenger jet was in the process of lining up on the full runway length. The surface wind was from 230º(M) at 10 kt and the runway surface was dry. The pilot was aware of the crosswind and delayed raising the tail wheel during the takeoff. However, as he did so the aircraft yawed to the left and this could not be controlled by the application of full right rudder combined with differential braking. The pilot reduced power to idle and concentrated on controlling the subsequent run off onto the grass. Unbeknown to the pilot, there was a shallow ditch at the runway's edge and on encountering the ditch the aircraft's undercarriage collapsed. The pilot and his two passengers were uninjured and able to vacate the aircraft without assistance before the airport emergency services arrived. The left yaw at the point of raising the tail wheel was caused by a combination of the propeller wash, the reduction in directional stability of the aircraft as the tail-wheel is raised, asymmetric blade effect, torque reaction and the gyroscopic forces acting on the aircraft as it pitched forward. The aircraft was subsequently towed clear of the runway to allow continued operations.

Aircraft Type and Registration:	Piper PA-18-150 Super Cub, G-BGWH
No & Type of Engines:	1 Lycoming O-320-A2B piston engine
Year of Manufacture:	1961
Date & Time (UTC):	14 April 2005 at 1454 hrs
Location:	Nayland Airfield, Essex (takeoff) Clacton Airfield, Essex (landing)
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Severe damage to main landing gear and propeller. Further damage to the engine, wing strut and fuselage
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	8,500 hours (of which 200 were on type) Last 90 days - 22 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries

The instructor was conducting a student's refresher course for farm strip flying from their base at Clacton. As the weather was below minima for solo flying they planned to land away at Nayland, the remaining strip to be used on the course. The weather was good with a surface wind from 230° at 03 kt. Runway 13 was in use at Nayland and its grass surface, which undulates, was damp.

Before departure from Nayland, the instructor and student walked across to Runway 13 to inspect the take-off track. After completing the engine checks and selecting 25° flap the student lined up and confirmed the runway direction.

Just before lift off, as the aircraft came over the brow of the first undulation, the aircraft drifted to the left. The left main landing gear ran diagonally off the runway onto the sloping shoulder of the runway. The instructor took control but was unable to regain the clear area on the runway. The aircraft hit a small earth mound that was covered by a bush on the down slope beside and below the runway shoulder causing damage to the right main landing gear.

Once airborne, the instructor assessed the damage to the aircraft visually from the rear cockpit. The engine and propeller appeared undamaged, as did the tailplane, the supporting struts and the left main landing gear. However, the right main landing gear could not be seen from the rear cockpit. The instructor decided to return to Clacton Airfield for a landing on its grass runway.

On return to Clacton the instructor informed them of the damage and asked for an inspection of his undercarriage as he did a low fly by. From this it appeared that the right main landing gear had been bent underneath the aircraft although the left main landing gear appeared to be undamaged. The crew of an air ambulance that was in the area at the time inspected G-BGWH while formatting on it. They confirmed the damage to the right main landing gear, but were unable to give any firm information on the serviceability of the left main landing gear.

The instructor was then asked by Clacton radio if he would like the local emergency services to be placed on standby at the airfield, which he agreed to; arrangements were made for them to attend. The pilot flew a few circuits to practice the approach to landing while he waited for the emergency services to assemble. When he was ready to land the airfields local fire appliance was positioned at the threshold of Runway 18 in a position to follow him during the landing roll.

The instructor attempted to land on the left main landing gear while trying to keep the right wing up with aileron. On touchdown however, the left main landing gear collapsed as soon as the weight of the aircraft came on to it. The aircraft then slid to a halt on its belly.

As the aircraft came to rest the airfield's fire appliance deployed to the scene and the local emergency services also arrived shortly afterwards. Both occupants exited the aircraft unassisted having sustained no injuries.

The aircraft was secured and moved into the hanger where the damage was assessed by the resident maintenance organisation. Subsequently damage was found to the main landing gear, engine, propeller, one wing strut and distortion to parts of the fuselage.

Aircraft Type and Registration:	Piper PA-30 Twin Comanche, G-AVPS
No & Type of Engines:	2 Lycoming IO-320-B1A piston engines
Year of Manufacture:	1967
Date & Time (UTC):	30 November 2004 at 1345 hrs
Location:	Farley Farm Airstrip, Romsey, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Both propellers bent, both engines shock loaded, lower fuselage skin and landing gear mechanism damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	76 years
Commander's Flying Experience:	3,000 hours (of which 1,300 were on type) Last 90 days - 20 hours Last 28 days - 15 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries

Synopsis

Shortly after the aircraft touched down on a grass runway, its landing gear collapsed. Although the green landing gear 'down locked' light was illuminated prior to landing, it is likely that the nose gear leg was not in fact down and locked. The investigation found that misalignment of landing gear components on Piper Comanche aircraft can cause the landing gear to remain unsafe, despite cockpit indications to the contrary, and that failure of the nose gear to lock down prior to touch down will result in failure of the transmission system and collapse of the main gear on landing.

History of the flight

The aircraft was being flown by its owner from Gloucester Airport to Farley Farm Airstrip for its annual inspection. The farm strip (Runway 04/26) is a well maintained grass runway approximately 750 metres long with a slight upslope to the northeast. On calm days it is normal practice to approach over a line of trees and land upslope on Runway 04. On the day of the accident the wind was approximately north-westerly at 5 to 7 kt resulting in a very light tailwind on Runway 04.

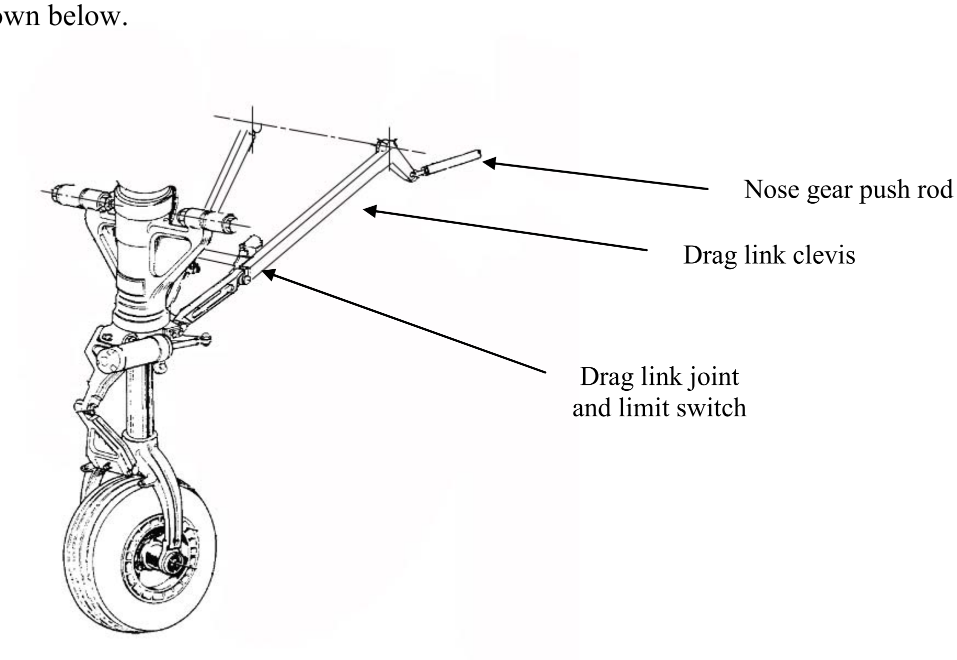
After flying over the airfield to assess surface conditions, the pilot lowered the landing gear and made an approach to land. He considered that he was too high on this occasion, and executed a go-around, without raising the landing gear. He was able to land from the second approach and estimates that he touched down, on the wet grass, approximately 250 metres from the Runway 04 threshold. The touch down appeared normal and the aircraft rolled along the grass runway on all three wheels. As the brakes were applied the landing gear collapsed and the aircraft came to rest in a level attitude. The pilot was uninjured and was able to vacate the aircraft unaided.

After the accident, the aircraft was removed from the runway and raised on jacks. Inspection revealed substantial damage to the landing gear actuating mechanism, which had probably occurred when the undercarriage collapsed after touchdown. The electric landing gear motor had been torn from the main spar, both propellers were bent and both engines were shock loaded. The pilot stated that the green landing gear 'down locked' light was illuminated before touchdown.

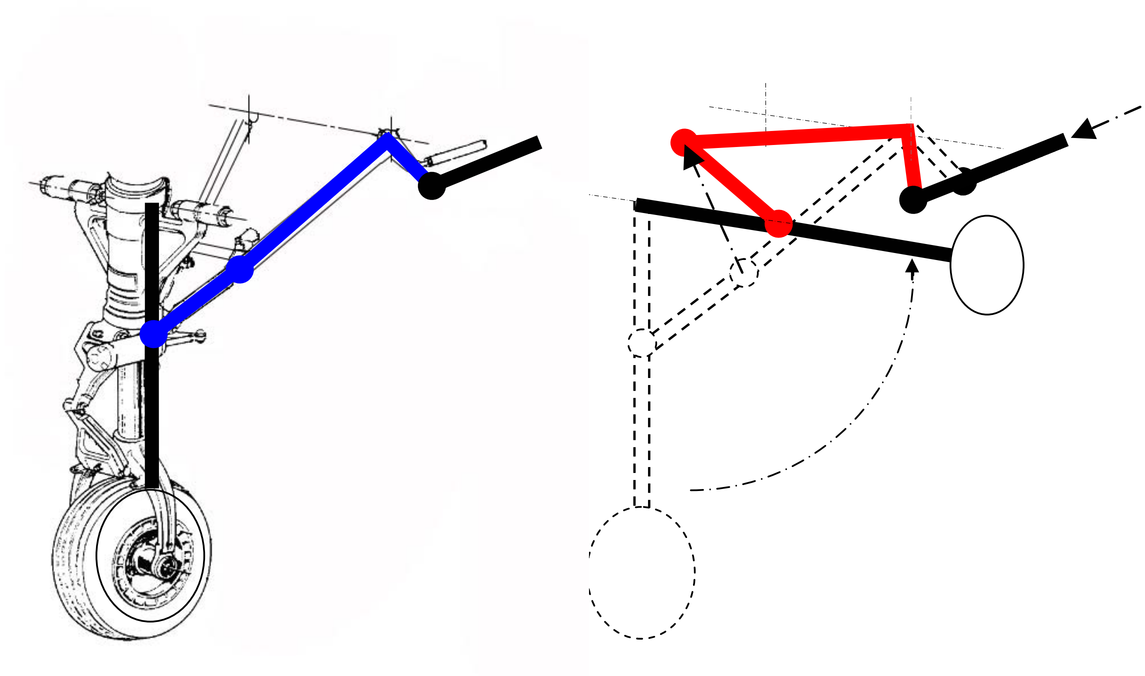
Landing gear description

The Twin Comanche landing gear is operated by a single electric motor driving a screw jack. The screw jack operates two 'Bowden' type cables to raise and lower the main gear and a push rod to actuate the nose gear. Limit switches are installed in the system to shut off the motor when the gear is fully extended or retracted. These switches also operate the green gear 'down locked' indicator light on the main instrument panel.

When the landing gear selector is placed in the down position, the screw jack pushes the main gear cables and pulls back the nose gear push rod. The push rod is connected to a drag link clevis, which forms the upper half of the two-piece nose gear drag link. As the push rod retracts, the drag link unfolds as shown below.



In normal operation, the drag link joint is driven slightly over centre (shown below in blue), and rearward forces on the nose gear leg are resisted by a mechanical stop in the drag link structure. If the drag link does not travel over centre, any rearward force will cause it to fold upwards (shown in red), resulting in a pull force on the screw jack. Because the screw jack is rigid when the electric motor is not running, the pull force will be transmitted directly to the motor itself, which is attached to the front of the wing spar where it passes beneath the cabin floor. The motor attachments, however, are not designed to resist landing forces directly.



If all of the limit switches close before all of the gear legs are fully down and locked, the motor will stop prematurely, even though the green "down locked" light is illuminated. Dirt collects readily on the nose gear drag link, and rigging tolerances are such that a small accumulation is sufficient to cause the nose gear limit switch to close before the nose gear drag link has locked over centre.

The nose gear limit switch is mounted above the drag link joint and is designed to close when the drag link locks over centre. If the rearward force on the nose gear leg was sufficient to force the drag link further over centre, (for example during a heavy landing), the limit switch components would be bent or broken away from the direction of over travel and the mechanical stop would be damaged. No such damage was present on G-AVPS. Consequently, the possibility that the drag link was forced to fold downwards, through the mechanical over centre stop, can be discounted.

Aircraft history

The pilot of G-AVPS had difficulty lowering the landing gear on flights immediately following the previous annual inspection, almost a year before the accident. On one occasion, the landing gear appeared to operate normally, but the green 'down locked' light did not illuminate. On another occasion, after selecting the landing gear DOWN, the nose gear leg only partially extended. The pilot was able to extend and lock the landing gear manually in each instance and the landing gear operated normally on subsequent flights.

Reports available on the AAIB website (www.aaib.gov.uk) and elsewhere, describe numerous occurrences involving mechanical failure of the landing gear on the Twin Comanche and on the PA-24 single engine Comanche, which has an almost identical system. Most are attributed to excessive friction in the system, misalignment of components due to poor maintenance and heavy landings or the presence of foreign matter. A number of operators worldwide have reported symptoms similar to those described in this report.

Conclusion

Damage to the retraction mechanism was consistent with a rearward force on the nose gear leg that was not resisted by the drag link, indicating that the nose gear leg was not locked down prior to touchdown. During the landing roll, the nose gear leg folded rearwards, imposing loads on the landing gear motor attachments in excess of its design limit. As the motor was pulled from its mounting the main gear actuating cables were pulled forwards, resulting in retraction of the main landing gear legs and the total collapse of the landing gear.

Aircraft Type and Registration:	Piper PA-38-112 Tomahawk, G-LFSM	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1978	
Date & Time (UTC):	23 April 2005 at 1425 hrs	
Location:	Liverpool Airport, Merseyside	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller tip damaged, nose wheel oleo compressed, detached from steering yoke and damaged	
Commander's Licence:	Student pilot	
Commander's Age:	Unknown	
Commander's Flying Experience:	25 hours (all on type) Last 90 days - 25 hours Last 28 days - unknown	
Information Source:	Accident report submitted by the student pilot's instructor and flying school	

History of the flight

The student pilot completed four good landings with her instructor and she had demonstrated all the correct emergency actions. Her instructor considered the student pilot ready for her first solo and the wind conditions were suitable, so he vacated the aircraft and sent the student on her first solo circuit to land. During the landing flare the student reduced engine power to idle but did not apply rearward pressure on the yoke to flare the aircraft. It touched down hard, the nose landing gear oleo was heavily compressed and the propeller tips touched the runway. After the landing rollout, the student had great difficulty in taxiing to the apron.

Engineering investigation

The nose landing gear oleo had lost gas pressure and oil was leaking from the leg; the leg had also separated from the main steering yoke. The engine was removed for a shock load inspection and the airframe was subjected to a full, heavy landing inspection.

Safety action

The student pilot was to be given further training with the Chief Flying Instructor until ready for more solo circuit flying.

Aircraft Type and Registration:	Socata TB9 Tampico, G-BMZE
No & Type of Engines:	1 Lycoming O-320-D2A piston engine
Year of Manufacture:	1986
Date & Time (UTC):	6 March 2005 at 1445 hrs
Location:	Eddsfield Airfield, Yorkshire
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, nose landing gear, right wing and fuselage distortion
Commander's Licence:	Private Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	120 hours (of which 53 were on type) Last 90 days - 15 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The owner/pilot of the aircraft had completed a pre-flight inspection of the aircraft in preparation for his departure from Eddsfield, an 800 metre unlicensed grass airfield. He had performed takeoff calculations which took into account the runway surface conditions and these confirmed that the available field length was sufficient for the aircraft operating weight and local conditions. The local air temperature and dew point meant that the weather conditions were likely to result in the formation of carburettor ice, and this was supported by the indication of the carburettor air temperature indicator in the cockpit. Therefore, after taxiing towards the runway, the pilot completed prolonged engine runs with carburettor air heat selected to ensure that the carburettor was free from ice build up. The aircraft was lined up on Runway 27, and the takeoff commenced normally. However, as the aircraft approached 60 kt, the pilot felt it pull to the right and the indicated speed decreased to 50 kt. Left rudder was applied to correct this, drift but the aircraft failed to accelerate beyond 55 kt. As the aircraft was not accelerating normally the pilot abandoned the takeoff but, due to the runway being wet, he elected not to apply the wheel brakes. In an attempt to avoid passing through a hedge at the end of the runway and onto a road, the pilot applied full left nose wheel steering, which resulted in the collapse of the nose landing gear. The aircraft came to rest aligned approximately south to north, with its right wing through the hedge. The passenger vacated the aircraft via the right door and, although the pilot initially attempted to leave the aircraft through the left door, due to fuselage distortion, this could not be opened and so he also escaped via the right door. Nether the pilot or the passenger sustained any injuries during the incident. The aircraft suffered damage to its right wing tip, propeller, engine cowlings, nose landing gear and distortion of the fuselage

Examination of the aircraft and the runway some days after the event showed that the nose wheel was unable to rotate due to a significant build up of mud and grass in it wheel spat. A smaller quantity of mud and grass was found in the right wheel spat. Examination of the runway surface showed clearly visible tracks made by the aircraft's wheels for the last third of its attempted take-off run. These tracks showed evidence of intermittent skidding of both the right and nose wheels.

In the days immediately before this accident, it had been raining. The condition of the runway surface during the above examination indicated that it was likely, at the time of the accident, that it had been sufficiently soft to allow mud and grass to become embedded up in the wheel spats and restrict wheel rotation. This appeared to have resulted in un-commanded braking and intermittent lock-up of both the nose and right main wheels, and this most likely prevented the aircraft from accelerating normally.

Aircraft Type and Registration:	Socata TB20 Trinidad, G-HGPI	
No & Type of Engines:	1 Lycoming IO-540-C4D5D piston engine	
Year of Manufacture:	1988	
Date & Time (UTC):	1 December 2004 at 1455 hrs	
Location:	Bournemouth International Airport, Dorset	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to aircraft underside, right wing and stabilator	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	77 years	
Commander's Flying Experience:	925 hours (of which 770 were on type) Last 90 days - 8 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

History of the flight

The aircraft was returning to Bournemouth Airport after a cross country flight from Cherbourg, France. When the pilot selected the landing gear down, only the nose gear 'down and locked' green light illuminated. The pilot recycled the landing gear up then down, but again only the nose gear indicated down and locked. The pilot then tried to lock the main gear down by pulling the emergency gear extension knob, but this was unsuccessful. After reporting the problem to the control tower he performed a low fly-by. During the fly-by the tower controller reported that the main landing gear appeared to be extended. The pilot carried out a normal circuit to the right to land on Runway 08. Upon touchdown the right main gear leg collapsed and the right wing tip struck the runway. The aircraft came to rest on the runway and the occupants vacated the aircraft unassisted. The airfield's fire and emergency services arrived on the scene soon afterwards but there was no fire.

Description of the landing gear system

The Socata TB20 Trinidad has a retractable tricycle landing gear that is hydraulically actuated. The landing gear selector sends an electric signal to an electro-hydraulic generator. The generator provides pressurized hydraulic fluid to the landing gear actuators. When the landing gear is fully extended, hinged struts lock the gear in place and microswitches are actuated that illuminate the green 'down and locked' light. In the 'up' position the landing gears are not locked but are held up by hydraulic pressure trapped in the actuators. The emergency landing gear extension system is operated by pulling a knob which opens a valve that releases the trapped hydraulic pressure, permitting the landing gear to free-fall under gravity. A compensating actuator on the nose landing gear and compensating springs on the main gear actuators assist in locking the gear down when the emergency system is operated.

Landing gear examination

An examination of the landing gear system was carried out by a maintenance organisation. The aircraft was raised on jacks and it was discovered that the left and right main gear hinged struts were stiff in operation. The nuts on the hinged struts were loosened and then gear retraction and extension tests were carried out. Even with the loosened hinges the electro-hydraulic generator appeared to be 'weak' and only barely able to extend and retract the gear. The electro-hydraulic generator was stripped and inspected but no obvious fault was found that would have reduced its effectiveness. The generator was cleaned and fitted with new O-ring seals prior to re-assembly. The left and right main gear hinged struts were removed, treated for corrosion, lubricated and then re-fitted. Following this work the gear retracted and extended satisfactorily. The emergency gear extension system was also tested and operated satisfactorily.

Maintenance history

The most recent maintenance carried out on the aircraft was a 50 hour check on 14 September 2004. During this check both the normal and emergency gear extension systems were tested and operated satisfactorily. It was also noted in the worksheets that the landing gear legs were 'lubricated as required'. This work was beyond that required by the manufacturer's maintenance manual which specified landing gear maintenance tasks to be carried out annually or every 100 hours. Following this check the aircraft logged 15 hours during the two and a half month period leading up to the accident. The aircraft's previous annual maintenance check was a star annual, completed on 3 February 2004. The aircraft's total flight time at the time of the accident was 1,783 hours. The pilot reported that the aircraft was not kept in a hangar but parked outside with a cover.

Discussion and conclusions

The maintenance engineer who examined the aircraft believed that the stiffness in the hinged struts was the primary reason why the landing gear did not lock down. Once the hinges were lubricated and the corrosion treated, the landing gear could be extended and retracted normally. According to maintenance records the hinges had been lubricated during the 50 hour check less than three months before the accident, but the aircraft was parked outside during this period so rain and lack of frequent use could have contributed to a deterioration of the state of the hinges.

INCIDENT

Aircraft Type and Registration:	Aerospatiale AS332L Super Puma, G-TIGF
No & Type of Engines:	2 Makila 1A turboshaft engines
Year of Manufacture:	1982
Date & Time (UTC):	21 January 2005 at 1540 hrs
Location:	Dutch Sector, North Sea
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to main and tail rotor blades
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	17,300 hours (of which 9,000 were on type) Last 90 days - 90 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot. Further information provided by the operator's maintenance organisation

History of the flight

The aircraft was operating a passenger service from Den Helder, Holland, to an offshore platform located approximately 150 km from the Dutch coast. The commander reported that the aircraft was in the cruise at 2,000 feet, approximately 40 nm south of the platform. Whilst avoiding a cumulo-nimbus cloud, which the crew had seen from a distance and which had also been detected on the weather radar, a flash was seen in clear air to the left of the aircraft. There was no accompanying bang, static noise, electrical failure, variation in compass indication or change in vibration level. They concluded that the lightning was clear of the aircraft and therefore continued the flight to the offshore platform in accordance with their standard procedures. The remainder of the flight, including the return leg, was uneventful. The crew subsequently reported that the wind was from 300º at 45 kt with broken cloud at 3,000 feet, the indicated outside air temperature was +2ºC and the visibility was greater than 10 km in light sleet.

On arrival at base the crew briefed the engineering staff on the event. Subsequent examination revealed slight damage to the main and tail-rotor blades.

Background to the incident

The AS332 is equipped with carbon composite rotor blades and has been used extensively in both the UK and Norwegian sectors of the North Sea for many years. In 1995 an AS332, G-TIGK, was lost after a lightning strike damaged the main and tail-rotor blades. The damage to one tail rotor blade was identified as the immediate cause of that aircraft loss and a modified tail rotor blade design was developed to reduce vulnerability to lightning effects. Lightning strikes continued to occur to the type periodically, although those reported to the AAIB were restricted to main rotor blade damage. The aircraft involved completed the sectors in question and the rotor blades, gearboxes and other selected components were thereafter removed for detailed examination. In many cases the main rotor blades were damaged beyond economic repair. Examination of these blades, however, indicated that damage was generally restricted to laminate layers close to the outer skins and the immediate structural strength was estimated as having only been reduced by a small percentage. In all but one case (G-TIGK) the degree of imbalance had not lead to the need for an immediate landing.

Since the accident to G-TIGK, a number of improvements have been made to the lightning forecasting facilities for helicopters operating from Aberdeen into the North Sea. Less comprehensive facilities are available at the Den Helder base.

It was noted during the investigation of a previous lightning event, involving considerable damage on a different type of aircraft, that the pilot observed a nearby discharge during the flight yet believed his aircraft had not been affected until the damage was noted following the landing.

Assessment of damage to G-TIGF

Photographs of the main-rotor blades, together with initial verbal descriptions of the tail rotor blade condition, were supplied to the AAIB. Subsequent examination of the tail rotor blades by company personnel left in doubt the initial view that they had been affected by lightning. The photographs of the main blade damage indicated that it was very much less severe than that resulting from a number of previous strikes to AS332 main blades examined by the AAIB. All main and tail rotor blades and both gearboxes were returned to the manufacturers for examination/repair as appropriate.

Meteorology

A Sferics plot of actual lightning discharge locations for the relevant period shows extensive lightning activity over northern Germany but only a small amount of low intensity activity in the relevant area of the Dutch sector of the North Sea. A weather report from the offshore platform, timed at 1600 hrs, recorded the following conditions: wind from 300º at 46 kt, temperature +5·6ºC, broken cloud at 1,100 feet and visibility greater than 10 km with showers of heavy rain at times. The crew reported that lightning activity was not included in the forecast for the route.

It is known from previous events that the presence of an aircraft can act as a trigger for a lightning discharge when conditions conducive to lightning are present but no discharges have been observed.

Discussion

Compared with the previous lightning incidents investigated by the AAIB, this event appears to be at the lower end of the damage range in terms of airworthiness significance. It is, however, not usual for AS332 blades which suffer lightning damage beyond the capability of local repair and are returned to the manufacturer for examination, to be to be subsequently repaired and returned to service.

Gearboxes normally require strip examination and comprehensive replacement of parts to eliminate any gears or bearings which have suffered arcing damage to their working surfaces as a result of current earthing from the blades to the structure via the rotor mast and hence via the contact faces of these internal components. In addition, any gearbox components which become magnetised are also discarded, since continuing gearbox integrity relies on magnetic chip detection systems within the gearbox lubrication arrangements and their effectiveness would be negated by any other magnetic source introduced in the vicinity of the oil flow.

Although much effort has gone into improving forecasting for lightning risk in the North Sea since the G-TIGK accident, lightning strikes to AS332 aircraft continue to occur. Improvements to the tolerance of the type to such events appear, however, to have considerably reduced the risk of aircraft loss from this source.

Aircraft Type and Registration:	Agusta A109E, G-PWER
No & Type of Engines:	2 PW206C turboshaft engines
Year of Manufacture:	2000
Date & Time (UTC):	3 March 2004 at 1939 hrs
Location:	1 mile east of Bournemouth (Hurn) Airport, Dorset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passenger - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	3,094 hours (of which 78 were on type) Last 90 days - 54 hours Last 28 days - 11 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was flying a visual approach to Bournemouth Airport in poor weather at night; radar data indicated that the aircraft was tracking the extended centreline of Runway 26 at between 800 to 1,000 feet amsl. The pilot declared that he was visual with the airport but, shortly afterwards, the radar data indicated that the aircraft had entered a turn to the left. The aircraft turned through about 540° before striking the ground, fatally injuring both the pilot and the passenger. The pilot had probably become disorientated, and his limited instrument flying background did not equip him to cope with degraded visual environment. There was no evidence from the wreckage recovered of any mechanical failure or unauthorised interference with the aircraft or its systems that may have contributed to the accident.

History of the flight

The pilot had planned to collect the owner of the aircraft from Battersea Heliport and fly him back to Bournemouth Airport. He was familiar with the route to be flown and was notified of the task on the day of the accident. Prior to the flight he was seen accessing meteorological data from a computer terminal at the company premises; this was the normal method used for meteorological briefing but there was no record of the weather information that he obtained. At 1819 hrs the aircraft departed Bournemouth Airport on a Special VFR[1] clearance to transit to Battersea Heliport where it landed at 1856 hrs; the pilot was the sole occupant of the aircraft on this flight. The owner walked to the aircraft accompanied by a member of the ground staff and occupied the rear left seat in the passenger cabin; his three pieces of hand luggage, which he had brought with him, were placed onto the seat opposite him. Having seen the passenger secure his seat belt the ground handler closed the cabin door and indicated to the pilot that the aircraft was secure. No other bags or freight were loaded onto the aircraft.

The aircraft departed from Battersea Heliport at 1859 hrs. The reported meteorological conditions at 1820 hrs had included a visibility of 7 km, broken cloud at 3,800 feet with no significant weather. Recorded radar data indicates that the helicopter followed a direct track towards Bournemouth. The helicopter was initially cleared to an altitude of 1,400 feet and, when clear of the London Control Zone, received further clearance to an altitude of 1,700 feet.

At 1920 hrs the pilot contacted Solent Radar, who provided a Flight Information Service. Because of traffic departing from Southampton, Solent Radar cleared G-PWER to fly not above 1,500 feet on a route via Romsey. Recorded radar data indicates that the aircraft descended to an altitude of 1,400 feet and followed the required routing. A professional pilot at Whitenap, on the south-east outskirts of Romsey, heard a helicopter pass overhead at what he estimated to be approximately 1,500 feet. He stated that the weather was cold and misty and that he could see the cloud reflecting the ground illumination, he estimated the cloud base to be at about 500 to 600 feet. He did not see the helicopter and considered that it was in or above the cloud.

After a hand-over from Solent Radar, Bournemouth Approach control cleared the aircraft "TO ENTER BOURNEMOUTH CONTROLLED AIRSPACE SPECIAL VFR VIA STONEY CROSS NOT ABOVE 2,000 FEET QNH IS ONE ZERO TWO THREE MILLIBARS": (Stoney Cross is a visual reference point (VRP) to the northeast of Bournemouth Airport). After acknowledging this clearance the pilot was instructed to change to the Tower frequency and to "REPORT VISUAL WITH THE FIELD". Having changed to the Tower frequency the pilot requested permission to "POSITION STRAIGHT IN FOR 26": this was approved and he was instructed to report the airfield in sight. The most expeditious route to comply with this clearance, and one with which the pilot was familiar, would have been direct from Stoney Cross to the airfield. This route transits large areas of poor cultural lighting but at Stoney Cross any low cloud should have been visible silhouetted against or obscuring well illuminated areas such as

[1] Special VFR: Clearance for Special Visual Flight Rules is an authorisation by ATC for a pilot to fly within a Control Zone although he is unable to comply with Instrument Flight Rules.

Ringwood. The weather at Bournemouth Airport, recorded at 1920 hrs was: surface wind 180°/10 kt, visibility 2,700 metres in light rain with a few clouds at 1,200 feet, scattered cloud at 1,700 feet and broken cloud at 2,500 feet.

The last recorded radar position was at Stoney Cross VRP, when the aircraft was tracking parallel to the M27/A31 which, with the vehicle lights, would have been a well defined line feature at night. The subsequent track of the aircraft was not recorded on radar due to terrain screening. Progress along the A31 and then down the A338 would have provided a simple routing to follow, with the lights of Ringwood giving good references and an easily identifiable position. If however low cloud and poor visibility prevented that option then using the ILS localiser would have provided an accurate track along the extended runway centre line and the best opportunity to acquire the runway and approach lights.

The Tower Controller and the Radar Controller were both in the visual control room of the ATC tower at Bournemouth Airport but were unable to see the helicopter which was observed on a remote radar monitor to be tracking the extended centreline of Runway 26. The pilot acknowledged his clearance to land and the tower controller asked, "ECHO ROMEO JUST CHECK YOU ARE VISUAL WITH THE FIELD". The pilot stated "ER NEGATIVE NOT THIS TIME ECHO ROMEO". The controller confirmed that they could not see the aircraft either and turned the runway and approach lighting up to the maximum intensity. Shortly afterwards the pilot transmitted, "ER JUST BECOMING VISUAL THIS TIME". The controller recalled that just as that transmission was made the aircraft, which was about 1 to 1·5 nm from the airport, commenced a descending turn to the left. The controller transmitted "GOLF ECHO ROMEO DO YOU REQUIRE RADAR AT ALL" to which the pilot responded "YEAH", eleven times in quick succession. Having acknowledged that response, the controller asked "GOLF ECHO ROMEO EVERYTHING OK"; the pilot responded "NEGATIVE NEGATIVE". The radar returns indicated that the height of the aircraft reduced from about 1,000 feet to 400 feet during the first 180° of the turn and, as the aircraft continued the left turn, it climbed back towards 1,000 feet. Having completed a turn of approximately 360° the left turn continued through a further 180°, continually descending before the height readout was lost on the radar. During these manoeuvres, the pilot twice maintained an 'open mike' with continuous transmissions, initially for 29 seconds followed nine seconds later by a further 18 second transmission. During these transmissions the pilot confirmed that he had a problem but did not describe what it was, but stated "YEAH WE'VE GOT POWER". Shortly before impact he transmitted "OKAY IT'S OKAY I NEED A CLIMB I NEED A CLIMB".

The controller had been unable to locate the aircraft visually but saw the fireball created by the impact with the ground. The aircraft had struck the surface of a grass field at high speed whilst in a nose down attitude banked to the left. Both persons on board were fatally injured.

Pathological information

Post mortem examinations of the occupants revealed that both persons had died from multiple injuries. No evidence was found in the pilot of any disease, alcohol, drugs or any toxic substance which could have caused or contributed to the cause of the accident.

Pilot's background and flying experience

The pilot had recorded his flying hours in three separate log books from which the information set out below was collated.

He commenced flying on 26 July 1993 and then went to the United States where he gained an FAA commercial licence, with an instructor rating, and spent some four years as a flight instructor accumulating flying hours. He was issued a UK Private Pilot's Licence (Helicopters) with an instructor rating on 19 June 1998. Since then he had continued flying as an instructor, mainly on the Robinson R22 helicopter but he also did some instructing on the Robinson R44. Having completed the necessary requirements he was issued with a UK Airline Transport Pilot's Licence (Helicopters), (ATPL/H), on 20 January 2000. A type rating for the Agusta A109C was issued on 21 March 2001 after the pilot had completed a conversion course between 23 May 2000 and 7 March 2001. A differences course for the more complex Agusta A109E was undertaken on 22 and 23 December 2003; since the successful completion of that training he had recorded 78 hours of flying on the type of which 15 hours 27 minutes were at night. He had demonstrated to colleagues a working knowledge of the autopilot, which he had accrued as a result of experience on the aircraft. He had operated the aircraft mainly between Bournemouth, Battersea Heliport and the owner's private residence in Dorset. The pilot did not hold a UK Instrument Rating.

As far as could be established, prior to 6 December 1999 the pilot had recorded a total of 44 hours night flying, of which 33 hours and 20 minutes was as pilot in command and 10 hours and 40 minutes were dual. A total of 30 hours and 40 minutes of instrument flying was also recorded up to that date. From 6 December 1999 until the date of the accident there was no further record of any instrument flying and only 40 minutes of night flying had been recorded until the pilot commenced flying G-PWER on 1 January 2004; since that date he had recorded 15 hrs and 30 mins of night flying in G-PWER.

Brief description of G-PWER

The Agusta 109E helicopter G-PWER had been purchased by the owner in December 2003 and was used for private and business purposes. It was fully equipped for operation under the Instrument Flight Rules (IFR) with an Electronic Flight Information System (EFIS), an autopilot and standby flight instrumentation.

The owner had previously owned a Robinson R44 helicopter which was used for the same purposes but as he intended to carry out more night and overwater flights, he decided to procure a twin engine, IFR capable helicopter. He was satisfied with the service provided by the pilot who flew him on a regular basis in the R44 and when he took delivery of the Agusta 109E he arranged for that pilot to complete the differences course in order to qualify him to fly it.

Meteorological information

An aftercast provided by the Meteorological Office showed a moist south-westerly airflow covering the route from Battersea to Bournemouth. The leading edge of an occluded warm front lying north/south had moved east into the Bournemouth area at the time of the accident. The weather associated with this front was overcast and misty with outbreaks of light rain and drizzle; the surface visibility was generally 5 to 6 km deteriorating to 1,500 to 2,500 metres in any precipitation. There were areas of broken stratus cloud with a base of 600 to 1,000 feet and a further layer of strato-cumulus cloud which was broken to overcast with a base at 1,700 feet. The mean sea level pressure was 1023 hPa.

The latest Bournemouth Airport Terminal Approach Forecast (TAF) was available from 1516 hrs on 3 March and covered the period from 1600 hrs on 3 March to 0100 hrs on 4 March. It forecast a surface wind from 180° at 12 kt with a visibility greater than 10 km and broken cloud at 3,500 feet. Temporarily the visibility was forecast reduce to 7,000 metres in rain with broken cloud at 1,200 feet. There was a 30% probability, between 1700 hrs and 2200 hrs, of a temporary increase in the surface wind from 180° to 15 kt with gusts to 25 kt, together with a reduction in visibility to 3,000 metres in heavy rain with associated broken cloud at 800 feet and broken cumulo-nimbus cloud at 1,800 feet. In the period between 2000 hrs and 2200 hrs the surface wind was forecast to change direction to 240° at 10 kt as the front moved across the area to the east.

Relevant elements of the weather recorded at Bournemouth Airport covering the period after the aircraft's departure for Battersea at 1819 hrs are presented in the table below.

Time of Observation	Surface wind	Visibility (metres)	Weather	Cloud
1820 hrs	190º/ 09 kt	4,000	Light drizzle	Overcast at 2,100 ft
1850 hrs	180º/ 11 kt	2,900	Light rain	Overcast at 1,700 ft
1920 hrs	180º/ 10 kt	2,700	Light rain	Few at 1,200 ft Scattered at 1,700 ft Broken at 2,300 ft
2020 hrs	190º/ 10 kt	3,000	Light rain	Few at 600 ft

Note: No observation was made at 1950 hrs because ATC were dealing with the accident.

The reported meteorological conditions were available on the Automatic Terminal Information Service (ATIS), which the pilot would be expected to use. Other airports nearby, such as Southampton and Boscombe Down, showed a similar rapid deterioration in visibility and cloud base as the occluded front passed over them. A professional pilot, who heard the helicopter pass overhead on its approach to Bournemouth, reported that the weather over the south-east of Romsey at the time was cold and misty and he estimated that the cloud base was about 500 to 600 feet.

Bournemouth Airport

Bournemouth Airport Air Traffic Control Zone (ATCZ) is class D airspace and extends to a radius of 5 nm from the airport reference point, which is the centre of Runway 26, and has a vertical extent from the surface to a height of 2,000 feet.

Runway 26 at Bournemouth is 2,271 metres long, 46 metres wide and has an asphalt surface. The airfield elevation is 38 feet and the threshold elevation for Runway 26 is 30 feet. Runway and approach lighting consists of white High Intensity Runway Edge Lighting, Precision Approach Path Indicators located to the left of the touch down zone and set to 3°, and a Calvert, five bar, High Intensity Approach Lighting System. Prior to the accident the runway and approach lighting were set to the maximum intensity. In addition there was concentrated and scattered lighting within the airfield boundary, both from the internal lights of buildings and external lighting gantries, which lighting illuminated parking and maintenance areas.

The aircraft's track from Stoney Cross took it over the area to the north-east and east of the airfield. This area is sparsely populated with only one major road near the airport, the A338, running north/south 1 km east of the runway threshold: a wood containing tall, mature trees bordered the eastern edge of this road. The small, dispersed village of Avon is located on the extended runway centreline at a distance of 2 km from the runway threshold. The area surrounding Avon for a radius of approximately 2 km has only isolated properties and minor roads. The lights from these isolated buildings and the headlights of passing vehicles would have provided only very limited sources for external visual reference.

Whilst the approach lights and airfield lighting would have provided good visual references the area to the east and northeast of the airfield was dark and featureless with virtually no external visual references discernible in the prevailing visibility. In addition, the reported surface visibility of 2,700 metres was probably further reduced by rain on the cockpit windows. There would also have been no discernable horizon and the only lights visible would have appeared well below the true horizon giving false visual cues to the pilot. The pilot would thus have been operating in a seriously degraded visual environment during the later stages of his approach to Runway 26.

Spatial disorientation

Three senses interact to orientate ourselves in our daily lives: vision, proprioception (pressure sensing organs in the skin and joints) and vestibular (balance apparatus in the inner ear). In the airborne environment the proprioception and vestibular senses are fallible and may even generate false cues; the pilot must now rely on vision alone. This is not a problem for the pilot if he is flying in daylight and clear of cloud; however, when flying at night or in cloud the external visual references are either degraded or non-existent. In order to achieve the desired flight path the pilot must now monitor closely his attitude and performance instruments and interpret them correctly. Such flying requires specific training and constant practice to remain proficient and safe. Procedural instrument flying, which enables a pilot to carry out an instrument approach, is a particularly demanding skill. Furthermore, the transition from instrument to visual flight, or from visual to instrument conditions, produces its own problems, and unusual attitudes or rapid changes in flight path can be especially difficult to resolve. Any inability to correctly apply the skills specific to instrument flying can lead to spatial disorientation and potential loss of control of the aircraft when flying in an environment where the external visual cues are degraded.

Flying regulations

The regulations which relate to the circumstances of the accident are contained within Civil Aviation Publication (CAP) 393, Section 2: these are based on *The Rules of the Air Regulations 1996*. The definition of 'Special VFR flight' is in Rule 1 and further information can be found in the UK Aeronautical Information Package (AIP) at ENR 1.2. The practical application of these rules, which cover the Special VFR flight being undertaken by the pilot of G-PWER, are contained in Rule 25 *Flight within controlled airspace* and Rule 26 *Flight outside controlled airspace.* The relevant text within the rules states:

> *Rule 25 (2):*
>
> *"…an aircraft flying within Class D airspace below flight level 100 shall remain at least 1500 metres horizontally and 1000 feet vertically away from cloud and in a flight visibility of at least 5 km;"*

This requirement is deemed to be complied with if:

> *"the aircraft is a helicopter flying below 3000 feet above mean sea level and remains clear of cloud and in sight of the surface."*

Rule 26 (2:)

"…an aircraft flying outside controlled airspace below flight level 100 shall remain at least 1500 metres horizontally and 1000 feet vertically away from cloud and in a flight visibility of at least 5 km."

This requirement is deemed to be complied with if:

"in the case of a helicopter the helicopter is flying at or below 3000 feet above mean sea level flying at a speed which having regard for visibility is reasonable, and remains clear of cloud and in sight of the surface."

The alleviation to remain 'clear of cloud and in site of the surface' does not differentiate between flight at night and by day.

Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder as neither was required by regulation.

Global positioning system

A GARMIN Global Positioning System (GPS) model 295, was recovered from the crash site. This model stores GPS track in a non-volatile memory (NVM) which is attached to the main circuit board within the unit. Both the front and rear of the unit had sustained impact damage and the front panel display was cracked. The unit was taken to GARMIN's UK site where the unit was examined, under the supervision of an AAIB inspector. A number of electronic components were found to have sustained damage and the unit could not be powered. The unit was then taken to the GARMIN facility in the United States where they had the capability to recover data from a damaged unit. The NVM was removed from the damaged circuit board, installed into a new unit and the NVM was successfully downloaded. GARMIN were able to confirm that the unit had not been in operation at the time of the accident.

Maintenance history of the aircraft

The aircraft, Serial No 11092, was manufactured by Agusta SPA in October 2000. At the time of the accident it was in possession of a Certificate of Airworthiness in the Transport Category (Passenger) which was current until 16 January 2005. The 'Maintenance Statement And Scheduled Maintenance Inspection Certificate Of Release For Service' was current until 4 December 2004, or until completion of 664.5 airframe hours, whichever occurred first. At the time of the accident the aircraft had completed 654 hours and all relevant Out of Phase Inspections/Component Changes listed in the above document were annotated as having been completed at the correct times. The Certificate of Maintenance Review was current until 8 April 2004 and was thus in force at the time of the accident.

Certain maintenance actions carried out shortly before the accident having potential relevance to the condition of the aircraft during flight are detailed under Manufacturer's Modification Actions (see below).

Significant features of the aircraft

This aircraft type is equipped with an Electronic Flight Information System (EFIS) consisting of two Electronic Attitude Director Indicators (EADIs) and two Electronic Horizontal Situation Indicators (EHSIs). An EADI is positioned above an EHSI on each pilot's instrument panel. The EADI and the EHSI are the primary flight displays used by the pilot to achieve the desired flight path. In certain failure modes loss of the pilot's EADI results in automatic transfer of the main display function to the EHSI below it, with the 'compass' display displaced to the bottom of the screen and reduced to the upper sector of the relevant arc (ie a presentation of the forward 180° of heading).

Engine, aircraft and systems parameters are displayed by means of two Electronic Display Units (EDUs) positioned side by side to the left of the commander's EADI. During normal operation parameter displays are distributed between the two EDU screens. Information from the EDUs is not necessary to achieve the desired flight path. In certain failure modes a screen may become blank; in that event pre-determined parameters normally visible on that screen will automatically be transferred and concentrated on the remaining screen thus ensuring that sufficient data for aircraft operation remains available to the pilot. Data on less critical parameters then cease to be displayed.

The electrical system incorporates two generators, one driven by each engine. During normal operation, the two generators charge the battery and supply two DC bus bars which in turn directly power a variety of services. The battery bus bar supplies a number of services directly. At the time of the accident a 35A circuit breaker, positioned behind a panel above the pilot's foot-well, protected the battery bus bar on G-PWER.

Aircraft configured in the same manner as G-PWER incorporate an emergency relay designed to reduce pilot workload in a generator bus failed condition by automatically transferring flight critical services to a direct supply from the battery bus bar. In such a generator bus failed condition the emergency relay is energised automatically, causing its contacts to be switched such that the battery bus bar now supplies both emergency and both essential bus bars, whilst continuing to supply those services permanently connected to it. In this failure condition the generators are thus isolated from direct connection to the emergency and essential bus bars, which nonetheless remain powered. No cockpit indication of the position of the emergency relay is provided.

An inverter for the 26V and 115V AC bus bars is supplied via the emergency relay from the generators in the normal condition and via the battery bus should a generator bus have a fault. A further inverter feeds these services and is directly powered from the generator supplies so is not affected by the relay but becomes inoperative in a No 2 generator bus failed condition.

The engines on this type are each controlled via a fuel management module (FMM) which, in the automatic mode, receives signals from the Electronic Engine Control units (EEC), but may be controlled manually via switches on the collective control lever in certain failure modes.

The flight controls on this type are powered via hydraulic servos. Two hydraulic pumps are each driven from the main rotor gearbox; each pump supplies a self-contained hydraulic system. Each of the three servos controlling the main rotor is a tandem unit, each section of which is powered from a different hydraulic system; redundancy is thus provided to enable pitch and roll control to be retained in the event of a single hydraulic system failure.

The automatic flight control system (AFCS) imparts movement to the mechanical pitch and roll inputs of the main rotor servos via linear electrical actuators. Two of these actuators are joined in series and formed a part of each roll input rod, whilst two further units perform a corresponding function on the pitch control inputs. Each of the AFCS computers operate one of the two roll and one of the two pitch linear actuators respectively; each computer is independently powered and each received signals from one of a pair of gyros, each in turn powered from separate inverters.

Accident site

The accident site was an area of flat pasture with a slight downward slope towards a water course. The wreckage was spread over a trail having a length of approximately 100 metres, terminating at the watercourse. The direction of the wreckage trail was approximately 120° magnetic. The structure of the aircraft was largely destroyed by fire.

The initial impact crater was approximately ½ metre deep, in firm ground, becoming shallower and then deepening once more. The first section contained the nose-wheel, various fragmented flying control tubes, wiring and numerous general fragments, all of which were totally burnt. The second deeply indented section, offset to the left of the trail axis, contained very little but was clearly made by the impact of the main rotor gearbox which was the next major item in the wreckage trail and was complete with some blade sections. This was followed by the equipment bay with the main landing gear, luggage bay, the No 2 engine and the tail-boom; all of which appeared to have initially come to rest as a unit with its axis near the vertical. The aft section of this unit had subsided onto the ground as a result of fire damage in the area of the rear cabin bulkhead and equipment bay. Numerous printed circuit boards from items of electronic equipment were spread over the accident site and a GPS unit, which was not part of the basic aircraft equipment, had been thrown the full length of the trail, coming to rest beyond the water course. To the left of the initial impact crater were ground penetration markings consistent with rotating contact of the main rotor blades in the field surface occurring at a steep angle of inclination.

The overall evidence indicated that the aircraft had struck the ground with a steep nose-down attitude and flight path, banked to the left at an angle in excess of 60° and was complete with all main and tail rotor blades attached. The undercarriage was down and the speed at impact was estimated as being in excess of 130 kt. The impact point was 1.5 km approximately east of the threshold of Runway 26 and 200 metres south of the runway extended centreline.

On-site examination of the wreckage

The full spans of the main load bearing structures of all four main rotor blades were present at the accident site. The blade roots remained attached to the rotor head and the head remained attached to the output shaft from the main rotor gearbox. Sections of trailing edge structure were not individually identified, but as these areas were highly fragmented and much of the wreckage was reduced to ash, there was every reason to believe that all this material was present at impact. Three of the four blade tip fairings were present; most of the material of the fourth tip fairing had been separated by impact forces and was not recovered. In view of the high level of destruction and the intensity of the ground fire this absence was not unexpected. The tip fairing performs its major function at high aircraft speeds and at low speed its loss would not have compromised control of the helicopter; furthermore its low mass would not cause its absence to result in a major imbalance. All pitch change links were in place connecting the pitch change horns to the swash plate and the rotating scissors links were connected and intact. All three hydraulic rams remained attached to the swash plate. The lower ends of the three actuator bodies had all separated from their attachments to the gearbox in a manner consistent with overload occurring in the impact.

Both tail rotor blades were almost undamaged but the drive trunnion was absent from its normal position, although the blades still rotated when the tail rotor drive shaft was turned. Under such movement, rotating motion was transmitted from the output shaft of the tail rotor gearbox to the tail rotor via its undamaged pitch-change mechanism. The two ends of the drive trunnion were subsequently identified in the wreckage and were found to have separated from the mid section as a result of overload.

The hydraulic pumps were both absent from their locations on the main rotor gearbox; they were, however, recovered amongst the items of loose wreckage in the trail. The No 1 engine was lying in two separate sections in the wreckage trail, having separated from the structure. All four cabin doors were also identified in the wreckage trail, together with the outer skin of the baggage door.

Wreckage examination process

The wreckage was transported to the Farnborough facility of the AAIB where detailed examination was carried out. Fractured sections of the transfer gear train of the main rotor gearbox, which had separated from the main casing of the latter, were identified and examined. The main reduction gear casing was initially examined before being transported to the UK facility of the agents for the manufacturer, where it was strip examined under AAIB supervision.

The following items were transported to the respective manufacturers, where they were examined under AAIB supervision and functionally tested where possible: both engines, both hydraulic pumps, the hydraulic power flying control units, the auto-stabilisation linear actuators, the four blade dampers, both fuel management modules and the flow divider units.

Examination of the remainder of the wreckage at the AAIB facility confirmed that no extremities of the aircraft were absent from the accident site. All four groups of bolts and nuts securing the brackets attaching the main rotor gearbox struts to the structure above the cabin were identified, still correctly secured to fragments of the latter. Certain items of the control system linking the cyclic stick and collective lever to the hydraulic actuators were recovered in a burnt, melted and/or fragmented state. Much of the remainder of that mechanical system could not be identified. Little more than fragments of the cockpit instrumentation and the electronic systems were recovered and identified.

Findings of detailed component examination

Examination of the gearing in the main rotor gearbox and in the transfer gear train revealed that all components were free from pre-impact damage. Similarly the surviving length of the tail rotor drive shaft was intact and able to transmit torque.

Strip examination of the engines revealed that the gas generator and power sections of both units were rotating with considerable speed at impact and were free from evidence of pre-impact failure. The output drive coupling of the No 1 engine exhibited torsional failure indicating that considerable power was being transmitted at impact. The gearbox of the No 2 engine showed heat damage to roller bearings consistent with high rotational energy at the time the impact occurred. The degree of impact damage to the FMM of the No 2 engine rendered a comprehensive examination impossible; it was established, however, that the position of internal components in both FMM units was consistent with both engines operating in automatic mode.

All main and tail rotor blades were present, although some sections of the main blades (one tip fairing and areas of composite skin and honeycomb core trailing edge fairing) were either not recovered or the original locations of the recovered portions not identified. The amount of blade material not recovered or fully identified was consistent with the impact features and the extent and location of the fire.

All the upper mechanical elements of the main rotor control system from the hydraulic servos to the blades remained connected confirming that, given correct control response of the actuators, normal blade control would have occurred. The tests carried out on the surviving main rotor blade servos, together with testing of the valve assembly carried out to the one severely damaged unit, in conjunction with examination of its partly destroyed main ram body, indicated that all units would have been capable of correct functioning with either or both hydraulic systems supplying power.

The tail rotor servo, which had been seriously damaged by heat, was tested; major external leakage and absence of function was revealed. Strip examination of all actuators confirmed no evidence of pre impact mechanical defect which could contribute to active or dormant failure and in the case of the tail rotor actuator confirmed that heat deterioration of the rubber seals fully accounted for lack of function and both internal and external leakage. Testing of the main rotor dampers confirmed their correct functioning.

The hydraulic pumps were both found separated from their mountings on the main rotor gearbox in a manner consistent with impact effects. Consequently their input drives were destroyed and functional testing was not possible. Strip examination revealed no evidence of mechanical failure.

The two auto-pilot/auto-stabilisation servos were partly dismantled and examined with a view to establishing whether they were performing a controlling function at the time of the impact. The examination was inconclusive.

Previous incident

Immediately after the accident it was reported that some weeks earlier the aircraft had suffered a double EDU failure during a night landing at the owner's residence. Information was received that the pilot was then not able to shut-down the engines by the normal electrical means after landing. The electrical system design and the aircraft maintenance documentation relating to this failure were reviewed after the accident.

On the 12 February 2004 the pilot made an entry in the Technical Log for 'Double EDU failure'. This followed a flight during which the aircraft had landed at both Battersea Heliport and at the owner's residence. Landings at these locations are recorded as occurring at 1715 hrs and 1840 hrs respectively, which would have been at night time and would probably have required the use of the landing light. Thereafter the aircraft was recorded as flying on 14 February from the owner's residence to Bournemouth Airport landing at1608 hrs, and then on 16 February from Bournemouth Airport to its maintenance facility where it landed at 1200 hrs. The landings on these flights would have been in daylight and would not have required the use of the landing light.

Following rectification the Certificate of Release to Service was issued on 16 February. The 'Action' section relating to the 'Double EDU failure' entered in the Technical Log on 12 February was dated 16 February and states, 'Fault traced to Bat Bus C/B. The corresponding Additional/Defects Sheet contained the comment 'Pilot reports both EDUs failed in flt.' The Rectification section states; 'Fault confirmed as No 1 EDU failure in flt, Loss of P1 I/C Fault traced to No 1 Batt Bus C/B popped. Unable to reproduce fault after C/B Reset'.[1] A further 'A' check was also carried out at the maintenance facility on the same date, together with two items not affecting the electrical system.

Thereafter, no further defects were reported up to the date of the accident; although the aircraft conducted landings at night which would have required the use of the landing lights. The only work carried out in the intervening period was on 23 February at the maintenance facility, when firstly, implementation of a service bulletin on the rotor system and regular programmed lubrication took place and secondly, Bollitino BT 109 EP-39 was implemented, (see below).

Manufacturer's modification actions

Two Bollitinos were issued by Agusta SPA at about the time of the incident on 12 February described above. These were the result of analysis of a single in-service problem on another aircraft which had been notified to the Italian Certification Authority.

Bollitino BT 109 EP-41 required the emergency relay to be tested in-situ to ensure that the generators supplied services directly during normal operation; evidence from operator experience suggested that on occasions the relay was remaining in the 'ground' position despite both generators functioning correctly.

Analysis by the manufacturer had indicated that an incident reported by an operator could be explained if the emergency relay remained incorrectly in the position corresponding with the

[1] The abbreviations used in these technical records are as follows. C/B: circuit breaker. P1: aircraft commander's position. I/C: intercommunication system.

energised condition (ie the position to be expected during flight in a generator bus fault condition) and the landing search light was deployed along with the normal services used in night operation. Under such circumstances the current, calculated by the manufacturer as passing through the battery bus-bar circuit breaker, would exceed the latter's 25A rating. As a consequence, the breaker would be expected to trip and a number of important services, including both EDUs, the commander's EADI display and the electrical signals between the engine control panel and the two Engine Control Units (also known as the Electronic Engine Controls) would be lost. These electrical signals control the engine shut-down function; signals from the fuel control panel would similarly be lost.

Details of the incident of 12 February 2004 and the associated maintenance action carried out immediately afterwards, were supplied to the aircraft manufacturer after the accident involving G-PWER. Their electrical specialists concluded that the improper operation of the emergency relay, allowing it to remain in the 'ground' position, followed by tripping of the 25A battery bus circuit breaker when the load of the landing light came on, explained the incident. It was noted that replacement of the battery bus circuit-breaker by a 35A unit, in compliance with BT 109 EP-39, would have eliminated the possibility of a repeat of the former event.

The aircraft Technical Log and associated documentation indicates that this replacement had been carried out by the maintenance company on 23 February 2004. The removed 25A circuit breaker was recovered from the premises of the operating company after the accident. The documentation also indicates that the other Bollittino, BT 109 EP-41(in situ test), had been implemented before the incident of 12 February and revealed no evidence of a sticking relay at that time.

Possibilities of unauthorised interference

The possibilities of unauthorised interference were considered. An improvised explosive device could have been positioned in the cabin or the baggage hold. All cabin doors and the undamaged skin of the baggage door were, however, recovered from the accident site. No evidence of damage other than that consistent with ground impact was found on any of them. In particular no high velocity particle impacts were noted in any of these door components. The tail-boom area of the aircraft was also free from any damage other than that inflicted by fire. Placing a device in any other location would have required unauthorised opening of cowlings, a time consuming activity likely to have attracted suspicion. In addition, explosions in these areas would result in separation of cowlings and probable incapacitation of the pilot. No evidence of any in-flight separation of any parts was found and the pilot was known to have been conscious immediately prior to the impact.

Tests and Research

Tests on a similar aircraft

Another Agusta 109E aircraft, serial number 11162, having a similar instrument screen layout to G-PWER and incorporating the same wiring configuration, including the automatic generator failure change over via the emergency relay as installed on G-PWER, was utilised for tests. These were carried out in conjunction with AAIB to simulate the effects of the improper operation of the emergency relay.

The emergency relay was replaced by an assembly which bridged the terminals feeding the contacts in such a way that the battery bus supplied both emergency and both essential bus bars. This simulated the failure of a generator in flight. In this configuration, the relay, although not energised was in other respects acting as would an energised relay. External ground power was supplied and the squat switch connection was disabled. The electrical system thus configured to represent a non design flight condition with both generators functioning, but with the emergency relay remaining in the ground position. The 35A battery bus bar circuit breaker was then manually tripped. This produced the following results:

> The EADI and EHSI displays, on the left side of the cockpit, continued to function normally. The Commander's EADI, on the right side of the cockpit, became blank whilst his attitude display appeared on the right EHSI instrument together with the heading display in compressed, partial compass, forward sector mode. Both EDUs were blank and all external communications from the commander's position became inoperative, regardless of the selection on his station box (used to control communications selection). In addition the landing searchlight would not deploy. This is presumed to replicate the conditions encountered on 12 February 2004 and shows that under such circumstances VHF communication cannot be made via the commander's station box. This contrasts with the known situation immediately before impact when VHF transmission from the aircraft was being both received and recorded.

The emergency relay was re-installed, thus simulating its normal operation. Ground power was made available to the generator systems. The battery bus bar circuit breaker remained switched off. This is assumed to be the condition of the aircraft on arrival at the maintenance facility on 16 February 2004. The results were as follows:

> The Commander's EDU display was now blank whilst all other displays were normal. No transmissions could be made from the No 1 VHF, in either the normal or fail mode on the station box. This concurs with the observations noted in the technical log following receipt of the aircraft at the maintenance facility on 16 February 2004.

With no external power supply and the generators not operating, both overhead Gen Bus switches were selected ON, the 35A battery bus circuit breaker remained OFF. This situation was intended to simulate the actions taken and subsequently reported to AAIB following the incident on 12 February 2004. The results were as follows:-

> The right EDU display was now blank whilst all other displays were normal. VHF Communications were available from the captain's position.

AAIB analysis of the electrical supply distribution arrangements for the wiring of G-PWER showed that the electrical control of the EEC (including the engine shut-down function) would not be possible in the defect mode postulated as occurring on 12 February 2004, ie with the emergency relay incorrectly positioned and the battery circuit breaker tripped. Shut-down would, however, be possible by means of the engine mechanical power levers which link directly to the two FMM units. This appears consistent with reports of events immediately following the incident on 12 February 2004.

Flight Assessments

Two flights were conducted in order to understand the problems which appear to have been experienced by the pilot.

The first flight was flown in daylight, in good weather, and in an Agusta A109E with an experienced instructor. The purpose of the flight was to identify the track and vertical profile of the aircraft involved in the accident as described by the witnesses. Manoeuvres were also flown in order to understand the aircraft behaviour, firstly with the stabilisation system engaged and then with it disengaged. In addition, the loss of elements of the electrical system and their effect on the stabilisation, cockpit displays and ability of the pilot to transmit on the aircraft radios were simulated in the air and on the ground.

The second flight was flown at night, in good weather, utilising a Bolkow BK117 helicopter with two experienced night rated pilots, both of whom were also instrument rated. The purpose of the flight was to evaluate the external visual references available at night during the approach to Runway 26 at Bournemouth. This aircraft was fitted with a video and thermal imaging camera in order to record the visual scene.

A summary of the conclusions drawn from the flights is set out below:

First flight

Estimated flight path

Using witness statements together with information from the ATC radio tape and other evidence it was possible to define a likely flight path, both horizontally and vertically, during the final stages of the approach. A flight was conducted to validate this profile.

The Air Traffic Controller recalled that the pilot transmitted "JUST BECOMING VISUAL THIS TIME" when the aircraft was about 1 to 1.5 nm from the airport. At about the same time the aircraft entered a descending turn to the left. It reached a minimum height of 400 feet after the first 180° of the turn and then climbed back towards 1,000 feet as the aircraft continued the left turn. Having completed a turn of approximately 360° the aircraft continued turning left through a further 180°, whilst continually descending until the height readout was lost on the radar. The aircraft then passed over a witness at a height estimated to be about 300 feet whilst descending and in a gentle turn towards the north. During the final moments of the flight the low rotor RPM warning was recorded. The aircraft manufacturer confirmed that this was symptomatic of a sustained, highly banked turn. The ground impact features indicate that the aircraft struck the ground whilst descending in a steeply banked turn to the left.

Effect of rapid lowering of the collective control

From the point at which the aircraft appears to have commenced the left descending turn, an approach angle of 7.5° was required to the runway threshold from a height of 800 feet, this increased to 9° from a height of 1,000 feet: the normal approach angle, as defined by the PAPIs, was 3°. Therefore, when the pilot became visual he would have recognised that he needed to lose height close in to the Runway 26 threshold. To achieve this he would have rapidly lowered the collective control.

In order to simulate this manoeuvre the aircraft was stabilised in level flight at 90 kt with the autopilot engaged; the cyclic trim release was then selected and the collective lever lowered rapidly to approximately 70% of its downward travel. No control inputs were made to counteract the reaction of the helicopter. The helicopter immediately yawed and rolled to the left and the nose dropped; the magnitude of the response directly correlated to the speed with which the collective was lowered. The yaw and roll were easily compensated for with cyclic and tail rotor control inputs given the good external visual references available on the assessment flight.

Loss of aircraft services

The loss of elements of the electrical system and their effect on the stabilisation, cockpit displays and ability of the pilot to transmit on the aircraft radios were simulated. The Agusta 109E is configured with all switches for the invertors, generator bus bars, generators and battery located on the left side of the overhead panel. The initiating speed for the loss of stabilisation was the 90 kt which approximates to the speed estimated by the Air Traffic Controller from the progress observed on the radar monitor screen in the visual control room of the ATC tower.

With both lanes of the autopilot engaged and the relevant modes selected, the aircraft accurately maintained the required flight path including a coupled ILS. Disengaging the autopilot caused the aircraft to turn left and descend but recovery was easily accomplished in visual conditions.

A coupled ILS was stabilised at 90 kt and both inverters were then switched OFF. This caused an instantaneous loss of the autopilot and all EFIS screens. The aircraft entered a descending turn to the left and accelerated but again recovery was easily accomplished in the visual conditions. A loss of both generators was not attempted in flight, nor was the loss of the generator bus bars, but either of these conditions would have resulted in the stability augmentation system remaining engaged. In the event of the loss of both inverters, both generators, or the generator bus bars, radio transmission would still have been possible.

A 'cut off' bar was fitted which, when operated, switched off both generators and the battery. If this were activated in flight all electrical power would be lost and all cockpit EFIS displays, the autopilot and all lighting would become inoperative. No radio transmission would then be possible.

Second flight

The BK 117 helicopter was flown on a clear night with no moon and with the visibility in excess of 10 km. The aircraft was operated out to a distance of four nm to the east of the threshold of Runway 26 and a number of approaches were flown maintaining the selected height until one nm from the threshold. Approaches commenced initially at 1,500 feet above the airfield elevation, later reducing to 800 feet. At a point adjacent to the accident site left orbits were flown, descending to 500 feet before climbing back to the initial height. With the visibility in excess of 10 km, the lights from the various conurbations provided a clearly defined horizon down to 500 feet which allowed the flight crew to maintain a safe visual orientation.

If the same visual scene was considered in a visibility of 2,700 metres very few lights would be available and no clearly defined horizon would have been visible. Car headlights on the A338 were obscured by the high trees on the eastern side of the road. If the aircraft was pitched nose down the available lights would offer no horizon and with the aircraft turning the apparent movement of individual lights would be highly disorientating. No depth perception would be possible to judge height and the aircraft instruments would be the only reliable source of aircraft flight path and attitude information.

Both pilots concluded that maintaining correct orientation in the vicinity of the accident site, at the heights flown, and using the available ground references in the conditions described on the night of the accident, would be extremely difficult and would require a high degree of competence in instrument flying.

Low RPM warning tone

The ATC recording of the Bournemouth Tower frequency contained an open microphone transmission from the pilot of G-PWER received within the final period of the accident flight and this recording was analysed by the AAIB. During the final 4 seconds a barely audible tone, which alternated in amplitude, was recorded. The signal was identified as a frequency of approximately 3,125 hertz with duration of approximately 0.05 to 0.08 seconds and a pulse period of approximately 0.14 to 0.16 seconds. A copy of the recording was then supplied to the aircraft manufacturer for further analyses. The manufacturer concluded that the frequency, sound duration and pulse period of the ATC recording were consistent with a LOW RPM warning horn. The manufacturer advised that the LOW RPM warning horn was activated at 95.5% NR power on or 89.5% NR power off.

Mobile telephones

Three mobile phones were recovered at the accident site. Two had evidence of heat and impact damage but were largely intact and the specific phones could be identified. The remaining phone had sustained significant fire damage and could not be identified.

In order to determine whether any of these phones may have provided a distraction to the pilot during the final moments of the flight they were taken to a computer forensics specialist to recover the data from each main circuit board memory and Subscriber Identity Module (SIM) card. No data could be recovered from the unidentified phone. The remaining two units were disassembled and the main circuit boards and SIM cards removed and downloaded. One SIM card had a Short Message Service (SMS) message stored, dated 8 February 2004. The second SIM card had 15 SMS messages stored, with the last message dated 17 February 2004. The main circuit board from both phones showed evidence of heat distortion and impact damage to electrical components. The circuit boards were installed into working models but neither could be powered and no data could be extracted from them.

The records for five mobile phone numbers relating to the pilot and passenger were requested from the service providers. Two phone calls were confirmed as having been made on the 3 March 2004. One phone number registered to the pilot had a call logged at 1348 hrs and a second number, with no subscriber details but believed to belong to the passenger, had a call logged at 1853 hrs. Of the three remaining numbers, two numbers had no logged calls for the accident date with the third number being disconnected, for which the service provider could not confirm if a call had been made on the date of the accident.

Performance data

The Aircraft Manufacturer was provided with a figure for the approximate radius of the final turn estimated to have been executed by the aircraft. This was derived from ATC observations and the position of the ground impact.

They were asked to compute the power requirement and bank angle to execute a level turn to the left at two steady airspeeds. These were respectively 100 kt and 60 kt, selected to be representative of the probable extremities of the aircraft speed during the approach. The local ambient conditions were specified and sufficient data provided to enable the manufacturer to compute the aircraft mass. The results were as follows:

100 kt sustained turn:
Power required 1,196 Brake Horse Power (BHP), bank angle required 67·4°

60 kt sustained turn;
Power required 462 BHP, bank angle required 36·8°

Note 1: The power, per engine, factored for installation losses is:
Take-off power rating 593 BHP: Maximum continuous power rating 555 BHP

Note 2: The transmission limit is 900 BHP

Analysis

Operational elements

The pilot was qualified to conduct the flight under Special VFR permitted by Rule 25 and 26, and was familiar with the route being flown both by day and night. Although he had only been flying the A109E helicopter for two months he had already achieved 78 hours on the type. He had recent experience of flying at night, having achieved 15.5 hours in the previous two months. However, he did not hold an Instrument Rating, had no record of any instrument flying training and his last recorded instrument flying was in December 1999.

The available radar data indicates that the pilot had flown the transit from Battersea at constant altitudes and headings consistent with the clearances given. The regular nature of the flight path suggests that the altitude and heading hold modes of the autopilot were being used.

The meteorological conditions were generally as forecast with the approach of the occluded warm front affecting the Bournemouth area with associated low cloud and reduced visibility in rain. The weather to the north and east was considerably better with higher cloud base and improved visibility. The pilot did not request any updates of the Bournemouth weather at Battersea or whilst en-route to Bournemouth and his radio transmissions showed no signs of concern for the weather. It is not known if he listened to the Bournemouth ATIS but had he done so, the weather would have been that recorded at 1920 hrs which reported the visibility as 2,700 metres in light rain with the lowest cloud at 1,200 feet.

During the approach to Bournemouth Airport a witness at Whitenap could not see the aircraft as it passed over him and therefore at that point it was either in or above the cloud. Flying above the small amounts of stratus in the better weather to the northeast would have allowed the pilot to maintain reasonable levels of visual reference with the available ground illumination. This would also have met the legal requirement to '*remain clear of cloud and in sight of the surface*'. Had he been IMC it is probable that he would have requested an update for the weather at Bournemouth and therefore he was probably clear of cloud and in sight of the surface during the transit.

The lowering and increasing amounts of cloud accompanied by the light rain moving east led to a rapid deterioration of the weather at Bournemouth which would have seriously affected the ability of the pilot to maintain visual references. He would have been forced to refer to the flight instruments or rely on the autopilot for maintenance of aircraft attitude and flight path.

The heights recalled by the ATC controller of 800 to 1,000 feet at approximately 1 to 2 nm suggests that the pilot was not carrying out a coupled ILS although this possibility could not be excluded as he had previously demonstrated his knowledge and use of that capability. At 800 feet, on the runway extended centreline and at about 1 nm to 1.5 nm the approach lights, which had been turned up to maximum brilliance, would have been the first recognizable airport lights seen by the pilot

In order to continue his approach to the runway the pilot would have had to de-select the height and heading hold modes and initiate a positive descent. Normally he would hold down the force trim release button on the cyclic control to disconnect the autopilot thus allowing the pilot to fly the aircraft manually. As was demonstrated during the assessment flight, when lowering the collective lever rapidly to descend the aircraft yawed and rolled left and pitched nose down. This would normally be countered with a significant application of right tail rotor pedal and right cyclic. If this manoeuvre was not properly coordinated, the aircraft would yaw in an out of balance condition. If visual references were then lost due to an unmonitored turn left away from the approach lights or entry into cloud the pilot would find himself in a descending left turn in an out of balance aircraft. Effectively the pilot would then be in an unusual attitude, accompanied by disorientating sensations. He would then have to fly by sole reference to the flight instruments, or utilise the isolated ground lights which could produce confusing or conflicting visual cues. A deliberate descending turn to the left, in an attempt to avoid low cloud obscuring the approach lights, particularly if this was initiated in an aggressive manner would place the aircraft in a similar situation.

Consideration was given to the pilot having inadvertently switched off elements of the electrical system switches on the overhead panel. The loss of those systems that still allowed radio transmissions should not have caused the pilot to loose control of the aircraft. Moreover, the pilot did not identify any technical emergency affecting the aircraft.

In the first period of 'open mike' transmissions which lasted 29 seconds, the pilot can be heard experiencing considerable difficulties and was unable to communicate the nature of his problem. He stated "WE'VE GOT POWER" but did not say whether it was electrical or engine power. In the second period of 'open mike' transmissions which lasted 18 seconds, he recognised that the aircraft needed to climb. The noise of the main rotor blades can be heard in the background, which indicated that the aircraft was manoeuvring in tight turns or attempting to pull out of a dive. The transmissions ceased as either the aircraft impacted the ground or the pilot released the transmit switch.

From analysis of the transmissions, it is clear that the pilot was working hard to restore the aircraft to a safe flight path but he was overloaded and probably disorientated. Whilst he identified that the aircraft had power and that he needed to climb, insufficient time and height were available for him to translate that recognition into corrective action and prevent the accident.

The mobile phones recovered from the wreckage and the records for mobile phone numbers relating to the pilot and passenger were examined. There was no evidence of any phone calls during the flight and they would therefore not have provided a potential distraction for the pilot.

Engineering elements

The aircraft struck the ground at a relatively high speed, with a high rate of descent and a high bank angle, on a heading which was unexpected, given the proximity of the accident site to the runway threshold.

Although the forward section of the tail rotor drive shaft was destroyed by fire, the condition of the tail rotor trunnion was consistent with significant tail rotor RPM being present at the impact and torque being capable of being applied via a complete and coupled drive shaft. With no blade damage, the only viable explanation for the nature of the failure of the trunnion is that the tail rotor shaft speed was arrested by disruption in the region of the transfer gears at the rear of the main rotor gearbox or the sudden arresting of rotation of the main rotor at impact. The momentum of the tail rotor blades would then produce a high torque reaction in the splines of the trunnion resulting in a bending/bursting stress capable of failing the narrow cross section of the trunnion immediately adjacent to the splined hole in the centre. The presence of both ends of the fractured trunnion at the accident site, and absence of other significant tail rotor damage confirms that the rotation was present and that sudden arrest of that rotation occurred at impact. There was no evidence to suggest that the tail rotor servo had suffered any damage or failure prior to the impact and subsequent fire.

The outputs from the three rams of the main rotor pitch servo units remained connected to the swash plate, all pitch change links remained attached to both their respective blades and the swash plate, the two scissors link assemblies remained connected correctly and all fractures and other damage to the servo bodies and their mounts were consistent with the effects of impact forces. This leaves no doubt that the blade pitch angles would have responded correctly to control inputs to the servos.

Although the hydraulic piping constituting the distribution system of the flying controls was destroyed, the duplicated nature of those supplies and of the double ram actuators ensure that no single failure in the hydraulic piping could lead to loss of effectiveness of the main rotor control; a simultaneous double failure of hydraulic piping is considered a highly remote possibility.

The almost complete destruction of all the mechanical elements of the flying controls system between the cyclic and collective levers and the ram inputs precluded any useful comments on their pre-impact condition.

Both engines revealed evidence of either high output torque or high internal RPM at impact. The No 1 engine FMM was in a sufficiently undamaged condition and free from evidence of internal failure for one to be confident that it had operated correctly up to the impact. Both engine FMM units contained evidence consistent with them being in automatic mode at that time. The total evidence is thus consistent with the fact that both engines were producing power, were in automatic mode and therefore their FMMs were receiving approximately correct signals from the EEC which in turn was receiving correct sensor input signals. This suggests that both engines were responding correctly to EEC inputs and hence to pilot power demands.

The sound audible on the ATC recording of the final phase of the flight was identified as being consistent in frequency and modulation with that of the LOW RPM horn. The accident site examination revealed evidence consistent with the aircraft being banked at an angle in excess of that required to achieve the calculated 100 kt turn and the wreckage trail had the characteristics of a high speed impact. The performance calculations indicate that at an airspeed of 100 kt, a sustained turn having dimensions reasonably consistent with ATC observations together with the location and orientation of the wreckage trail, require an installed power exceeding that available. Under such circumstances, operation of the LOW RPM horn is a reasonable outcome even if both engines continue to function correctly.

No realistic assessment could be made of the pre-impact state of the instruments and avionics given their destruction during the impact and fire.

The reported multiple loss of services on G-PWER during a landing at night some weeks before the accident was studied. The analysis of the electrical design of the aircraft type, carried out by the manufacturer, to diagnose a suspected fault condition reported on another aircraft was described and made available to the AAIB. The results of the analysis were confirmed by tests conducted by the AAIB. The recorded information, entered by the pilot in the Technical Log, is consistent with both the theoretical and demonstrated effect if the aircraft carried out the flight of 12 February with the emergency relay malfunctioning. If the battery bus circuit breaker tripped under the load of the large current draw when the landing light was switched on, with most electrical systems already operating, then the two EDUs would become blank and certain other systems would cease to function normally. In addition, it would not be possible to turn off the engines by normal electrical means as was reported at the time. If, however, the emergency relay functioned correctly during the later flight to the maintenance facility and the battery bus circuit breaker remained in the tripped position, the theory predicts, and the tests demonstrated, that one EDU would function and the other would remain blank. This is consistent with the situation as noted at the maintenance facility in the Rectification section of the Additional/Defects Sheet raised on 16 February. The location of the battery bus circuit-breaker is not readily accessible and therefore it is not easily reset by the pilot. The action section of the Technical Log, detailing the rectification carried out confirms, however, that the circuit breaker was re-set by personnel at the maintenance facility. The analysis reveals that this action would return all services to an operable state and no further related problems appeared in the Technical Log thereafter, indicating that the immediate problems were successfully rectified.

The analysis of the electrical design of the aircraft by the manufacturer and the recorded work carried out by the maintenance company to address the immediate problem and subsequently to embody BT 109 EP-39 indicates that the nature of that problem was rectified by the maintenance company, was identified theoretically by the manufacturer and steps taken by them to prevent a repetition of it throughout the fleet. Those steps had been implemented on G-PWER before the accident. The general consistency of the results of the tests carried out on aircraft Serial Number 11162 with those predicted in the manufacturers' specialists' study, together with the presence of recorded VHF radio communications with the aircraft immediately prior to impact, indicates that the instrument system operating problems experienced some weeks before the accident were not present during the accident sequence.

Conclusions

The aircraft struck the ground with a high forward speed and a high rate of descent whilst banked steeply to the left; the main rotor was turning with considerable energy. The aircraft was judged to have been structurally complete with all major elements of the main rotor system and the tail rotor blades present. The main rotor gearbox and the transfer gearing were all free from pre-impact defects.

The aircraft would have been fully controllable in pitch and roll, given appropriate rotor RPM, provided correct inputs to the three main rotor servos were available and at least one hydraulic system was free from damage to, or failure of, its distribution piping. There was no evidence to indicate that normal yaw control was not available.

Both engines were free from evidence of pre-impact mechanical failure and were turning at high rotational speeds at impact. The evidence was consistent with both engines operating in automatic mode at impact. The above evidence is consistent with both engines producing demanded power or maximum normally available power at impact. There was no evidence of the detonation of an explosive device or of other unauthorised interference with the aircraft or its systems.

An earlier event, involving loss of cockpit displays, was explained by an analysis carried out by the manufacturer. The aircraft maintenance records indicate that the immediate problem was rectified solely by re-setting a circuit breaker; the success of this process was predicted by the manufacturer's analysis. Tests carried out by the AAIB on a similar aircraft produced results which agreed with those of the theoretical analysis carried out by the manufacturer. The test results were consistent with the entries in the aircraft Technical Log made by the pilot following the earlier event and with those made immediately afterwards by the aircraft operators' maintenance company. A subsequent modification carried out by the maintenance company, changing the battery bus circuit breaker to a higher rated 35A component in compliance with a manufacturer's mandatory Bollettino Tecnico and annotated in the aircraft maintenance records, was aimed at breaking the train of occurrences which led to the earlier event.

The AAIB tests confirm the manufacturer's electrical analysis showing that successful VHF transmissions received from the aircraft late in the flight and recorded by equipment at Bournemouth

Airport could not have been made had the previous mechanism of loss of cockpit display been present at the time those transmissions were made.

The frequency, duration and pulse period of the sound on the ATC recording were consistent with a LOW RPM warning horn. An analysis of the engine power requirements to perform certain manoeuvres showed that a flight consistent with observations and deductions of the pre-impact flight path could result in the operation of the LOW RPM warning on the aircraft despite both engines continuing to function normally.

The accident occurred when the pilot encountered a significant deterioration of the weather in the immediate area of Bournemouth Airport whilst operating SVFR on a visual approach to Runway 26. During the final stages of the approach the pilot probably became disorientated due to a loss of visual references when attempting to fly by sole reference to his flight instruments or limited ground lights or a combination of both. The pilot's limited instrument flying background did not equip him to cope with the difficult situation in which he found himself.

Recommendations

Whilst the aircraft was being operated at night, probably in accordance with Rules 25 (C) (ii) and 26 (b) (iii), it either entered an area of limited visual references or inadvertently entered IMC which prevented the pilot from maintaining external visual orientation. The freedom for helicopters to remain clear of cloud and in sight of the surface when operating below 3,000 feet, albeit in Rule 26 (b) (iii) "*at a speed which having regard for visibility is reasonable*", does not provide an adequate margin of safety for preventing inadvertent IMC or spatial disorientation, especially as there is no differentiation between day and night. It is therefore recommended that:

Safety Recommendation 2005-055

The Civil Aviation Authority should review the Rules of the Air and relevant regulations in their applicability to helicopters and should consider imposing minimum in-flight visibility requirements for day and night. These minima should afford an effective safety margin to prevent inadvertent flight in instrument meteorological condition or loss of adequate external visual references. The requirement for a clearly defined horizon, particularly over water or featureless terrain should also be considered.

Aircraft Type and Registration:	Eurocopter EC 120B, EI-IZO
No & Type of Engines:	1 Turbomeca Arrius 2F turboshaft engine
Year of Manufacture:	2001
Date & Time (UTC):	7 November 2003 at 1431 hrs
Location:	Swansea Airport, West Glamorgan, Wales
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	Estimated 350 hours Last 90 days - not supplied Last 28 days - not supplied
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was stationary in the hover over the apron area at Swansea Airport when it unexpectedly yawed left and pitched nose down. The surface wind was a gusting crosswind, varying in direction, from the right and slightly behind the helicopter at 15 to 20 kt. The pilot attempted to recover but the cyclic control reached its aft limit of travel and he was unable prevent the forward fuselage and front of the right skid contacting the paved surface, followed by the main rotor blades. The helicopter rolled over and slid along the ground for some distance before coming to rest against a vehicle. All persons on board escaped uninjured.

History of flight

The helicopter was operating in the local Swansea area in connection with the Wales Rally Great Britain 2003. It departed from Cardiff Heliport at 0735 hours and, during the course of the day, visited a number of the designated landing sites. On board were the pilot, who was also a co-owner of the helicopter, and four passengers.

The pilot was flying from the right seat with a safety pilot seated in the left who was operating the radio and assisting with the navigation. Dual controls were fitted. Early in the afternoon the helicopter was flown to Swansea Airport to refuel and stop for lunch. After approaching from the east the helicopter carried out a descending right turn to a hover into wind on the south side of the airfield. It was then cleared to cross the active Runway 10 to park on the apron area. The pilot hover taxied in a north-easterly direction, with a crosswind of 090º to 120º at 15 to 20 kt, and came to a stationary hover over the apron. The safety pilot contacted the tower and sought clearance to park in their present position. The tower controller agreed and advised them that they could turn into wind if they wished. The safety pilot pointed out to the pilot an area to their right that he thought suitable for parking.

Before the pilot was able to initiate the right turn the helicopter yawed approximately 20º to the left and pitched nose down. It accelerated forwards a short distance and then the nose and right skid contacted the ground. Both pilots in the front seats attempted to recover from the pitch down by applying full aft cyclic control but they were unable to prevent the ground contact. The passenger seated immediately behind the pilot recollected being able to see the ground through the canopy above the pilot's head, indicating that a steep nose down pitch attitude was attained. The main rotor blades struck the ground and the helicopter slewed round and slid along the ground on its right side.

The tower controller had a clear view of the apron area and was watching the helicopter while it was in the hover. He saw what he thought was a turn to the left, a pitch down and a move forward. Initially he thought that the helicopter was transitioning into forward flight but then realised that control had been lost. He saw the helicopter roll over and slide towards the base of the tower, at which point he moved away from the window, activated the crash alarm and took cover.

The helicopter came to rest lying on its right side against a small airport tractor. The fire service arrived at the scene and assisted the pilot and passengers in evacuating from the left rear entry door. There were no injuries.

Meteorological information

The south-western United Kingdom was under the influence of an unstable airmass with an easterly airflow. The Swansea Airport weather observation at 1309 hrs recorded a surface wind of 110º/20 kt, in CAVOK conditions with a temperature of 12ºC and a dewpoint of 6ºC. At 1537 hrs, 66 minutes after the accident, the surface wind was 090º/14 kt.

There were two surface wind reports passed to operating aircraft just before the accident and recorded on the Air Traffic Control (ATC) tape. These gave the surface wind as 100º/20 kt and 120º/15 kt, one minute and 30 seconds respectively, before the accident.

A pilot operating another helicopter on the south side of the airfield at the time of the accident reported that the wind was gusty, varying in direction and strength up to a maximum of 25 kt.

Pilot experience

The pilot bought a half share in the helicopter when it was new, two and a half years earlier, and had flown it approximately twice a week since then. His type conversion course was carried out by a qualified instructor independent of the manufacturer or distributor. The pilot had flown the helicopter in a variety of wind conditions either solo or with up to a total of five persons on board. He also often flew with a safety pilot and on the accident flight the safety pilot held a Commercial Pilot's Licence (Helicopter) and was a qualified instructor on type.

Impact and ground slide

The surface markings indicated that the initial ground contact point of the helicopter was on the paved apron some 60 metres south of the control tower. The final resting point of the helicopter was approximately 15 metres from the tower. Light ground markings suggest that extremities of the helicopter and/or rotor system were in contact with the paved surface for most of the distance between these points.

Examination of the helicopter, the wreckage distribution and the ground markings revealed evidence consistent with the helicopter fuselage having initially contacted the paved surface with light force whilst in a steep nose-down attitude, banked slightly to the right, with a low rate of descent and limited forward speed. Immediately thereafter, the main rotor blades struck the ground. The combination of the inclined main rotor disc and the reaction of the blades striking the surface is assumed to have caused the helicopter to accelerate in an approximately northerly direction, (parallel with the initial longitudinal axis of the fuselage) and for the fuselage initially to rotate about the main rotor axis such that the helicopter motion then became tail-first.

Damage to the tail-boom indicated that at some stage during this process, the tip trajectory of one or more of the damaged main rotor blades passed through that structure, severing the fenestron. The helicopter also began rolling to the right. The backward motion was arrested when the lower rear area of the fuselage collided with the exposed edge of a vertically orientated steel plate forming the ballast weight and radiator grill of a small tractor. Ground evidence showed that this impact displaced the tractor sideways. The impact and cutting action inflicted by the edge of the steel plate severed the aft central attachment of the aircraft skid system, allowing the whole skid assembly to rotate in a forward direction through some 270° about its forward cross member mounting. This permitted the helicopter to slide to a halt lying on the skin of its starboard side.

The main rotor blades, reduced to root sections less than one metre in length, were still attached to the rotor head. Dense items of main rotor blade debris (ie sections of tip weights and fragments of erosion strips) were found to have been projected in a number of directions up to a maximum distance of approximately 150 metres. The bulk of the lengths of each of the main blades, being of GRP composite material, were shredded and spread over a wide area of grass and paved surface. The overall distribution was consistent with these items being shed during the initial impact and continuing rotation of the blades in ground contact.

Slight damage, resulting from dense rotor debris impact, was sustained by two vehicles, three parked aircraft, a fuel installation and a hangar. One of these damaged vehicles was in a car park outside the airport perimeter fence. There was no evidence to indicate that any items separated from the helicopter before the initial ground impact.

A small spillage of hydraulic fluid was noted at the final resting place of the helicopter the day after the accident and a headset cover was found in the tail boom after the accident although it was believed to have become lodged there during the ground slide.

Helicopter examination

Examination of the cabin confirmed that the shell was structurally complete. It had not suffered any permanent distortion or any intrusion and the transparencies were only slightly damaged. There was no damage to the seating or any other items within the occupied volume. The flying control system was examined and no evidence of pre or post impact damage was noted. Functioning of the cyclic and collective controls confirmed that the control systems from the pilot inputs to the hydraulic servos were correctly connected and capable of functioning appropriately

The hydraulic pump/reservoir unit was unbolted from the main rotor gearbox without disconnecting the flexible hoses between the unit and the three main rotor servos. The main rotor head was turned by hand and corresponding rotation of the output drive to the hydraulic unit was noted. Both the drive connection within the gearbox and the corresponding drive connection on the hydraulic unit shaft were examined and found to be undamaged and serviceable.

The aircraft battery was re-installed and an attempt was made to drive the exposed input shaft of the hydraulic unit with an auxiliary power source. With the battery selected 'ON' it was noted that appropriate pitch change movement of the blade roots took place when the cyclic and collective controls were operated. Initially however, the low hydraulic pressure caption on the instrument panel warning system remained illuminated. The reservoir fluid level, being slightly depleted, was replenished and the hydraulic unit operated again. Again the hydraulic low pressure caption remained illuminated and it was not until a more effective drive for the hydraulic unit input shaft was obtained, to rotate the shaft with sufficient speed, that low pressure caption extinguished. At the same time, full and simultaneous movement of cyclic and collective controls could be made and full and appropriate pitch range movement of the main rotor blade roots was noted. No hydraulic leakage was evident.

The helicopter

Certification

The EC 120B is a multipurpose five place helicopter certified in accordance with JAR 27 requirements. The manufacturer supplied the following information regarding certification and the flight test programme:

> *'Personnel weight used during certification testing was 80 kg (JAR minimum requirement 77 kg).*
>
> *At the most critical Centre of Gravity (CG) position the most critical wind condition is considered to be a left tailwind.*
>
> *The maximum demonstrated wind at the most critical CG position was 30 kt (JAR certification requirement 17 kt), this was not considered limiting'.*

The Approved Flight Manual (AFM) does not contain specific information regarding wind limitations and neither is it required to do so. It does include a statement that the helicopter complies with JAR 27 requirements.

Weight and balance

The specific weight and CG limitations for EI-IZO are provided in the AFM. The maximum authorised weight for takeoff and landing is 1,715 kg. The datum for the CG is defined as 4 metres forward of the mast centroid.

The Equipped Empty Weight (EEW) of EI-IZO was 1,058.5 kg, measured on 21 May 2001, with a CG at 4.183 metres aft of the datum. The two front seats are at a station 2.35 metres aft of datum and the rear seat row is 3.25 meters aft. There is a single load space for the baggage or cargo, accessed by a door on the starboard side, within which there is a net fitted to enable items to be easily secured. The centre of this load space is 4.10 metres aft of the datum. Fuel (4.09 metres aft of datum) has a negligible effect on the CG position but the forward limit of the CG envelope changes with a corresponding change in weight. From these figures it can be seen that all persons on board and any cargo loaded forward of the mid position each contribute a forward moment.

There are two methods provided in the AFM for calculation of the CG, either numerical or graphical. The baggage in the hold area was not secured and had moved in the accident so it was not possible to determine its exact position during flight. However, as the baggage was of a fairly light and bulky nature it was assumed that it was evenly distributed within the area. The fuel on board was recovered following the accident and measured at 40 litres (32 kg).

The CG position, utilising the best available data, was calculated as shown in Table 1 below:

	Mass (kg)	**Arm (metres)**	**Moment (mkg)**
EEW	1058.5	4.183	4428
CREW	155	2.35	364
PASSENGERS	240	3.25	780
CARGO/BAGS	10	4.1	41.0
FUEL	32	4.09	131
TOTAL	**1495.5**	**3.84**	**5744**

Calculated Weight and CG for EI-IZO

Table 1

The graphical method provided a result that was similar although less accurate. Both of these methods were found to be time consuming and somewhat difficult to interpret. However, both results when plotted showed that the CG was 5 mm forward of the forward limit of the CG envelope.

The distributor of the EC120B in the United Kingdom provides customer training courses when supplying new helicopters; information regarding the loading limitations is taught on the course. A computerised load calculation spreadsheet programme can be supplied for customers but it is not intended to replace either of the methods from the AFM and is only to assist pilots with loading calculations. The spreadsheet method gave the same result when using the above data. For the accident flight however, the pilot did not complete a specific weight and balance calculation for the load carried.

The following warning is included at the top of the spreadsheet:

> *'It shall be the pilot's responsibility to verify that all cargo is stowed and tied down properly so that in-flight shifting is impossible'*

The AFM similarly requires the pilot to ensure that there are no loose items in the cargo area during the pre-flight inspection.

There have been a number of Service Bulletins issued with reference to weight and balance. Details of these are shown in Table 2 below:

NUMBER DATE AC/STATUS	TITLE	REASON	PRINCIPLE MODIFICATIONS
SB 24-001 Mar 1999 EI-IZO At build	Relocating the battery aft	Improving weight balance by relocating its centre of gravity aft	Relocation of the battery and the addition of weights below the battery shelf
SB53-001 Sept 1999 EI-IZO At build	Provision for installation of ballast in the fenestron	To provide provisions on the helicopter for the installation of ballast aft of the fenestron to improve aircraft balance and increase the payload	Removal of the ballast plates below the battery shelf and the addition of ballast plates (8 kg) secured to the fenestron aft frame
SB53-005 Oct 2000 Optional (EI-IZO not inc)	Increased possibilities for adjusting the CG	To allow the operator to re-adjust the CG when the ballast installed in the fenestron is not sufficient	Installation of one to four ballast plates under the battery tray
SB 53-009 May 2003 (EI-IZO not inc)	Fenestron ballast increased to 19 kg		

History of Service Bulletins

Table 2

Flight controls

After the accident the left crew seat was found to be locked in the fully forward position. With a person seated in the seat, of the same height and weight as the safety pilot, it was found that full aft cyclic pitch control movement could be achieved. It was noted, however, that it was not possible in this seating position to obtain full right cyclic, because the left seat pilot's right knee impinged against the centre instrument pedestal preventing more than approximately half right cyclic stick being achieved.

A check of the 'full and free' movement of the flight controls forms part of the 50 hour or 62 day maintenance inspection but is not performed as part of a pre-flight check. This is because of the possibility of causing damage to the rotor head assembly.

Other incidents

During the investigation it was reported to the AAIB by another pilot of an EC 120 helicopter that he too had experienced a similar uncommanded pitch down in the hover from which he considered himself fortunate to have recovered. He described the wind conditions as gusty at up to 25 kt from behind and as he slowed the helicopter to a hover he found that the cyclic pitch control lever was at the aft limit of its travel. The helicopter pitched down but he was able to recover by using the collective lever to gain height and recovered into a climb. He discovered on subsequent calculation that the helicopter had been loaded outside the forward CG envelope.

Analysis

Impact dynamics and survivability

The light scour markings of the fuselage lower nose indicate that the aircraft initially contacted the ground gently, confirming that it had been at a low height and low, or zero, forward speed when the event began. The low forward speed at first ground contact indicated that the pitch-down must have occurred rapidly.

The geometry of the nose and skids dictates that at the time of initial blade contact, the nose-down angle would have been such as to cause the horizontal component of main rotor force to have been high and therefore to have imparted a rapid acceleration along the fuselage axis, once the full nose-down angle was approached. This would account for the motion of the aircraft in a northerly direction, immediately after first ground contact. The complex motion thereafter appears to be partly as a consequence of the reaction to the blades repeatedly striking the paved surface. Both the degree of destruction of the blades and the distribution of composite debris is consistent with them continuing to rotate under power sustaining many sequential strikes during the period between the first ground contact and the final impact with the tractor. It is thus clear that the engine continued to deliver power during this period.

The separation of the rear of the tail-boom as a result of one or more blade strikes was to be expected given the modified blade path relative to the fuselage as a consequence of ground strikes, physical blade damage and complex motion of the aircraft after the initial ground contact.

The fact that the main rotor blades were under power at a time subsequent to the initial ground contact and the main rotor gearbox drive to the hydraulic unit was found to be intact and to turn in unison with the rotor head, indicates that the hydraulic pump must have been rotating correctly at the time of the initial event. The tests showed that under such circumstances the pump operated correctly and the control system produced the appropriate pitch changes to the main rotor blades. Hence there was no evidence to indicate incorrect rotor system response to pilot inputs.

Although the sequence of post initial impact motion was complex, the considerable distance the aircraft travelled indicates that the occupants were subjected to only relatively low accelerations until the helicopter struck the tractor. The unusual (rearward) direction of that final, more severe impact ensured that full support was provided by the seats and the headrests/restraints minimising the possibility of deceleration injuries. Lack of intrusion into the occupied volume and absence of major damage to transparencies also contributed to lack of occupant injury.

Operational factors

The wind conditions at the time of the accident were moderate to strong with significant gusts, making the task of hovering and manoeuvering the helicopter close to the ground a demanding one. The left yaw observed both by the pilots and ATC prior to the pitch down, and the pitch down itself, was probably the result of the effect of a gust or lull in the wind acting on the helicopter. As it became destabilised in pitch, the pilot then found there was insufficient cyclic control authority to recover.

It was considered whether the safety pilot could have inadvertently interfered with the cyclic control during the hover. He reported however, that after asking ATC where to park he had pointed with his right hand to suggest to the pilot where he thought they should set down. Therefore this hand must have been free of the cyclic control.

The manufacturer initially suggested that the cause of the pitch down could have been due to one or both of the flight crew seats having been at the full forward position together with the position of a crew member causing physical interference and limiting the aft travel of the cyclic stick. The left crew seat was indeed found to have been fully forward, but when tested full aft cyclic authority was available. Whether or not there was inadvertent interference from either pilot however, could not be ascertained.

It was noted during the investigation that, with dual controls fitted and the left seat occupied, only about half right lateral cyclic control movement was possible but in normal operation this may not be apparent to the pilot as he cannot conduct a 'full and free' control check prior to flight. This fact was drawn to the attention of the manufacturer who responded that the whole of the 'stick aft and stick right' area is never used. The manufacturer also provided information issued by their flight test department concerning the areas in which the cyclic stick moves under different flight conditions. This showed that full right cyclic was not required for certification purposes or for any of the various recorded flight test conditions.

The estimated weight of the helicopter at the time of the accident was 1,495.5 kg, some 220 kg less than the 1,715 kg maximum. The two separate approved methods of CG calculation and the computer spreadsheet all showed that the CG was 5 millimetres forward of the CG envelope. The manufacturer advised that there would be a reduction of aft cyclic authority of 1% for a CG position 10 millimetres forward, thus there could have been a reduction of around 0.5% of aft cyclic authority. It was considered therefore that this degree of loading forward of the limit, although undesirable, would have had only a marginal effect upon the control of the helicopter.

There is a series of service bulletins relating to weight and balance for the EC 120. Each modification has effectively increased the aft moment to prevent operators encountering forward CG limits. EI-IZO had been built in accordance with SB24-001 and SB53-001 but not had any subsequent modifications added. While there was no requirement for these to be done they would have improved its capability to carry a full load of passengers.

Both the graphical and calculation methods for determining the CG are time consuming and it is not surprising that they could be overlooked for what was thought to be a routine load. The UK distributor has provided, for its customers, a simpler method of checking CG and, on their own training course, offers advice on avoidance of CG problems. However, this pilot did not have the benefit of this information. His perception was probably that the five occupants were of average weight and may have been unaware of the potential for a CG problem. The fact that he had operated the helicopter on a number of previous occasions in a similar configuration without difficulty would have reinforced this view.

It was considered by the AAIB that the present method for calculating the CG was unduly complicated for routine use and that a simpler method would be desirable. This was proposed to the manufacturer who responded that they did not consider that a simpler method was practicable but that with correct ballasting and use of customer options, as per the various service bulletins, the aircraft could be configured to remain within its CG envelope regardless of the fuel load within the following range:

> *'either with a light-weight pilot of 60 kg or with 5 persons weighing 80 kg.*
> *In this case the pilot would not need to check the center of gravity as long as he is sure that he weighs more than 60 kg or that he and his passengers do not each weigh more than 80 kg.'*

The forward CG and associated reduction of aft cyclic control authority do not seem sufficient explanation alone for the loss of control of the helicopter. The wind conditions were gusting and varying in direction from across to behind. Control authority for wind speeds of up to 30 kt have been demonstrated during flight test, but these would have been in steady wind conditions. Variations in direction and strength of the wind will give rise to longitudinal trim changes, and once a pitch rate has developed there may then not be enough control authority to counter it, especially at heavier weights with a forward CG. The manufacturer's assessment was that the conditions of forward flight at very low speed with a tailwind were the main cause with the heavy aircraft weight and forward CG as aggravating factors. The report of one other apparently similar incident of uncommanded pitch down shows that prevention of this problem may warrant further safety action.

The cargo net was not in use on this occasion and from its condition it appeared that it had not been used regularly. It is interesting to note that the space aft of the cargo area leading into the tail boom is not separated by any partition and it may be possible for loose objects to migrate into the tail boom during flight. Indeed a headset cover was found in the tail boom after the accident although it was believed to have become lodged during the ground slide and did not affect the control of the helicopter.

The following safety recommendations are made:

Safety Recommendation 2005-033

It is recommended that Eurocopter highlight the circumstances of this accident to EC 120 operators, with a view to emphasising the importance of correct loading and the possible adverse effects a gusting tail wind can have on a hovering helicopter with a centre of gravity (CG) close to or on the forward CG limit.

Safety Recommendation 2005-034

It is recommended that Eurocopter include information, in the EC 120 Approved Flight Manual (AFM), concerning the locus of the cyclic control and the possibility that restriction in its movement, brought about by the morphology of either of the front seat occupants, may not be apparent prior to flight, when dual controls are fitted, because a pre-flight 'full and free' control check by the pilot is not routinely performed.

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

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

1/2004	BAe 146, G-JEAK during descent into Birmingham Airport on 5 November 2000	February 2004
2/2004	Sikorsky S-61N, G-BBHM at Poole, Dorset on 15 July 2002	April 2004
3/2004	AS332L Super Puma, G-BKZE on-board the West Navion Drilling Ship 80 nm to the west of the Shetland Islands on 12 November 2001	June 2004
4/2004	Fokker F27 Mk 500 Friendship, G-CEXF at Jersey Airport, Channels Islands on 5 June 2001	July 2004
5/2004	Bombardier CL600-2B16 Series 604, N90AG at Birmingham International Airport on 4 January 2002	August 2004
1/2005	Sikorsky S-76A+, G-BJVX near the Leman 49/26 Foxtrot platform in the North Sea on 16 July 2002	February 2005

ABBREVIATIONS COMMONLY USED IN AAIB BULLETINS

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