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COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

SPORT AVIATION / BALLOONS

ADDENDUMS and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	Bombardier CL600-2B19 CRJ200, D-ACHH
No & Type of Engines:	2 CF-34-3B1 turbofan engines
Category:	1.1
Year of Manufacture:	2000
Date & Time (UTC):	16 March 2005 at 1419 hrs
Location:	En route to London Heathrow Airport from Cologne
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 33
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	3,936 hours (of which 1,812 were on type) Last 90 days - 160 hours Last 28 days - 67 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

During the cruise, the Engine Instrument and Crew Alerting System (EICAS) gave a "SMOKE CARGO" warning. The crew carried out the appropriate emergency procedure and made a priority landing at London Heathrow Airport. A normal but expeditious disembarkation was conducted with the airport fire services in attendance. Fire crew checked the cargo compartment but were unable to find any sign of smoke, fire or heat damage. The investigation concluded that the warning was probably caused by the smoke detector reacting to dust, condensation or electromagnetic interference. This aircraft had been fitted with a revised design of smoke detector, which was intended to reduce its susceptibility to these factors. It appears not to have been effective in this case.

History of the flight

The aircraft was on a scheduled flight from Cologne to London Heathrow Airport. While cruising at an indicated airspeed of 250 kt, the EICAS gave a "SMOKE CARGO" warning. The crew carried out the appropriate emergency procedure using the Quick Reference Handbook and briefed the cabin crew and passengers. ATC were informed of the nature of the emergency and coordinated a priority ILS approach to a landing on Runway 27L at Heathrow. The aircraft stopped immediately after vacating the runway, in order to conduct a normal but expeditious disembarkation, with the airport fire services in attendance. Fire crew checked the cargo compartment but were unable to find any sign of smoke, fire or heat damage.

Previous occurrences

There have been several instances of spurious cargo smoke indications on CRJ200 aircraft. Studies carried out jointly by the aircraft manufacturer and the smoke detector manufacturer identified two likely causes:

1. The smoke detector works by reflecting light off smoke particles entering the detection chamber. Any dust or condensation present within the detection chamber will also reflect this light and activate the detector.
2. There have been instances of electromagnetic interference, such as from hand held walkie-talkies and mobile telephones, causing the detector to produce a warning.

These studies concluded that the first cause could not be prevented completely and that cargo with high moisture content was likely to contribute to false warnings. They found, however, that because dust particles usually form the nuclei of condensation water droplets, condensation was less likely to occur if the detection chamber was clean. Many of the detector units that had produced apparently spurious warnings were found to be contaminated with dirt, and the aircraft manufacturer responded by issuing service letter RJ-SL-26-001, which recommended annual cleaning of the detector.

The smoke detector was also redesigned to incorporating features intended to reduce its susceptibility both to dust ingress and electromagnetic interference. Airworthiness directive TC AD CF-2001-21 was issued in September 2001 (the year after D-ACHH was manufactured), requiring replacement of older smoke detectors with units of the new design within 18 months. Although the operator had complied with this directive on all its CRJ 100/200 aircraft by 31 December 2002, it has since recorded four instances of cargo smoke warnings on D-ACHH, the most recent of which is the subject of this investigation. Two of the other occurrences were attributed to interference from mobile telephones.

The AAIB investigation did not establish whether the new design of smoke detector had reduced the incidence of spurious cargo smoke warnings on the worldwide CRJ fleet. However, these further occurrences suggest that the new design has not been effective on the subject aircraft. The AAIB has written to Transportation Safety Board of Canada, informing them of these findings.

The cargo smoke detector on D-ACHH was replaced again after this latest incident and there have been no further reports of similar occurrences.

Conclusion

The cargo smoke warning was almost certainly spurious and was probably caused by the smoke detector reacting to dust, condensation or electromagnetic interference. The revised design of the smoke detector, which was intended to reduce its susceptibility to these factors, appears not to have been effective on the subject aircraft.

ACCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash Eight, G-JEDP
No & Type of Engines:	2 Pratt & Whitney PW150A turboprop engines
Category:	1.1
Year of Manufacture:	2003
Date & Time (UTC):	10 February 2005 at 1852 hrs
Location:	Glasgow Airport, Scotland
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 74
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	11,273 hours (of which 5,985 were on type) Last 90 days - 149 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

As the aircraft commenced its take-off run, the take-off warning horn sounded. The takeoff was rejected, but while taxiing for another attempt, the pilots noticed a burning smell on the flight deck. When advised by the cabin crew that there was also a smell of burning and some smoke in the cabin, the commander stopped the aircraft on the taxiway and initiated an expeditious disembarkation using the forward passenger door only. An engineering investigation carried out by the operator's maintenance personnel and the engine manufacturer found that a piece of the right hand engine compressor inner support had become detached, causing damage to a compressor oil seal and allowing oil to contaminate the engine bleed air. The engine manufacturer is aware of the issues and is addressing them through component re-design and engine modifications.

History of the flight

The aircraft was operating a scheduled passenger flight from Glasgow to Birmingham. As it commenced its take-off run from Runway 23, the take-off configuration warning horn sounded. The takeoff was rejected at a speed of approximately 10 kt and the aircraft vacated the runway. The pilots checked all settings and selections and found that these were correct for takeoff. The co-pilot then carried out the after landing and taxi checks and the aircraft taxied back towards the holding point for Runway 23. The engine bleeds were selected ON during this procedure and, shortly afterwards, a burning smell was noticed on the flight deck. Both of the cabin attendants reported that they could smell burning and saw grey or charcoal coloured smoke emanating from the left hand cabin air vents. The commander stopped the aircraft on the taxiway and asked the co-pilot to switch off the engine bleeds, to determine if the observed smoke was in fact water vapour. However, because both cabin attendants confirmed the continued presence of smoke and the smell of burning, the commander shut down both engines.

In consultation with the cabin crew, the commander decided not to initiate a full evacuation, but to vacate the aircraft in a normal but expeditious manner. The aircraft was equipped with two doors for normal passenger use, one at the front and one at the rear of the cabin, both on the left hand side of the aircraft. The commander elected not to use the rear door because the stowable air stairs used at this door had been difficult to deploy on previous occasions, and a faulty door seal had rendered the door itself difficult to open. In the event, all of the passengers were able to vacate the aircraft safely using the front passenger door only. However, the left propeller, though feathered, was rotating at high speed in the strong prevailing wind and could not be stopped prior to disembarkation. The co-pilot led the passengers away from the propeller to a grass area clear of the aircraft, and the commander completed a total shut down of the aircraft. The fire crew, one of whom reportedly deployed a fire hose very close to the rotating propeller, entered the aircraft and used thermal imaging equipment to asses the condition of the cabin. They found no evidence of fire but discovered that the left hand lockers were considerably warmer than those on the right hand side. Maintenance personnel were unable to reproduce the condition during ground tests carried out immediately after the event.

Subsequent event

The following day, after landing at Glasgow, cabin crew aboard the same aircraft reported that there had been an unusual smell in the cabin during the descent. All of the cabin crew reported suffering from headaches and one cabin crewmember vomited. Both pilots had been aware of an unusual smell but were not adversely affected by it.

Engineering investigation

Propeller feathering

When the engines are shut down on the ground by placing the condition levers in the FUEL OFF position, the propellers move towards coarse pitch but do not feather fully. The small residual forward pitch may be sufficient to cause fast rotation in strong winds.

Take-off warning

The take-off configuration warning horn will sound during the take-off run if the following conditions are met:

1. Inboard and outboard spoilers extended
2. Elevator trim out of the take-off range
3. Parking brake lever set to PARK
4. One or both condition levers not at MAX/1020
5. Flaps extended more than 20º or less than 3.6º

Smoke and other air conditioning abnormalities have no direct effect on the take-off warning system. Consequently, either the above conditions were not met prior to the attempted takeoff, or there was a coincident fault with the take-off warning system which has not recurred since this incident.

Smoke in the cabin

Having failed to find any fault with the air conditioning system following the first incident, the operator's maintenance personnel inspected the engines after the subsequent event and found cracking of the inter-compressor case struts. The right hand engine was then removed and inspected further with the assistance of Pratt and Whitney Canada (PWC), the engine manufacturer.

The inspection carried out by PWC revealed that a piece of the compressor inner support (CIS), approximately 38 mm long, had become detached. Investigation of this and other similar occurrences on Dash-8-400 aircraft worldwide enabled PWC to identify a probable failure sequence. The fit of the CIS to the low pressure (LP) compressor stator was such that an aerodynamic excitation had been set up, leading to fretting and eventually cracking of the inner support, to the extent that a piece of the CIS broke away. In most cases, it was found that such a piece would follow the normal gas path, exit the compressor and have no further consequences. In this and some other cases, however, the piece had fallen into the LP axial compressor drum. The resulting vibration during engine operation damaged the bearing and air/oil seal, allowing oil to enter the compressor air flow.

Bleed air for cockpit and cabin air conditioning is extracted from the high pressure centrifugal compressor, downstream of the LP compressor. Consequently, oil that has entered the gas path in the area of the LP compressor will contaminate the cockpit and cabin air. Shutting off bleed air from the affected engine should, therefore, be sufficient to prevent more oil from entering the air conditioning system; although it is likely that residual oil within the air conditioning system would continue to produce smoke for some time after this action was taken. It was the operator's normal practice to carry out all takeoffs with engine bleeds selected OFF. When, in this instance, the engine bleeds were selected ON again following the rejected takeoff, oil was able to enter the air conditioning system. Had the aircraft taken off at the first attempt, smoke would have entered the cockpit and cabin in flight.

The engine was replaced and there have been no further reports of smoke in the cabin or cockpit of G-JEDP.

Follow up action

As a result of its investigations into this and other similar occurrences worldwide, PWC issued Service Bulletin (SB) number 35158, effective from 22 July 2005. This SB was revised to number 35158R1 on 29 July 2005. The SB involves borescope inspection of the CIS (termed the Inner Compressor Support (ICS) in the SB). If cracking is found, the engine must be re-inspected within 65 hours. If a piece is missing, the engine must be changed. The operator has stated that it has been carrying out these inspections, even though the procedure is not mandatory.

The CIS itself has been redesigned, using a different material and relocation of the fit between the CIS and the LP compressor stator in an attempt to reduce the fretting and vibration which may have lead to cracking of the original component. All engines that are returned to the PWC service centre, for whatever reason, are being fitted with the new type CIS, regardless of whether or not cracking has been found during previous inspections.

Rear passenger door

The aircraft manufacturer stated that the left hand rear cabin door is primarily an emergency exit. It may also be used as an additional passenger loading door and an optional sliding air stair is installed on all aircraft of this type used by the operator. On previous flights this door had been difficult to open due to a torn seal and an entry to that effect was made in the aircraft technical log, noting that the seal was to be replaced upon the aircraft's next return to its Birmingham base. The steps associated with this door, on the other hand, were not the subject of any proposed remedial action, but were considered by some operating crew to be of poor design and liable to jam in their stowed position on all Dash 8-400 aircraft operated by this company.

The aircraft manufacturer advises that, in the event of an emergency evacuation, the left rear exit may be used but the air stair should not be deployed. This is stated clearly on a placard beside the rear door of all Dash 8-400 aircraft operated by this company.

Conclusion

No cause could be found for activation of the take-off configuration warning.

Smoke in the cockpit and cabin was caused by oil contamination of the air conditioning system. A piece of the right hand engine compressor inner support had become detached, causing damage to a compressor oil seal and allowing oil to contaminate the engine bleed air.

INCIDENT

Aircraft Type and Registration:	Embraer EMB-145EP, G-RJXG
No & Type of Engines:	2 Allison AE3007/A1/1 turbofan engines
Category:	1.1
Year of Manufacture:	2001
Date & Time (UTC):	25 September 2001 at 1411 hrs
Location:	On approach to Manchester International Airport, Manchester
Type of Flight:	Public Transport
Persons on Board:	Crew - 4 Passengers - 17
Injuries:	Crew - None Passengers - None
Nature of Damage:	Light fuselage skin and rivet burns. Heat damage to right wingtip
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	8,919 hours (of which 905 were on type) Last 90 days - 117 hours Last 28 days - 19 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The aircraft was carrying out a scheduled flight from Aberdeen to Manchester. The commander, who was the handling pilot, reported that during the flight the weather radar was displaying weak returns of cumulonimbus cloud activity, but he manoeuvred the aircraft in order to avoid the affected areas, primarily by visual means.

He accepted radar vectors to position the aircraft downwind for the landing runway. Just as the aircraft entered cloud, a lightning strike occurred. The commander subsequently reported that there was neither turbulence nor significant precipitation at that time. Recorded data indicated that the aircraft was close to FL70 at the time with a low thrust setting.

The first officer informed the commander that he had observed a left engine over-temperature indication. Within 5 to 10 seconds of the strike, both crew members noted that the left engine operating parameters were decreasing rapidly. They were not aware of any warning or caution indications at the time.

A distress call was broadcast and checklist procedures for both engine failure and single engined approach were carried out. An uneventful single engined landing then took place at 1415 hrs.

Aircraft damage

Subsequent examination of the aircraft revealed evidence of lightning strike damage on the left side of the fuselage. This extended from just aft of the flight-deck windshields to a point above the junction of the wing trailing edge and the fuselage. The evidence took the form of marks on longitudinal skin joints and a row of rivet burns, initially low down on the fuselage side, then continuing aft at a higher level above the wing. Considerable lightning damage was evident on the composite right wing tip fairing.

The left engine was subjected to a complete borescope examination and the two Full Authority Digital Engine Control (FADEC) units were replaced. Engine ground runs were carried out satisfactorily. The engine then performed normally during subsequent flights. The FADEC units were returned to their manufacturer for examination. They were found to be undamaged and no fault codes were found to have been recorded. When rig tested they operated in accordance with their performance specifications. They were also returned to service with no subsequent abnormalities being noted.

Description of the FADECs

On the EMB-145, each engine is controlled by one of two FADECs, designated 'A' and 'B'. All signals between each FADEC and its respective engine and between the FADECs and the aeroplane are completely duplicated. The FADECs are interconnected by dedicated Cross-Channel Data Links (CCDL) which are used to transmit engine data and FADEC status between the two FADECs on each engine. Each FADEC is also connected to one of the two FADECs on the opposite engine via an inter-nacelle data bus. Through this bus, the FADECs communicate the information necessary to implement thrust reverse interlock and Automatic Take-off Thrust Control System functions.

Each FADEC receives command signals from the Control Pedestal and from the Powerplant Control Panel and sends a command signal to the Fuel Pump and Metering Unit (FPMU) torque motor, which meters the fuel flow to the engine in order to reach the fan spool speed calculated by the FADEC thrust management section (N1 REQUEST). In addition, the FADECs command the Compressor Variable Geometry (CVG) actuators in order to optimise the compressor efficiency and compressor stall margins.

In normal operation, the engine control logic receives a fan speed request (N1 REQUEST) from the thrust management logic and controls the engine fuel flow and CVG to obtain the required engine steady-state and transient response. The FADEC contains a schedule of CVG position versus corrected gas generator speed (N2) that has been selected to provide the optimum compressor efficiency for steady-state conditions and adequate stall margins during transients. The FADEC senses the CVG position and commands the CVG actuator to maintain the CVG position at the desired setting.

The Air Data Computers (ADCs) provide the ambient and airspeed data used by the FADECs to calculate the maximum available thrust (N1 TARGET) for each selected thrust-rating mode. Each thrust lever modulates engine thrust linearly between the IDLE and THRUST SET position.

The two FADECs of each engine alternate in the powerplant control and while one controls the powerplant, the other remains in standby mode. The standby FADEC monitors all inputs, performs all computations, and performs built-in-test and fault detection, but the output drivers (fuel flow and CVG control), which command the engine, are inactive.

Transfer from the active FADEC to the standby FADEC may be accomplished automatically, in response to a detected fault, or manually, through the FADEC Selector Knob, located on the overhead panel.

If N2 reduces to below 53.5%, the active FADEC will initiate a shutdown sequence on the engine to protect it from damage. There is, however, no communication of this condition, via the inter-nacelle data bus, to the FADECs on the opposite engine so, potentially, it is possible that the FADECs controlling both engines could signal shutdowns independently and simultaneously.

The engine control logic incorporates engine protection logic to protect the engine from damage due to exceedences of speed (N1 & N2) and Inter Turbine Temperature (ITT) limits. There is a surge avoidance fuel flow schedule built into the FADEC logic which is intended to avoid rapid transients and assist in the restoration of steady compressor flow conditions and permit the engine to accelerate and return to the desired operating condition following a compressor stall; this schedule is not, however, intended to provide active surge recovery. The FADEC also has an auto re-light function which activates the ignition system whenever a flameout is detected by the FADEC and N2 is higher than 53.5%, provided that the Ignition selector knob is set to 'AUTO'.

Flight Data Recorder (FDR)

Examination of FDR data, supplied via the aircraft manufacturer, showed that the thrust lever angle of the left engine had remained steady for some 9 to 10 seconds with very slightly varying fuel-flow, when a slight drop in both low pressure (N1) and high pressure (N2) spool speeds occurred. At this point there was a sharp, but limited rise in fuel flow and a considerable, rapid, rise of inter-turbine temperature (ITT); the spool speeds, however, continued to decay rapidly.

About two to three seconds later, the fuel flow reduced sharply and the ITT stabilised briefly before rising again, but more slowly than before. About four seconds later, ITT peaked at 965ºC and, as it did so, the fuel flow reduced further. About two seconds later, ITT began to reduce increasingly quickly and the fuel flow rose rapidly but briefly to a high value. There was no recorded rise in ITT in response to this increase in fuel flow, which then reduced rapidly to a very low figure before ceasing completely. Both spool speeds continued to decay at reduced rates throughout this period.

FADEC 1A was recorded as having been in control of the left engine at this time and is presumed to have been so throughout the incident. It detected no internal faults and no master warning was being generated although a brief period of Master Caution was evident immediately after the maximum fuel flow figure was recorded. The CVG vane position was not recorded.

Interpretation of engine related FDR data

It could be seen that, initially, the FADEC units were operating normally, such that the fuel flow was varying in accordance with its normal mode, controlling fan speed (N1) in response to throttle movements. During flight, either in turbulence or with varying airspeed, short period changes in intake conditions cause corresponding changes in fan loading. Varying fuel flow values are commanded to compensate for this effect, preserving a steady N1.

The initial engine behaviour from the point where N1 and N2 reduced, without a throttle command, believed to be immediately after the lightning strike (see 'Recorded lightning strike data'), was consistent with a compressor stall. It is believed that the spool speeds reduced, initially, as a result of the loss of mass flow through the engine brought about by adverse intake conditions caused principally by the aero-thermal effects of the lightning strike and that these conditions initiated a compressor stall.

The recorded limited increase in fuel flow at the point when the spool speeds started to decrease was an expected response to restore the selected speed, consistent with the inbuilt surge avoidance law. The ITT then appears to have increased as a result of this rising fuel flow and the decreasing mass-flow of air resulting from the steadily decreasing spool speeds, evident from the traces. It is also possible that mass flow was further reduced by aero-thermal effects of the lightning on the inlet conditions. The fuel flow then decreased sharply to a lower steady figure for about 3 to 4 seconds, which was consistent with the ITT limiter coming into operation at 948ºC. This steady fuel flow was that normally scheduled to allow the engine to operate well clear of the surge line but under the conditions prevailing did not allow it to stabilise and recover.

However, the ITT continued to rise, indicating a persisting surge condition, to its peak recorded value, at which point the fuel flow was further reduced, as a result of the ITT reaching the maximum permitted figure, to prevent turbine overheat damage.

Following this the ITT fell, briefly permitting the fuel flow to be increased in order to attempt to restore the spool speeds. However, since these speeds continued to decay the automatic shutdown facility intervened when N2 passed below the minimum scheduled figure (53.5%). It has been demonstrated that the engine cannot recover from speeds below 53.5% and the FADEC acts on the assumption that a major mechanical or structural defect may have occurred in the engine and shutdown is commanded to prevent additional engine damage or hazard to the airframe.

Final fuel shut-off was commanded approximately 11 seconds after the onset of the event. The flow rate then took 4 seconds to decrease to a very low value before ceasing totally.

The fact that FADEC 1A was recorded as being in control indicates that it remained so throughout the incident with FADEC 1B in standby mode. This, together with the fact that no fault was detected on FADEC 1A by the recording system, confirmed the subsequent post incident examination and testing of the FADEC units by the manufacturers, which found no faults.

Since post-incident testing and examination of the engine revealed no mechanical damage which was likely to have made it prone to surging, the only reasonable explanation for the initial reduction of N1 coincident with the increase in fuel flow is a disruption of the intake airflow. The subsequent continuing reduction in spool speeds, which was consistent with the fuel flow scheduled by the FADEC logic not being designed to re-establish surge–free operation, led to an automatic engine shut-down.

The automatic shut-down was the logical consequence of the FADEC control laws responding to the variations in engine speeds and temperatures recorded on the FDR. In particular it appears that the reluctance of the ITT to reduce, prevented the FADEC from restoring acceptable running conditions in the engine in the 11 seconds between the first indications of the incident and shut-down. It is probable that the aero-thermal effects of the lightning discharge, alone, were sufficient to initiate this event. It was considered that the continuing inability of the FADEC to be able to restore stable running conditions could be consistent with either, the effect of persisting disrupted intake airflow, the effects of the very hot, low density plasma passing into the engine or the large static charge associated with lightning discharges affecting the inputs to the FADEC, particularly the temperature sensing. Although the presence of a high static charge has been observed to affect temperature sensing in non-aeronautical electronic control systems, the engine manufacturer had conducted tests to validate the temperature sensing capability under such conditions.

The damage evident on the outside of the aircraft suggests a longitudinal distribution of lightning effects. It is thus reasonable to expect that such a longitudinal effect extended well forward of the aircraft, allowing the path of the engine intake to translate within a column of air through which the lightning discharge had also passed. The aero-thermal effect of such a strike, although not fully understood, is known to be potentially detrimental to intake flow conditions.

The engine manufacturer reviewed the recorded data and pointed out that the software in use at the time of the incident did not contain any compressor stall detection and recovery logic and that the engine and control system had responded as expected.

The engine manufacturer has considered developing surge detection logic for the FADEC of the AE3007A engine as it could minimise or eliminate the possibility of the engine suffering adverse reaction during any future lightning strike. However, at the present time it is considered that the technical complexity involved and risk of false surge detection inherent in such logic outweighs the established risk of suffering an in-flight shutdown as the result of a surge.

Recorded lightning strike data

Data was obtained from a lightning location system covering discharges in the general area of the incident, during the time period in question. The detection system that was utilised recorded the signatures of lightning strikes over a wide area and therefore did not guarantee to detect all strikes in any particular defined locality. A second database, listing strikes detected by an instrumentation system operating on a different principal, was also utilised. This system is designed specifically to detect only cloud to ground strikes and is optimised to cover a more limited area centred on the United Kingdom.

One isolated recording of lightning activity was detected by the first system at a time of 1408:16 hrs, at a position approximately 17 km north-northwest of Manchester Airport. Three cloud to ground strikes were recorded by the second system, all at least 23 km from Manchester Airport, during the period between 1400 hrs and 1408 hrs. These were all recorded as being of low power. Neither of the three cloud to ground strikes was detected by the first system and the strike recorded by that system was not recorded by the second (dedicated cloud to ground) system.

From the above data it appears most likely that the aircraft encountered a relatively low power cloud to ground lightning strike at 1400 hrs.

Significance of lightning damage

The physical damage to G-RJXG was limited to the structure. Both metal and composite materials were affected, the latter more dramatically. No ‘secondary’ damage was reported (ie to wiring or avionics). No physical engine damage occurred. The immediate effect on the aircraft was not judged to be hazardous. Loss of thrust from one engine did not result in any significant handling problems, as it was within the normal experience of recurrent crew training for dealing with non-normal procedures.

Other information

Another lightning event had occurred to another EMB-145 in April 2001, which had resulted in a pilot shutting down an engine due to high indicated ITT. This event occurred in France and the engine manufacturer was aware of it. The engine manufacturer's investigation concluded that the lightning strike had induced aero-thermal disturbance to the engine inlet which resulted in an engine stall.

No further similar occurrences on the EMB-145 are recorded on the UK CAA database. With this fleet having operated a total of some 6.2 million engine hours at the time of this incident, (now about 14 million) there is no immediate concern that the lightning strike/engine stall phenomenon is statistically prevalent. However, data supplied via the aircraft manufacturer, obtained during their investigation, revealed that some background data existed on apparently similar events occurring to other types.

A study of twin aft-engined commercial aircraft revealed that fuselage diameters ranged from approximately 5 ft for typical small business jets to nearly 11 ft for aft-engined airliners, such as the DC-9/MD80 series. The EMB-145 fuselage diameter is 7 ft 5 in, thus placing it near the middle of the range considered. Additionally, there are some twin engined combat aircraft types, with forward fuselage side engine intake configurations, which have fuselage widths and lateral intake spacing no greater than those of the small business jets.

It is understood that a survey was carried out involving forty aircraft lightning strike events during the 1970s. This covered Learjet, Cessna Citation and HS 125 models, which have fuselage diameters ranging from about 5 ft 6 in to 6 ft 4 in and, consequently small lateral spacing between their engine axes. Twenty of these reportedly resulted in engine flame-outs, most being re-lightable. One, of unknown type, suffering a double flame-out at 35,000 ft. A number of events were also reported on military aircraft, such as F111 and F4 but the severity of the latter events is not known.

A North American NA 265-80 (Sabreliner) business jet type, which has a fuselage diameter of approximately 5 ft 9 in, suffered a fatal accident in the USA after a lightning strike event at night. This had led to a double engine flame-out, followed by progressive loss of battery power (accelerated by failure to carry out electrical load-shedding), which prevented a re-start of either engine. The engine type was not FADEC equipped.

Expertise on lightning behaviour and engine behaviour subsequent to a strike

An opinion was sought from the lead research specialist within the main test facility in the UK, devoted to lightning testing of aircraft structural and systems components. In his view, lightning conditions similar to those encountered by this aircraft presented a significant risk of a double engine flame out on the aircraft type (ie aero-thermal effects disrupting the intake flows of both adjacently mounted engines). The view of leading lightning specialist in the USA was that a risk existed of lightning effects sweeping longitudinally down both sides of a narrow fuselage and that this could, therefore, affect the intake flows of both engines of narrow bodied aircraft, where the engines are necessarily mounted close to the fuselage sides (ie typical of many combat aircraft and all aft-engined business jet and airliner types).

A significant risk was thus considered to exist that a single strike could cause both engines to flame-out as a result of aero-thermal effects, with potentially catastrophic consequences. The specialist in the USA made the point, however, that this effect appeared to be most prevalent on aircraft with narrow fuselages. Although it appears that the 'narrower' aircraft may be more at risk, insufficient data exists to assess the relative risk of double engine flame-out to types such as the EMB-145 compared with 'wider' and 'narrower' aircraft but statistics suggest the risk is very low.

It is relevant to note that most FADEC equipped engines have surge protection logic, with the capability of automatically shutting down engines in circumstances described above, whereas engines with more traditional fuel control systems, upon which more data is available, do not have this feature. The latter group of engines, the majority in service, are more likely to suffer transient over-temperature conditions as an indirect result of a lightning strike, but may stand a greater chance of continuing to run thereafter since shut-down is primarily in the pilot's control.

In practice, lightning strike damage to aircraft does occur, both in the UK and elsewhere. Unfortunately, however, reliable data on lightning events is difficult to obtain, particularly when little or no physical damage has occurred. In this instance, the physical damage presented no identifiable hazard.

Only two reports of lightning-induced engine flame-outs on other types were found on a UK database and both of these events produced physical damage and/or component failures, which in turn led to the power losses. It would therefore seem that aero-thermally induced engine flame outs are rare in the UK. The low population of narrow fuselage, twin aft-engined aircraft, compared with that in North America, makes the absence of any data on this class of aircraft understandable.

The fact that two instances of lightning induced engine auto-shutdown have occurred to EMB-145 aircraft during a short period, however, indicates that repetitions might be expected. The recorded lightning data for this event suggests that this strike was not in the higher power category, so it would appear that such an effect does not require unusually powerful strikes for it to occur. The EMB-145 fleet is relatively new and has progressively increased in number over recent years, so a greater number of aircraft are now potentially vulnerable. However, since 1998, in UK airspace there have been 49 instances of lightning strike on EMB-145 aircraft; none since the subject strike has resulted in an in-flight engine auto-shutdown.

Engine restart considerations

Study of the recorded data on engine behaviour during this incident indicates that within 20 seconds of fuel shut-off being automatically commanded by the FADEC, N2 had decreased to a figure below the 10% minimum required for a windmill start, according to the emergency re-light procedure for the type. The published engine re-start envelope confirms that when operating below 10,000 ft an APU Bleed Air assisted start is required if the airspeed is below 220 kt; the 'Engine Failure/Shutdown' procedure has the appropriate step of 'APU (if serviceable) -- Start'. Since the commander did not report any abnormalities when performing this procedure it must be presumed that the APU was both available and started in this instance.

Should a double engine flame-out have occurred in this case, it is clear that the APU would have been required to be started prior to its use to assist re-starting of the first engine, with a consequent considerable loss of altitude before a re-start could have been achieved. Even from

FL70, it was considered that attempting to enter the unassisted re-start envelope by diving the aircraft was not a viable option. Clearly, had a double engine flame-out resulted from a lightning strike later in the approach, there may have been insufficient altitude to achieve both APU and one main engine start.

In April 2004, the CAA published an Aeronautical Information Circular (AIC 29/2004) concerning lightning induced engine malfunctions, specifically referencing this incident but not confining its applicability to this aircraft type, alone. The Circular concluded with two recommendations, the second of which recommends that operators review their procedures and to consider starting the APU, when available, before entering areas where the potential for lightning strikes exists.

There are however, two considerations which must be taken into account when looking at this possibility. The first is that, since the APU intake is likely to be within the affected aircraft zone if a double flame-out caused by a lightning strike occurs, the probability exists that the APU itself may be similarly affected and flame-out. If the implications of this incident are followed, it is possible that re-starting the APU may also be problematic. The second consideration is that the APU is an allowable deficiency for takeoff on this aircraft type specifically; this condition is applicable to other aircraft types which may need to be considered. Although it is clear from experience, that the statistical possibility of a double flame-out is extremely low, the acceptability of having the APU as an allowable deficiency is questionable when certificating an aircraft type which needs pressurised air for main engine starting.

With this deficiency classified as allowable, consideration may need to be given to the procedure to be followed if engine flame-out due to lightning occurs. In this instance, the crew appears to have accepted the loss of the engine and proceeded to an uneventful single engine landing. During the descent before landing, however, the aircraft remained vulnerable to a second flame-out resulting from another strike. Even with the APU available, they would have had a decreasing time in which to start the APU to assist main engine starting; without an APU available, a forced landing, in this case in a predominantly urban area, would have become inevitable.

Whilst accepting that the engine auto-shutdown occurred at a time of increasing workload for the crew, it might have been prudent to attempt to restart the engine as soon as possible, as the 'Engine Failure/Shutdown' procedure suggests and leave it at idle power if it could be started. Although the section of the Operations Manual related to 'Lightning' suggests attempting a restart, it qualifies this by stating 'dependant on the phase of flight' and does not indicate which stage of flight is considered critical. It is considered that flight at relatively low altitudes is more critical, particularly in Terminal areas.

Safety Recommendations

The FADEC logic had, by design, no surge recovery features and the surge prevention logic was unable to re-establish stable running conditions during the length of time which passed between the lightning strike and the eventual auto-shutdown of the left engine. The forward movement of the aircraft over the useful time period in question (probably about 0.5 km over 5 to 6 seconds) should have carried it clear of any air directly affected by the lightning strike and thus restored the availability of acceptable intake conditions. That the engine did not recover implied that poor airflow conditions may have persisted within the intake, the engine or both, or that the scheduled fuel control inputs made were optimised to restoring demanded power rather than ensuring that stable running conditions were obtained before restoring set power.

The engine manufacturer has considered the possibility of installing surge recovery logic in the FADEC but believes that, at this time, the risks outweigh the benefits.

Although statistically small, there is a potential hazard of a lightning strike affecting both intake airflows on narrow body aircraft equipped with twin fuselage mounted engines, with the associated potential for a double engine flame-out and the following recommendations are therefore made:

Safety Recommendation 2005-094

It is recommended that, in order to minimise the risk of uncommanded shut-downs, EASA, FAA and the Centro Tecnico Aeroespacial (CTA) of Brazil in conjunction with aircraft and engine manufacturers should review and, if necessary, initiate appropriate research into the aero-thermal disruption of intake flow and other effects of lightning strikes on fuselage mounted turbine engines in order to establish whether there is a safety of flight issue that should be addressed by appropriate future rulemaking. They should also consider the application of any proposed rules to types currently in service.

Safety Recommendation 2005-095

It is recommended that, with advances in the technology which becomes available to them, Rolls-Royce Corporation continue to explore the potential to make modifications to the FADEC logic to enable the re-establishment of stable running conditions, after detection of a surge condition, before the FADEC attempts to restore selected engine power.

The minimum airspeed for unassisted air starts of the engines fitted to this aircraft type is 220 KIAS. Aircraft approaching to land in conditions where there is an increased risk of lightning strike would be vulnerable to double engine failure and potentially unable to re-start an engine whilst flying at low speed in a high-drag configuration. Therefore, it would be wise for approaches in such conditions to be conducted with the APU running or, at the very least, available. Consequently, it is recommended that:

Safety Recommendation 2005-096

It is recommended that, consideration be given by Embraer to amending the EMB 145 operating procedures and minimum equipment list to ensure that, in the event of an engine flame-out and continued flight in a zone with a high probability of lightning strikes, the supply of APU air for main engine starting remains available.

ACCIDENT

Aircraft Type and Registration:	Acrosport 1, G-BSHY
No & Type of Engines:	1 Lycoming O-290-G piston engine
Category:	1.3
Year of Manufacture:	1992
Date & Time (UTC):	2 May 2005 at 1300 hrs
Location:	Private airstrip near Keal Cotes, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Aircraft damaged beyond repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	1,712 hours (of which 375 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The pilot was attempting to land at a private grass airstrip which was about 1,300 ft (396 m) long and had a hedgerow about 12 ft high running perpendicular to it, approximately half way down its length. The landing strip was orientated 130º/310º and had a tree situated beyond the hedgerow, towards the far end of the strip and close to the left hand edge when viewed from the 310º direction. The tree was about 40 ft high.

The aircraft was a single seat biplane which offered little forward view when on the ground due to its tail-wheel type landing gear. The forward view was also limited in the air, especially after takeoff or during a go-around due to the aircraft's nose-up climbing attitude. During landing, in order to gain a clear view ahead, the pilot would sideslip the aircraft slightly to gain a forward view down the side of the aircraft, rather than attempting to look over the nose. When approaching the strip from the north, his normal practice was to sideslip to the left after flying a left hand circuit. On the day of the accident the weather was good with only light and variable winds but the pilot flew the circuit to the right to avoid helicopter traffic and he sideslipped to the right on finals.

The pilot did not have a good recollection of the accident. He reports landing on the airstrip in the 310º direction.

He remembers landing 'long' having misjudged the approach and as a result initiating a go-around. During the go-around he was suddenly aware of the top of the tree next to the strip directly ahead of him. In an attempt to avoid the tree the pilot pulled the aircraft near vertical, however the bottom of the aircraft collided with the branches, the force of the impact pushing the main landing gear assembly into the cockpit area causing multiple fractures to his ankles and lower legs. The aircraft struck the ground about 20 ft beyond the tree, sideways on, and on its right hand side. The pilot was able to switch off the electrical master switch and he reports the fuel tanks had ruptured, covering him with fuel. He was unable to open the canopy, the mounts of which had become distorted, but he was able to punch a hole through the plastic transparency. By this time a colleague, who had been watching the landing, arrived at the aircraft and was able to enlarge the hole sufficiently to extricate the pilot.

There was no fire and the pilot considers that he would have been able to extricate himself without any help, but with considerably more difficulty in view of his leg injuries. He sustained no other major injuries, a fact that he attributes to the strength of the fuselage, his four point harness and his wearing of a protective flying helmet. The top of the helmet showed evidence of damage caused by impact with the canopy mounting.

Pilot's assessment of the causal factors

The pilot's report was quite frank and he attributed the accident to his failure to maintain the runway centreline and being unable to see the tree ahead. He was familiar with the strip and was aware of the presence of the tree. He believes that during the approach, his sideslip to the right meant the tree was masked by the nose of the aircraft. The tree remained masked from view during the subsequent touchdown and go around and it only became apparent when it was too late to avoid.

The accident serves to act as a reminder of the hazards that obstacles at such airstrips present, even when pilots are aware of them. It also serves to show that appropriate safety equipment, such as helmets and four point harnesses, can and do save lives. The tree has now been cut down.

ACCIDENT

Aircraft Type and Registration:	Cessna 172S Skyhawk, G-WACM
No & Type of Engines:	1 Lycoming IO-360-L2A piston engine
Category:	1.3
Year of Manufacture:	2001
Date & Time (UTC):	19 July 2005 at 0920 hrs
Location:	Wycombe Air Park, High Wycombe
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to lower portion of firewall and distortion of right-hand landing gear leg. Minor damage to aft fuselage from tail strikes
Commander's Licence:	Private Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	107 hours (of which 35 were on type) Last 90 days - 7 hours Last 28 days - 0.7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The pilot was taking a friend for a flight from Wycombe Air Park. The weather was good, with broken cumulus cloud at 3,000 ft and excellent visibility. The wind speed was from 270º at 12 kt, gusting to 20 kt.

The pilot was a week beyond his '30 day' club currency so he flew in the circuit with an instructor for three circuits before setting off with his passenger on a return flight to Silverstone. This local flying took about 40 minutes and the pilot then returned to Wycombe and set up for an approach to Runway 25R, which has a length of 735 m and an asphalt surface. The pilot reports that the approach was normal but, because of the gusting wind, he used an approach speed of 75 to 80 kt. He considered the approach was stable and that he was just slightly to the left of the runway centreline with the flaps set to 20º. Clearance to land was given at about the time at which he crossed the M40 motorway (about 200 m from the threshold) and his airspeed at the threshold was close to 75 kt, which was above the recommended approach speed. The late ATC call was due to another landing aircraft vacating the runway.

Both the pilot and other witnesses noted that the aircraft touched down nose first and that this resulted in a substantial 'bounce'. The aircraft drifted to the left of the runway in a series of about five further bounces before the pilot was able to bring it to a halt on the grass taxiway, between the asphalt and grass runways. Neither the pilot nor the passenger was injured. The airport emergency service responded promptly and the aircraft was made safe.

Causal factors

The pilot considers that his approach speed was too high and that he should have initiated a go-around, either before the landing or after the first bounce. He considered that contributory factors in the accident were both his lack of recent flying and some degree of distraction from the previous landing aircraft still on the runway and the resulting late clearance to land. The instructor who had performed the currency check commented that the pilot had flown the three circuits well. She suggested that the poor later landing had been partly due to adding too much speed for the gusty wind, as the pilot appeared to have added 10 to 15 kt rather than a conventional 5 kt. The instructor also commented that the flying club prefers the full 30º flap for landings, the setting recommended by Cessna.

ACCIDENT

Aircraft Type and Registration:	Cessna U206F Stationair, G-BGED
No & Type of Engines:	1 Continental Motors Corp IO-520-F piston engine
Category:	1.3
Year of Manufacture:	1974
Date & Time (UTC):	27 June 2004 at 1800 hrs
Location:	Beacon Village, near Honiton, Devon
Type of Flight:	Aerial Work
Persons on Board:	Crew - 1 Passengers-5
Injuries:	Crew - 1 (Fatal) Passengers - 3 (Fatal), 2 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	628 hours (of which in excess of 172 were on type) Last 90 days - 6 hours 42 minutes Last 28 days - 4 hours
Information Source:	AAIB Field Investigation
	All times in this report are local (UTC+1)

Synopsis

Shortly after takeoff, with the pilot and five parachutists on board (including one 'tandem' pair), the aircraft's engine began to lose power. The pilot flew to the east away from the airfield for a distance of some 6 nm, achieving a maximum height of approximately 1,100 ft agl, before turning back. As the engine lost power the pilot was unable to maintain height and, in attempting a forced landing, the aircraft clipped the tops of several tall trees and crashed steeply nose down into a sloping grass field.

Nine Safety Recommendations are made.

Background

The aircraft involved in the accident was operating from a parachuting school located at Dunkeswell Airfield, near Honiton in Devon. The school owned and operated a Cessna 206 (G-ATLT) but, early in 2004, they leased an additional Cessna 206 (G-BGED) to be used at times when the demand for parachute jumping was sufficiently high. Both aircraft were kept at the school and each had been modified for use in parachuting operations.

History of the flight

On the morning of the accident the pilot arrived at the parachuting school in time to conduct his first flight of the day, taking off at about 1000 hrs. This flight was on the leased aircraft G-BGED and involved taking five parachutists (four static line parachute students and a jump master) to 3,500 ft. The aircraft made several passes over the airfield in order to drop the four students before returning to land. The jumpmaster remained onboard throughout the flight and reported that, on the descent back to the airfield, the pilot pointed out that the alternator warning light had illuminated. The aircraft made an otherwise uneventful landing and taxied back to the clubhouse apron where it was shut down; the whole flight took about 35 minutes.

Witnesses report seeing the aircraft outside the clubhouse at some point during the day with its engine cowling removed. A member of the school also reported being told by the jumpmaster, who subsequently received fatal injuries in the accident, that there was a problem with the alternator belt.

The pilot then conducted a second flight in G-BGED, taking off just before midday. This time there were three qualified parachutists on board and the aircraft climbed to 10,000 ft for a jump over the airfield. The aircraft then landed before again shutting down outside the clubhouse. The duration of this flight was about 31 minutes.

The pilot then flew the club's own aircraft, G-ATLT, for a further parachuting flight over the airfield. This aircraft had, up to that point, been flown by another of the club's pilots during the day and, from his records, the flight was conducted by the accident pilot with the right fuel tank selected.

Late in the afternoon it was decided that both club aircraft would depart together to make a parachute drop over the airfield at 10,000 ft. Five parachutists boarded G-BGED, two single parachutists, a tandem pair and the jumpmaster, with the aircraft being flown by the same pilot who had conducted the two earlier flights on the aircraft that day. Both aircraft lined up on Runway 23 at about 1752 hrs at which time the surface wind was westerly approximately 10 kt. The wind at 1,000 ft amsl was also westerly at between 15 and 20 kt and at 2,000 ft amsl remained westerly at between 20 and 25 kt. The area had been subject to showers in the afternoon and cloud cover remained broken with some slight to moderate showers still reported. Visibility was reported as being 15 to 20 km, but deteriorating to between 4,500 m and 12 km in showers. An aftercast showed that some eight minutes after G-BGED took off, Dunkeswell Airfield was subject to slight showers with a reportes cloudbase of 2,400 ft amsl (1,600 ft aal). This weather was moving in an easterly direction at approximately 20 to 25 kt. The temperature was +14°C and mean sea level pressure 1020 hPa.

G-ATLT took off first, making a climbing turn to the east after departure. G-BGED took off shortly afterwards and was seen by one of the parachutists in G-ATLT to get airborne and continue its initial climb out, apparently as normal. G-ATLT continued its climb to 10,000 ft, initially climbing to the east before turning back to drop the parachutists over the airfield.

Reports from the two parachutists on G-BGED, who survived the accident, indicated that soon after taking off they were aware of a problem with the aircraft. Their memories of exactly what happened are unclear. However, it was apparent that the pilot had initially informed the jumpmaster that they were losing power and, later, that he was attempting to return to Dunkeswell but they might have to land in a field. As the problem continued, one of the survivors recalls asking the jumpmaster whether they should jump, but being told the aircraft was too low.

At 1800 hrs the radio operator at Dunkeswell Airfield received a distress call from the pilot of G-BGED informing him that the aircraft was losing power. The operator requested the aircraft's position and whether the pilot thought the aircraft would be able to make it back to the airfield. The pilot replied he was to the east and that he would not be able to make it back. Unable to get replies to further calls to the aircraft, the Dunkeswell radio operator notified the police at 1802 hrs that an aircraft accident might have occurred.

One of the survivors recalled checking to see whether the rear door was open during the latter stages of the flight, which it was. The other survivor remembers the pilot telling everyone to 'brace' and being shown the position to adopt by one of the other parachutists; this being hands on head with the chest bent over towards the knees. The parachutists were now sat on the floor facing rearwards. The last recollection of the flight by this survivor was of seeing trees seconds after the 'brace' call.

Witnesses on the ground report seeing the aircraft flying low over trees close to the site of the accident. They describe hearing the "engine coughing and spluttering", which one witness described as sounding as if it was misfiring. Another witness described hearing the engine "revving loudly, cutting out and misfiring". The aircraft disappeared from view and was then heard to crash. One of the last witnesses to see the aircraft still airborne reported that the sky was clear and sunny at that time.

Two witnesses close to the accident site made their way quickly to the field where the aircraft had come down. The first person at the scene described seeing the aircraft lying in the field with fuel leaking from the right wing and a person staggering around nearby. Other witnesses also reported seeing fuel leaking from the wings but subsequent enquires were unable to establish the rate of leakage and whether the fuel was leaking from the right or left wing, or both. There was no fire.

The first witness at the scene managed to contact the emergency services using her mobile phone and was instructed not to approach the aircraft due to the danger of fire posed by the leaking fuel. She remained clear of the aircraft and managed to get the nearby survivor to come over to her. She remained on the telephone guiding the emergency services to the site whilst at the same time re-assuring the survivor. The other witness arrived shortly afterwards and made his way to a nearby road to meet the emergency services. Using his four wheel drive vehicle he was able to lead them along a track through an adjacent wood to get them to the crash scene. Both witnesses demonstrated considerable resource in dealing with the situation and there is no doubt that their actions enabled a quicker response than would otherwise have been possible.

An air ambulance and police helicopter were quickly at the scene followed later by the local fire service who had the problem of locating the site by road. It was then established that two further survivors remained in the aircraft. The survivors were the tandem pair and one of the single parachutists. The pilot, jumpmaster and the other single parachutist received fatal injuries in the impact.

Immediate treatment was given at the scene before the two most critically injured survivors were transferred to hospital by helicopter. The third survivor was transported by road ambulance. The most seriously injured parachutist, the tandem pair instructor, died later that night from his injuries.

Pathological information

Only one of the six occupants, the pilot, was seated and restrained and his injuries were consistent with high longitudinal and vertical impact forces. The base of his seat had failed during the impact, allowing him to move forward and strike the instrument panel. The post-mortem examination of the pilot showed that he died from multiple injuries.

Figure 1 illustrates the probable locations of those parachutists aboard G-BGED at the time of the impact, all of whom were seated on the floor and unrestrained. The 'tandem' instructor and student were seated beside the pilot leaning against the wooden box and facing

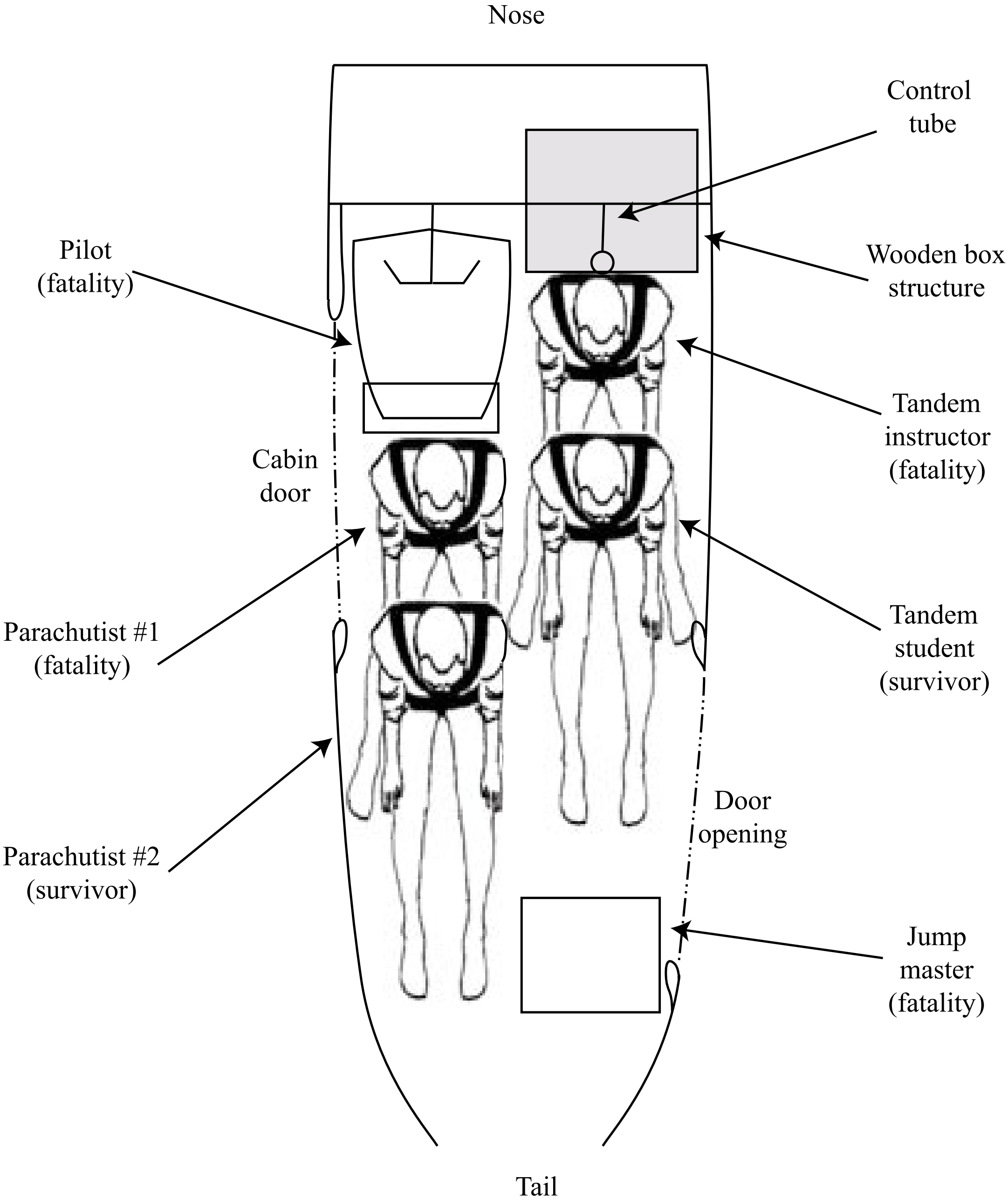


Figure 1

Seating layout for G-BGED

rearwards. The two single parachutists, identified as Parachutist No 1 and 2, were facing rearwards, with No 1 leaning against the back of the pilot's seat. Parachutist No 1 was fatally injured and had sustained a fracture of the pelvis and been struck in the face. Parachutist No 2, seated against Parachutist No 1, survived and, although he had sustained spinal injuries, his pelvis was intact. He was able to exit the aircraft after the impact and subsequently was treated by the emergency services. The tandem parachutists both sustained pelvic fractures. The fatally injured instructor had a deep laceration to the back of his head, indicative of striking his head on the right side control wheel tube. There was evidence to suggest that the harness of the surviving tandem student attaching him to his instructor, had been cut, although it was not established whether this occurred pre- or post impact or by whom. The injuries to these four parachutists were consistent with high longitudinal and vertical forces resulting from the aircraft's impact with the ground.

The injuries sustained by the fifth parachutist, the jumpmaster, were significantly different and the pathologist concluded that he most likely sustained these by falling to the ground separately from the aircraft. This conclusion was substantiated by the fact that he was found approximately two metres to the left of the main wreckage.

Accident site and wreckage examination

The aircraft had crashed into an up-sloping narrow grass field, immediately beyond an area of woodland. There was evidence of contact between the leading edge of the right tailplane and the tops of trees, approximately 15 m tall, bordering the field, with freshly broken branches being found around their bases over a track distance of some 100 m. At this point, the aircraft had been on a track of 280ºM, following which it had descended at a steep angle to the horizontal. The impact with the trees appeared to have yawed the aircraft to the right, and it struck the ground with a high rate of descent, in a 30º nose down and right wing low attitude whilst on a heading of 010ºM. The right wing tip had impacted first, followed by the underside of the forward fuselage and the left wing. The aircraft wreckage was substantially intact, although the right wing front spar attachment had failed and the nose wheel had detached. This was found some 15 m from the main wreckage.

Lack of significant damage to the propeller blades indicated that the engine had been producing low power at impact. The auxiliary fuel pump START switch was found in the ON position, the spring loaded EMERG switch was found OFF. Approximately 15 litres of fuel were recovered from the right wing, but none was recovered from the left wing. There was little evidence on site of staining from fuel spillage on the ground.

Aircraft description

General

G-BGED, a Cessna U206, was a single engined, six passenger, all metal high wing aircraft. It was powered by a fuel injected Continental Model IO-520-F horizontally opposed, six cylinder, overhead valve, air cooled, fuel injected engine with a wet sump oil system. This drove a metal, three bladed, constant speed propeller, controlled by a constant speed unit (CSU) attached at the front of the engine. Dual magnetos, an electrical engine starter, a belt driven alternator and a vacuum pump were located at the rear. The aircraft had an entry door on the left side of the cabin at the pilot's seat position and a double cargo door on the right side of the cabin, but for parachuting operations, the cargo doors had been removed.

Modifications for use in parachuting operations

In 1982, G-BGED was approved for parachuting by the CAA. The conditions of the CAA Flight Manual supplement included; removal of all seats with the exception of the pilot's, removal of the cargo doors for ease of egress during parachuting operations and the installation of a spoiler attached to the hinges of the forward cargo door jamb. All loose equipment was required to be removed or secured before flight.

A later modification to fit a perspex roller door in the cargo door opening, for occupant comfort in flight, had also been approved by the CAA. This door was required to remain open for takeoff and landing.

On 2 March 2004 a plywood board floor covering the cabin area was fitted, and the right control wheel and front right seat were removed by the aircraft's maintenance organisation. Additional modifications were made in that the tube to which the control wheel attached was capped with a tennis ball, and a wooden box shaped framework had been placed in the right side leg space below the instrument panel, providing a back rest for the forwardmost parachutist.

Fuel system

A diagram of the aircraft fuel system is shown in Figure 2. This type of aircraft has two bag tanks, one in each inner wing with a capacity of 119 litres each. Fuel is gravity fed through two reservoir tanks (left and right) to the fuel selector valve, all of which are located beneath the cabin floor. This valve is operated manually through a linkage from a handle positioned on the cockpit floor between the front seats. Depending upon the setting of the selector valve, fuel from the left or right tank flows via an electric auxiliary fuel pump and a fuel strainer to the engine-driven fuel pump. A pressurised supply of fuel is sent to the fuel metering unit which then regulates the fuel to the distribution manifold and finally to the engine fuel injector nozzles. The fuel/air mixture is controlled by means of the throttle and mixture control knobs. Excess fuel from the metering unit is returned by way of the selector valve to the reservoir tank of the wing tank being used. There is an additional filter within the fuel metering unit.

The engine-driven fuel pump provides sufficient fuel flow/pressure for normal engine operation with the electric auxiliary fuel pump acting as a back-up in the event of an engine-driven pump failure. The electric auxiliary pump is manually selected by means of a yellow and red split rocker switch on the lower left side of the instrument panel. The yellow right half of the switch is labeled START, and its upper ON position is used for normal starting and minor vapour purging during taxi. The red left half of the switch is labeled EMERG and its upper HI position is used in the event of an engine driven pump failure during takeoff or high power operation. The HI position may also be used for extreme vapour purging. With the right half of the switch in the ON position, the pump operates at one of two flow rates dependant on throttle setting. Maximum fuel flow is produced when the left half of the switch is held in the spring loaded HI position. When this is selected, an interlock automatically trips the right half of the switch to the ON position. The auxiliary pump is also required to assist in restarting the engine should fuel exhaustion from the selected tank occur. However, if the engine-driven pump is functioning normally, with a good supply of fuel, and the auxiliary pump 'START' switch is placed in the ON position, an excessively rich fuel/air ratio can result and lead to a loss of power and/or a 'rich cut'.

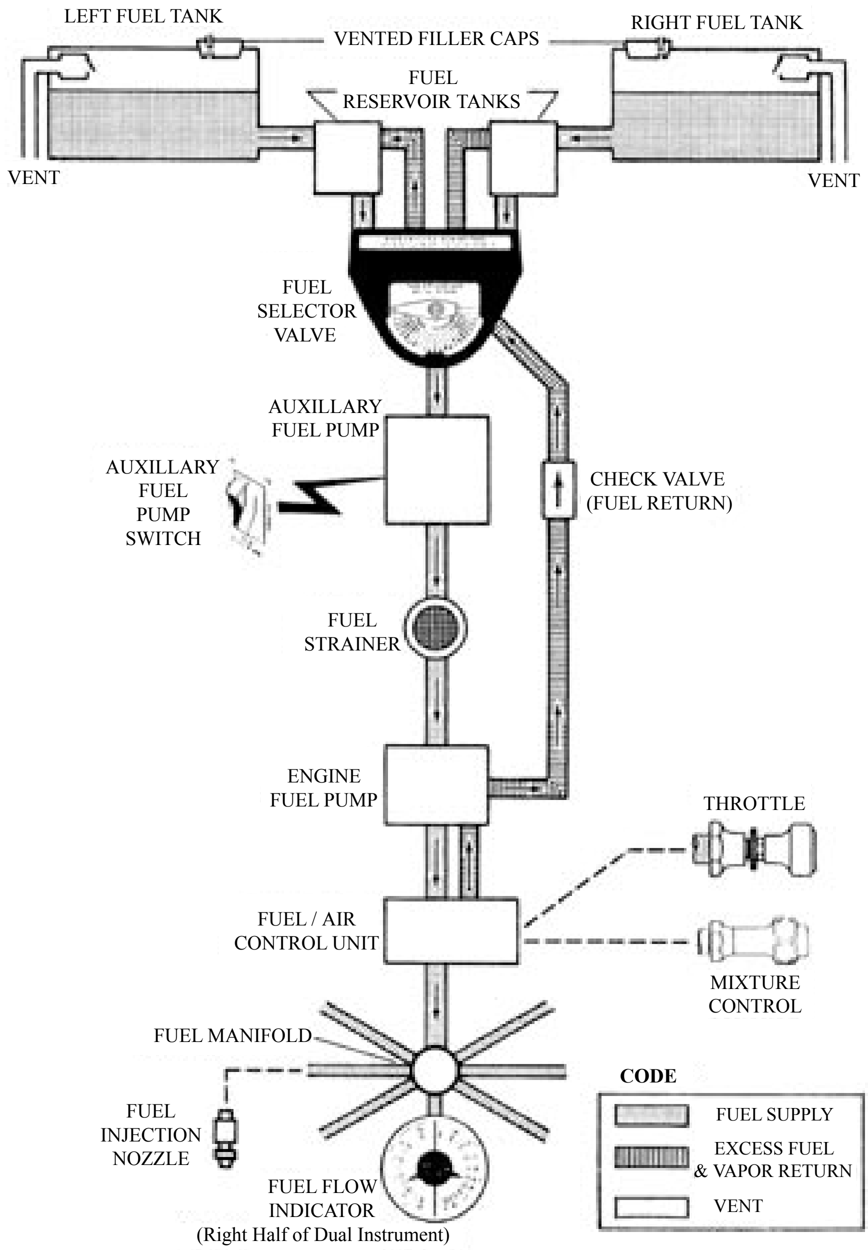


Figure 2

C206 Fuel system

Aircraft and maintenance history

G-BGED was constructed in 1974 since when it had accumulated 4,785 hours. The propeller had been completely overhauled to zero time condition and fitted to G-BGED in March 1999, since when it had completed 1,172 hours. A new engine, Serial Number 818871-R, was fitted in September 1999 and, at the time of the accident, had completed 988 hours. The last annual check had been carried out on 5 March 2004 and the most recent maintenance, a 50 hour check, 1 hour 10 minutes prior to the accident. The aircraft was certificated in the private category.

A week before the accident another pilot had been flying G-BGED and had completed a 'high lift', which involved climbing to 10,000 ft followed by a prolonged descent. The pilot recalled that it had been a very cold day and he had set a high manifold pressure during the descent in order to minimise the cooling rate of the cylinders. At about 2,000 ft in a high left hand downwind position, he opened the throttle but there was no immediate power increase and the engine began to run roughly. Realising the engine was not running at full power he expedited his approach and the aircraft landed safely. A ground run was subsequently carried out but the engine ran smoothly and there were no symptoms of the rough running encountered in flight. The aircraft was due for a 50 hour check and was subsequently flown to its maintenance organisation at Exeter Airport. On 21 June 2004, an engine run carried out prior to any maintenance activity revealed that, at the end of the run, the engine was slow to shut down after the mixture lever was pulled to the fully lean position. The mixture control was adjusted and the engine shut down normally following a further ground run the following day. The 50 hour check, which included an oil change, was completed on 24 June 2004 and the aircraft was flown back to Dunkeswell.

Prior to this, a defect had been reported to the maintenance organisation on 27 May 2004, after the alternator belt was reported as having been found '*adrift*' with the ammeter indicating a discharge from the battery. A new belt was fitted and tensioned, and a ground run conducted to confirm that the battery was charging satisfactorily. Also, on the 30 April 2004, there was a report of the '*alternator belt loose*', when the belt was re-tensioned and the alternator locked, and before that, on 20 February 2004, a report of the '*alt belt worn and out of adjustment*', following which a new belt was fitted.

Following the first flight on the day of the accident, during which the low voltage warning light had illuminated (indicating that the battery was not charging), it is probable that the alternator belt had been tightened, but there was no record of this having been done.

Maintenance requirements

The CAA publication, CAP 660 '*Parachuting*', sets out the minimum standards the CAA requires to be met, prior to the grant or renewal of parachuting Permissions and Exemptions, together with requirements for the conduct of parachuting operations. This states:

> *'……all maintenance work and modifications must be certified by an appropriately licensed aircraft maintenance engineer, or an authorised person employed by an approved aircraft maintenance organisation.'*

Detailed wreckage examination

Flying controls

The wreckage was recovered to the AAIB's facility at Farnborough where a detailed examination was carried out, in conjunction with the manufacturer's representative. Continuity of the flight control system, which consists of conventional aileron, elevator and rudder control surfaces manually operated through mechanical linkages, was confirmed. The extension of an electric actuator, which operated the elevator trim tab to provide electric trim in addition the manual system, was measured as 1.5 inches, equating to 5º tab down, full travel being 25º up and 5º down. (This tab position may not represent the pre-accident setting as both trim cables had been pulled as the tail section deformed in the impact.) Both flap surfaces were found at full travel (40º) and this was confirmed by measurement of the electric flap actuator extension.

Alternator belt

The alternator belt was found to be correctly tensioned, but the quality of the wire locking through the securing bolt on the mounting arm was not to aviation standard and appeared to be reused wire.

Engine

The engine was returned to engine manufacturer for detailed examination and possible testing, under the supervision of the AAIB. However, the crankshaft propeller flange showed evidence of torsional cracking and therefore the engine could not be test run. A detailed strip examination was carried out and this showed that the basic engine had been mechanically sound before the accident and that it had been in good condition, given its time-since-new and operational usage.

The accessory gearbox was intact; the various gear teeth were undamaged and exhibited normal operating wear. The engine oil sump had been ruptured with the result that only approximately one pint of oil was recovered. The sump contained a small amount carbon but no metal or other debris was observed.

Both magnetos, the ignition switch and harnesses were tested satisfactorily and all the spark plugs were in a serviceable condition; their electrodes were clean and exhibited only light deposits.

The vacuum pump was intact; however, the drive coupling was broken and the pump could not be rotated by hand. The pump was disassembled and the rotor and one vane were found to have broken; the five remaining vanes were intact. It is considered that this damage occurred at impact.

The engine driven fuel pump was free to rotate and its drive was intact. The pump was tested and functioned satisfactorily through its full range of operation.

Propeller

The propeller showed very little evidence of rotation at impact, or any damage usually associated with an engine producing high power. One blade exhibited a nick on its leading edge and, generally, some chordwise scoring was present. The propeller assembly was removed from the engine and sent for a detailed strip examination at an approved maintenance facility, under the supervision of the AAIB. No failures were identified and internal witness marks in the hub from all three blades showed the blade pitch angles had been at approximately 11º at the time of impact with the ground. This is the minimum, 'fully fine', blade angle. The CSU was tested satisfactorily.

The most recent maintenance on the propeller had been carried out in 2002 when, in accordance with Airworthiness Notice 75, the propeller was disassembled for a bare blade inspection. During assembly of the blades into the hub, each blade retention nut is torqued tightened to an appropriate value and then locked into position by drilling a 'staking' hole across the blade nut and hub interface. These holes are then filled with an expansion plug in order to lock the two together and prevent any loss of blade nut torque loading. It was noted during the examination that two previous 'staking' holes on the hub were closer than the minimum specified spacing of 3/16 inches between holes and, as such, the hub should not have been returned to service.

Fuel system

The fuel tank selector handle linkage had separated at the selector valve; the valve was found in the left tank position but with the handle set to the right tank position. Examination of the linkage failure showed this to have been occasioned in the impact.

The two reservoir tanks beneath the cabin floor were cut open and each found to contain approximately 40 to 60 ml of fuel. The fuel strainer was removed and approximately 70 ml of fuel was recovered. Its internal filter was found to be clear of debris.

Figure 3

Contaminated filter removed from G-GBED (left) and identical clean filter (right)

Each wing bag tank had a vented fuel cap installed and their gaskets, vents, and filler ports were intact. The bag tank in the left wing had a wrinkle on the lower surface below the outboard filler port. Tests were carried out on the left fuel tank to establish if fuel could have drained out either in-flight or post impact. With the left wing level and the bag tank filled with water, a small amount of water was observed dripping out of a vent hole in the bottom of the wing. The wing was then repositioned with the leading edge 30° down, to reproduce its attitude as found in the wreckage, and a slow drip was observed coming from an access panel opening near the external vent tube. No further leaks were found and no further water drained away from the tank.

The fuel metering unit filter was removed and was found to be 80% to 85% blocked with debris, as indicated in Figure 3.

The throttle arm and throttle plate were intact and moved freely through the full range of travel. The mixture arm had been bent into the throttle body but straightening the arm allowed it to move freely through its full range of travel. The inlet supply fuel hose nut was found to have been cross threaded on the inlet elbow fitting, causing damage to the elbow fitting threads. This nut, however, was found to be tight with no evidence of fuel leakage[1]. The fuel metering unit was bench tested with the contaminated filter installed, and then re-tested with a clean filter in its place. Although the unit did produce a flow of fuel, this was below the normal value. Disassembly of the unit revealed internal damage consistent with being occasioned during the impact and this damage had the effect of restricting the flow of fuel through the unit. The aircraft service information requires the fuel metering unit filter to be checked every 100 hours, but this check was not required to be done the during maintenance prior to the accident as it had been carried out during the Annual Check on 5 March 2004.

A fuel distribution manifold valve flow vs. fuel pressure test was conducted and found to be within the

Footnote

[1] In a response to this finding, the manufacturer advised that *'Cessna Service Bulletin, SE81-42 Fuel Vapour Owner Advisory, mentions loose connections, cracked or leaking flares at fuel line connections and minor leaks in fuel lines can produce conditions similar to fuel vapour.'*

manufacturer's specifications. The manifold valve was disassembled and its diaphragm found intact and filter screen clean of debris. The cylinder fuel nozzles were unrestricted and exhibited normal operating wear.

Further testing

A functional fuel metering unit, with the contaminated filter from G-BGED's unit installed, was mounted in a new engine which was then run on the manufacture's test bed. The engine was tested at various power settings, including full power, and the tests repeated with an uncontaminated filter. There was no discernable difference in the performance of the engine with either filter installed.

Fuel samples

A sample of the fuel recovered from the right wing tank of G-BGED was analysed by QinetiQ Fuels and Lubricants Laboratory and found to comply with the specification of Avgas 100LL. However, a small quantity of sediment was noted to be present.

The two most recent fuel samples taken from the bowser operated by the school were also analysed. The school's records indicate these samples were taken on 25 June 2004 and 27 June 2004; the day of the accident. The sample taken on 25 June failed to comply with specification for Avgas 100LL; the liquid had a green colouration. This can occur if the fuel has remained in a hose for a period of time and the hose has not been flushed prior to taking the sample. However, a high gum content is often associated with this but, in this case, the gum content of the sample was within specification. The sample also had low vapour pressure. However, these characteristics were unlikely to cause the engine to loose any significant power. The sample taken on 27 June did comply with the specification requirements apart from a small quantity of sediment being evident and it exhibited a slight haziness in its appearance. Haziness is often an indication of water contamination, but tests indicated less than 10 ppm free water and 45 ppm total water content, which is not excessive for aviation fuel.

Fuel system debris

Visual examination of the debris deposited on the outside of the fuel metering unit filter was also conducted by QinetiQ, and this showed that it comprised a dark, very fine compacted particulate within heavily matted fibres, as seen in Figure 4. An Energy Dispersive X-Ray (EDX) analysis indicated a predominantly carbon based composition of both the fibres and the particulate. Their report concluded that:

> *'the evidence suggested that the particulate on the blocked filter was typical of debris found in fuel systems. It is probable that the presence of the fibres effectively reduced the porosity of the filter, thus capturing particles that would normally have passed through and therefore increasing the concentration above a level that would normally be seen. The origin of the fibres could not be determined.'*

A scanning electron microscope was used to measure the mesh size of an identical filter as 191 x 183 μm (0.0075 x 0.0072 inches).

The fuel metering unit filter was removed from the parachute club's other similar aircraft and debris was also found, but the level of contamination was much less than that seen on G-BGED. Analysis by QinetiQ again showed that the debris consisted predominantly of fibres, with flakes and particulate matter also present. EDX analysis indicated a predominantly carbon based composition to the fibres and flakes although a few paint flakes and a single

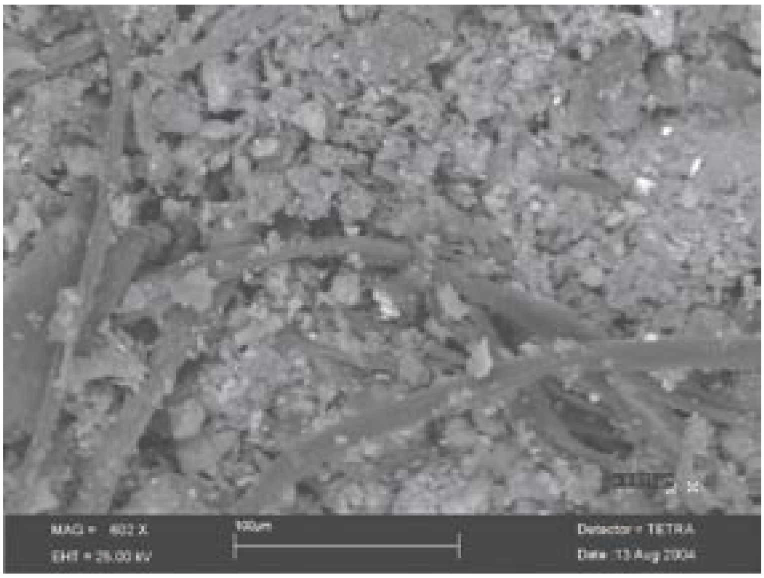


Figure 4

Magnified image of the fibres and debris removed from the filter

aluminium flake were also found. The particulate was predominantly composed of silicon with some magnesium and aluminium. Their report concluded that:

> *'the majority of the debris consisted of fibres and flakes, the appearance and composition of which suggest are organic in origin. The remaining chunky particulate is typical of dust, sand and grit. This debris is typical of external contaminants and is to be expected in a filter. The paint flakes and aluminium particle are likely to have originated from the aircraft, again are typical of what is found in a filtration system and are not cause for concern. The quantity of debris examined is very small compared to the amount present in the original filter examined from G-BGED and the lack of elements found in the original analysis suggests that this is a cleaner system.'*

Fuel storage

The school operated its own fuel bowser, a fuel sample from which was normally checked by the first person to use it each day that flying took place. Fuel samples were retained in five litre containers, numbered one to seven, which were used in consecutive order and were kept in the school's clubhouse. However, the fuel samples retrieved amounted to considerably less than five litres in each container and this low sample to container volume ratio may have led to the measured low vapour pressure.

A written record was maintained of each fuel check but the details were not necessarily entered into the record by the person doing the actual check. This was the case on the day of the accident. Thus, whilst it has been possible to identify the person entering the details of the fuel check into the log, it has not been possible to positively identify the person who actually carried out the check, although it is thought to have been one of the individuals subsequently fatally injured in the accident. There was an assumption by the school pilots interviewed that, if the bowser operating panel had been opened up, then the bowser had been checked.

The bowser was fitted with a counter mechanism which indicated the quantity of fuel dispensed, measured in litres. The gauge could be set to zero at any time but this was not routinely done either before or after use. The pilot of G-ATLT stated he did not zero the gauge before or after refuelling but he thought that the pilot of G-BGED did re-set the counter after each refuelling operation. The reading on the bowser at the time of the accident was 129 litres (about 30 US gallons).

No record was kept at the bowser of fuel dispensed, either during individual aircraft refuels, or on a daily basis, but the bowser contents were periodically monitored by use of a dipstick.

Aircraft fuel management

Prior to commencing operations, the first pilot to fly a particular aircraft should normally carry out a full walk round check, which would include a water drain check of the fuel tanks. Both aircraft were fitted with fuel strainers, located at the lowest point of the fuel system, and these should also normally have been checked for water prior to the first flight of each day. A fuel tank dipstick, used to enable the contents of the tanks to be established, was found within the wreckage of the aircraft.

The fuel tanks were located inboard in the wings on both aircraft and normal practice was to refuel G-ATLT to 22 US gallons a side, sufficient for three flights to 10,000 ft, plus a reserve of about 45 minutes. G-BGED had previously been modified for use as a floatplane and was slightly heavier. As a result, to retain acceptable operating performance, it was only refuelled to 60 litres (equivalent to about 16 US gallons) a side, sufficient for two parachutist dropping flights to 10,000 ft, plus a reserve of about 45 minutes.

The fuel selector valve in both aircraft allowed selection of either left or right tank, but not both tanks together. Normal operation of G-ATLT was to use one tank for the first flight and then to select the other tank for the second flight. A third flight was then possible by using one tank in the climb and until the parachutists were dropped, and then the other tank for the descent. Normal operation for G-BGED would be to use one tank for the first flight and then to select the other tank for the second flight before refuelling.

During the investigation, it was not possible to ascertain the amount of fuel on board G-BGED at the start of the day. Also, no witnesses were found who actually saw the aircraft being refuelled during the day, although the aircraft had been seen parked in front of the bowser. The pilot of G-ATLT stated that he had re-fuelled G-ATLT twice on the day of the accident. The first re-fuel was after the first three flights, at about midday, and the second was after the sixth flight of the day at about 1430 hrs.

As the aircraft fuel gauges on both aircraft were considered inaccurate, dip sticks were used to check the actual fuel quantity on board after refuelling. The recommended practice was for pilots to maintain their own written record of the fuel on board the aircraft during jumping operations, including a record of which tank had been used for which flight. The record maintained on the day of the accident by the pilot of G-ATLT showed the fuel required for a drop from 10,000 ft was about 10 US gallons. After the accident no such record could be found for G-BGED, although it is possible that it became mislaid during the emergency response.

Previous incidents

In the course of investigating this accident, information concerning two previous incidents of fuel mis-management which reportedly occurred on the same type of aircraft was given to the AAIB. On one of these occasions, the pilot, who was reportedly the pilot involved in this accident, changed fuel tank selection whilst accelerating along the runway. The engine 'coughed' and he then decided to abandon the takeoff.

On the second occasion, on 19 August 2000, aircraft G-ATLT suffered engine problems whilst in the climb to drop two tandem pairs of parachutists and a cameraman. It was reported that the engine suddenly lost power whilst in the climb at about 5,000 ft. A glide attitude was established and the aircraft was turned onto a heading towards a disused airfield. As the pilot was unable to quickly confirm to the jumpmaster that he could re-start the engine, the two tandem pairs and the cameraman made an emergency exit from the aircraft, as it was high enough for their parachutes to deploy safely. They landed from their jump at a motorway service station, this being the most suitable area they were able to reach. The pilot then switched fuel tank selection, and operated the fuel pump HI and LO switches. Shortly after making a MAYDAY call, the engine re-started, although it 'coughed' and continued to 'miss', but it provided enough power for level flight, and so the pilot was able to recover it to Dunkeswell and land safely. During the landing rollout, the throttle was retarded and the engine stopped. A short time later the engine was restarted and the pilot taxied to the parachute school. Subsequent investigation revealed that the left tank, which was initially used for the flight, was dry and that the right tank contained approximately 17 gallons of fuel. The pilot later reported that although it is his usual practice to keep a detailed log of time, fuel useage and tank selection, on this occasion he noted the tank selection change but failed to carry out the action.

Recorded data

G-BGED was fitted with two GPS receivers, a Garmin GPS 100 and a Bendix/King Skymap II version 4. The GPS 100 did not record track information and so provided no information useful to the investigation. The Skymap II recorded the GPS position, GPS altitude, track (ºT) and ground speed for the last 28 flights, including the accident flight. The data was recorded every 30 seconds. GPS altitude is subject to larger errors than GPS horizontal positioning but these errors tend to change slowly with time rather than being erratic. In this case the GPS recording included the take-off roll on the accident flight and indicated that the GPS altitude error was only 15 ft at the time. For the purpose of this investigation the GPS altitude was therefore be assumed to be relatively accurate.

The accident flight was recorded by Burrington radar and showed that, although secondary radar coverage of the flight was constant, primary radar coverage was intermittent. No altitude encoded Mode C returns were recorded.

The Meterological Office provided a weather aftercast for the region on the day of the accident. There was also a wind monitoring station just beside Dunkeswell Airfield which is used to record wind speeds at various altitudes and the Meterological Office were able to supply data from this monitoring station that covered all the flights stored in the Skymap II. The wind data was used with the recorded ground speed and altitude to calculate the aircraft's true airspeed (KTAS) during the recorded flights.

Data analysis

The radar data and GPS data correlated except for a very slight divergence in the last minute of flight. The radar head sweep rate was eight seconds and the track coverage was slightly less than that of the GPS data. However, since the aircraft was not transmitting Mode C altitude, the radar data only provided horizontal position information. Due to these limitations, other than for general GPS track location confirmation, the radar data was not used. The use of the GPS data for the analysis also provided a like-for-like comparison with the GPS recordings of the previous flights.

The GPS track times for the flights on the day of the accident were as follows:

Flight	GPS track Start time	GPS track Stop time	GPS track Duration
1	10:48:28	11:23:53	35m 25s
2	12:51:10	13:19:42	28m 32s
3	17:52:43	18:00:14	7m 31s

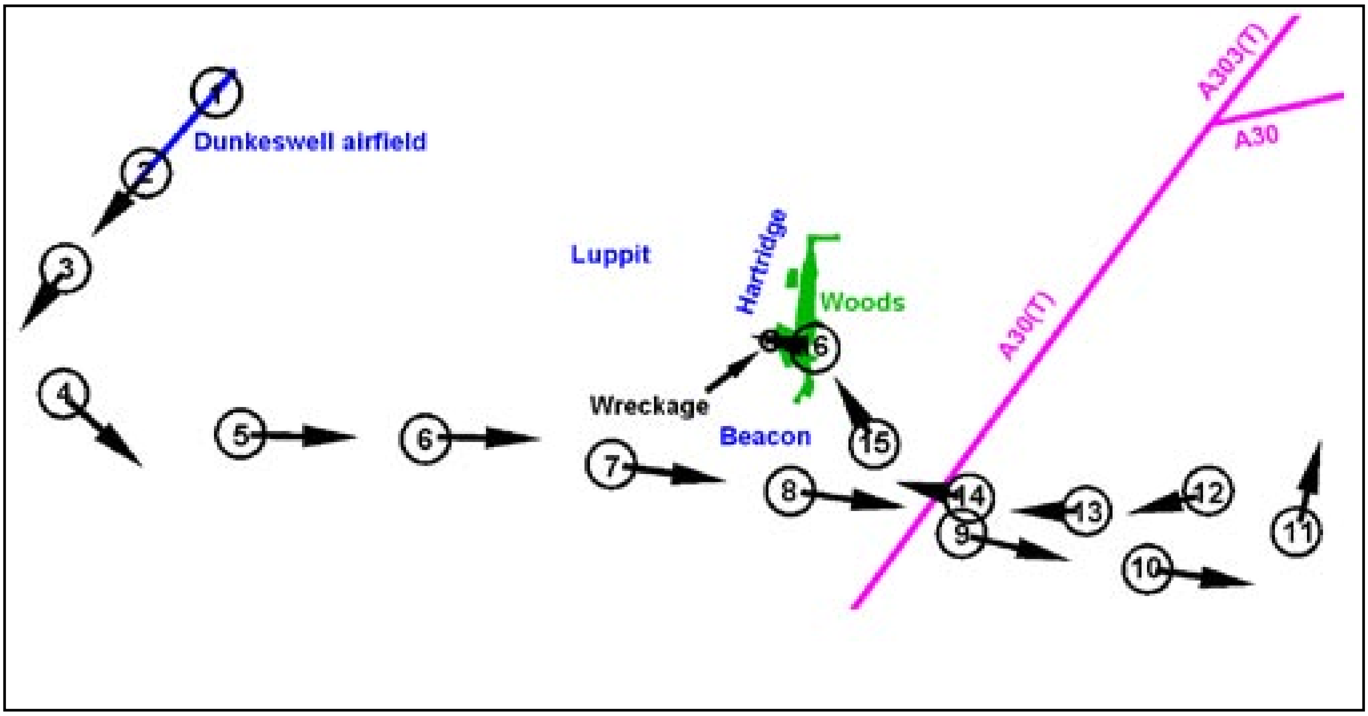
Table 1

GPS logged flights

The GPS recording on the accident flight started during the take-off roll from Dunkeswell on Runway 23 with a ground speed of 22 kt. The last recorded point in the log was seven and a half minutes later with a ground speed of 52 kt, a track of 282°T and a GPS altitude of 1,051ft amsl. Taking into account the wind conditions, this final airspeed was 69 KTAS. The approximate terrain elevation at the accident site was 750 ft.

Figure 5 shows the plan view of the accident flight which identifies the last GPS position before equipment power or antenna connectivity was lost. This location is consistent with the wreckage location. The recorded track shows that the aircraft turned away from an area of high ground near Dumpdon Hill. This track took the aircraft towards another area of high ground, Hartridge, upon which it crashed.

Figures 6, 7 and 8 show the altitude, altitude rate and true air speed parameters respectively, of the accident flight against the first 16 samples of the previous 27 recorded flights. These indicate that the rate of climb was apparently normal for the first 2.5 minutes (6 samples). After this, the climb rate reduced below that of all the previous flight profiles. Given that the airspeed was maintained during this period at approximately 80 KTAS, it would



Note: 16 GPS recorded track points sampled at 30 second intervals covering the period from 16:52:43 to 17:00:14 UTC. The recorded heading is indicated by arrow direction. The arrow length is proportional to recorded ground speed. The last fix point before satellite tracking was lost was at the same location as the wreckage as shown. Wind is from the West between 12 and 20 kt. Speed and heading are instantaneous non-smoothed values.

Figure 5

Plan view of the accident flight
Accident to G-BGED on 27 June 2004 at Beacon Village

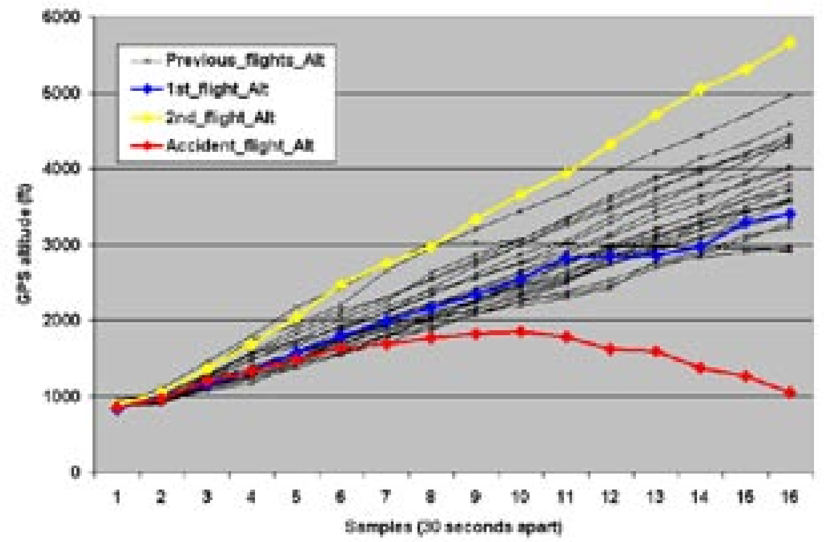


Figure 6

Take-off altitude profile of the 1st and 2nd flights of the day, the accident flight (3rd) and other previous flights.

Accident to G-BGED on 27 June 2004 at Beacon Village.

Note: The 1st flight had similar passsenger loading to the accident flight. The 2nd flight was with two less passengers. Fuel loading unknown.

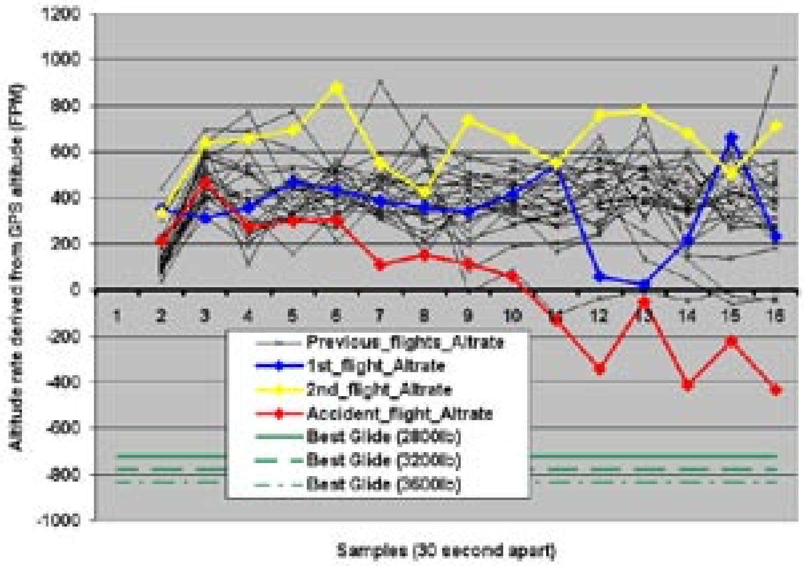


Figure 7

Take-off altitude rate profile of the 1st and 2nd flights of the day, the accident flight (3rd) and other previous flights.

Accident to G-BGED on 27 June 2004 at Beacon Village.

Note: The 1st flight had similar passsenger loading to the accident flight. The 2nd flight was with two less passengers. Fuel loading unknown.

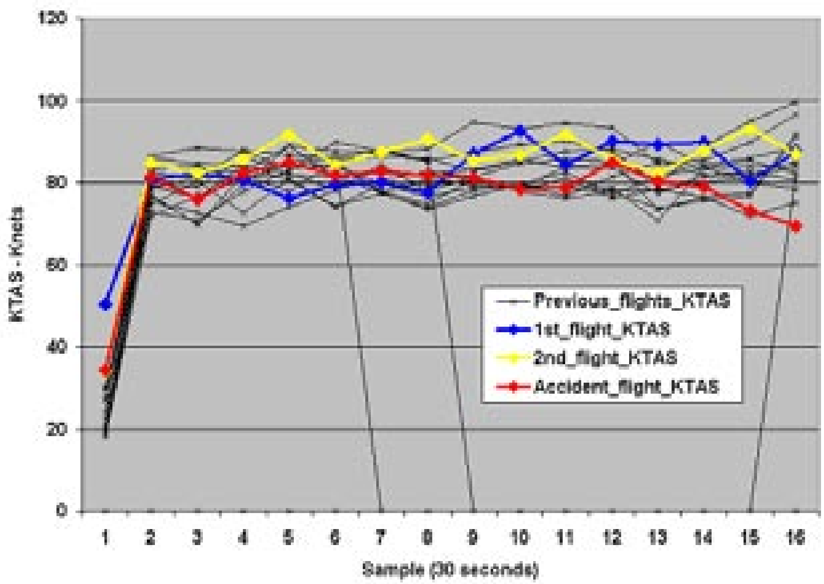


Figure 8

Take-off true airspeed profile of the 1st and 2nd flights of the day, the accident flight (3rd) and other previous flights.

Accident to G-BGED on 27 June 2004 at Beacon Village.

Note: The True Airspeed (KTAS) was derived from the GPS recorded ground speed and the wind data supplied by the Met Office.

appear that a reduction in power had occurred. In the last minute of flight the airspeed also reduced.

Figure 9 shows the altitude of the aircraft relative to the terrain beneath the aircraft. This shows that at the highest point of the flight, the aircraft had on average approximately 1,100 ft terrain clearance. During the last minute of recorded flight the terrain immediately below the aircraft was undulating such that the aircraft terrain clearance was never more than 900 ft.

Pilot history

The pilot of G-BGED held a private pilot's licence which was originally issued in 1984. He had flown aircraft engaged in parachuting operations for many years and was himself a qualified parachutist and had a current BPA parachute pilot's authorisation at the time of the accident.

Records of the pilot's BPA flight tests show that, in 1991, he successfully demonstrated a simulated forced landing in a Cessna 206 from a minimum height of 2,000 ft with the aircraft at a weight of at least 90% of its maximum all-up-weight. Further records show that in 1995 on another test he again successfully demonstrated a simulated forced landing, this time on a Cessna 180C. Both tests were to qualify him to fly these two aircraft types for parachute dropping.

Changes made to the currency requirements for private pilots lead to the BPA to change their test requirements for pilots in February 2000. It was considered that currency and training requirements now in place through the CAA were sufficient for the general handling requirements of a pilot taking part in parachuting operations. As a consequence training and testing in order to gain a BPA pilot's qualification was changed to include only those aspects directly related to the parachuting operation itself.

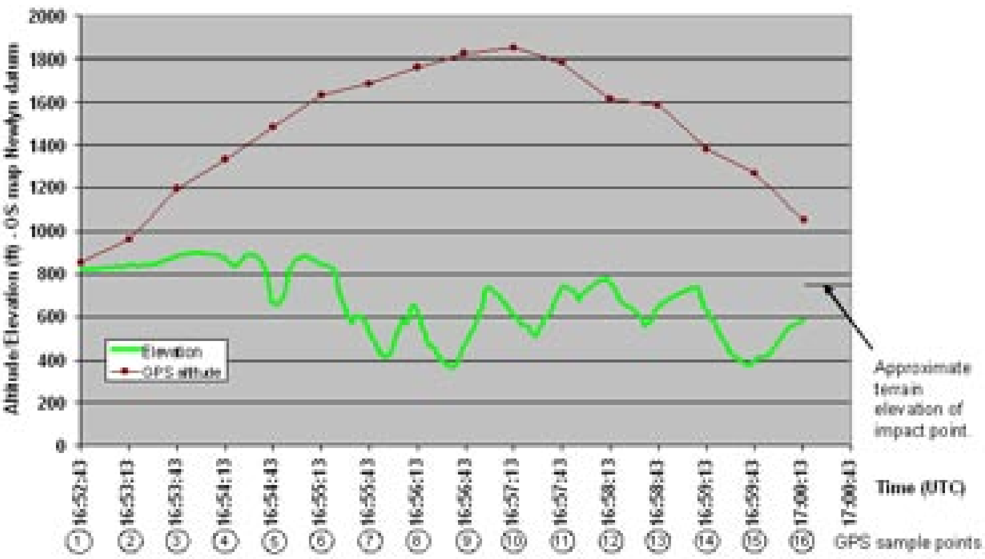


Figure 9

Aircraft altitude relative to terrain

Accident to G-BGED on 27 June 2004 at Beacon Village.

Note: GPS altitude is not as accurate as GPS horizontal position accuracy. Both the GPS altitude and the Terrain elevaion shown are with reference to the Newlyn altitude datum (as per OS maps) and so can be compared on the same scale.

Tests prior to February 2000 were conducted in accordance with BPA Form 108D. This detailed elements of flying tests to be completed, whether the pilot had successfully completed each section and any relevant remarks by the examiner. It also instructed that the test should be completed with the aircraft at 90% or more of its maximum all up weight. As a result of the changes to the test requirements this form was discontinued and the only records now retained are whether a pilot has passed or failed a test.

Records also exist of this pilot's various BPA authorisation renewals. However these provide no specific information on his achieved performance.

The pilot of G-BGED had flown on three other days in the six months prior to the accident, all of these being parachutist dropping flights, and all were flown on the same type of aircraft involved in the accident. His log book also shows that on 7 December 2003 he had flown for an hour's training with an instructor in a Piper Super Cub. There was no requirement to make detailed record of this training and so again it was not possible to substantiate the standard of his flying that particular training flight. The instructor however recalls no particular problems with the pilot's ability on that flight. There was a further 50 minute flight logged on 1 January 2004, again in a Super Cub, although the nature of the flight was not recorded. Of note, however, is that the performance of the aircraft flown on the training flight would have differed considerably from the heavily laden aircraft subsequently involved in the accident.

Parachute pilot qualifications

In order to qualify as a pilot of an aircraft engaged in parachuting operations, a pilot must meet certain experience and training requirements as laid down by the Civil Aviation Authority (CAA) and the British Parachute Association (BPA). The continuing validity of a parachute pilot's qualification is then reliant on him maintaining appropriate flying currency, as required by the CAA, for the maintenance of a licence, and carrying out sufficient parachuting flights, as required by the BPA. The pilot of G-BGED had complied with these requirements.

As part of the CAA's currency requirement, a private pilot with a single engine piston (SEP) rating is required to undertake a training flight of at least one hour's duration with a suitably qualified instructor in the 12 months prior to the rating expiring. Guidelines for the items to be covered during the training are covered in the CAA's Aeronautical Information Circular AIC 127/1999 (White 378). This includes the operation of the aircraft in an emergency, incorporating simulated precautionary landings. Whilst the flight is not considered a test, a log book entry is required by the instructor, only to be made if the pilot has demonstrated his ability to carry out a safe flight to an adequate standard. Should a pilot not meet the required standard, then his log book would simply not be signed by the instructor. Whether successful or not, there is no requirement to record any details of the training conducted or the standard achieved.

In order to maintain a parachute pilot's authorisation, the BPA requires that this is renewed annually. To achieve this, a pilot has to demonstrate that at least three parachutist dropping flights as pilot-in-command (PIC) have been conducted in the previous twelve months, or at least one flight made as PIC accompanied and supervised by a BPA Pilot Examiner or Chief Pilot. This flight is not a test and there are no laid down requirements for such a flight. No record need be made, other than an appropriate entry in the pilot's log book. However, the pilot must also demonstrate that he is current with parachute dropping techniques, emergency procedures and relevant BPA Operations Manual requirements.

Oversight of parachuting operations

All parachuting from civil aircraft over the United Kingdom is subject to a written permission from the CAA in accordance with Part V section 57 of the Air Navigation Order. Guidance is further given in CAP 660, which was originally based upon the BPA Operations Manual. Both documents detail the additional requirement for individual clubs to publish their own standard operating procedures in order to address the specific requirement of everyday operations not otherwise covered. An audit is carried out at least once every three years by the BPA, of member organisations, to comply with their delegated duties as agreed with the CAA.

At club level, the operation of aircraft used to drop parachutists is the responsibility of the appointed Club Chief Pilot (CCP). The areas of responsibility of such a pilot cover all aspects of the flying operation, including the aircraft, pilots and the provision of fuel. This task is not inconsiderable and this role may also be carried out by the same person acting as the Club Chief Instructor (CCI), who is responsible for ensuring that all the requirements, for both the parachuting and flying operations, as stipulated in the BPA Operations Manual, are met. The role of the CCP requires no stated qualification or training. Parachute pilot examiners form an additional part of the oversight process and they are required to have specific qualifications as listed under section 9, para. 1.4 of the BPA Operations Manual. However, their appointment relies upon experience and recommendation, but no specific training or test is required. Thus, whilst a system of oversight exists, the qualifications of those involved are not subject to any quantifiable standard.

Organisational documentation

The BPA Operations Manual and the Pilot's Information Manual were examined in the course of this investigation and elements of the contents were discovered which raised concerns in relation to the operation of parachuting aircraft. For example, there was a lack of differentiation between training requirements and elements required to be tested as part of gaining a qualification. Other information, particularly related to the Pilot's Information Manual, was mis-leading, out of date or incorrect. It was acknowledged by the BPA that this manual was out of date and they indicated it was in the process of being re-written. The manual was, however, at the time of the accident, still available to pilots, who had no way of knowing that its entire contents were anything other than correct.

Accident flight - nature of the operation

One of the surviving parachutists was a member of the public conducting a 'free fall' parachute jump for charity. He had no previous experience of parachuting and was jumping as a 'tandem pair', ie, attached to an experienced parachutist instructor and using a tandem parachute. In order to undertake the jump, this individual had to pay the charity involved £350. Of this, £100 was retained by the charity, with the remaining £250 being divided variously between the interested parties involved in organising or conducting the jump. These included an agent who organised such jumps for various charities, the parachuting club, and the tandem instructor. It could, therefore, be argued that the tandem jump was being undertaken as a commercial venture, with several parties profiting from the event. It transpired that the club concerned relied upon such jumps, together with short duration 'static line' jumping courses, to financially support its sport parachuting operation but, of note, their parachute pilots were not paid for their services. This meant that the flying operation was not subject to the standards that would otherwise apply to a commercial operation.

Analysis

This analysis concentrates on possible reasons for the loss of engine power, aircraft handling, operational oversight, survivability and recorded data issues, and leads to nine Safety Recommendations

The engine power loss

As a result of the examination of the wreckage, no conclusive cause for the engine power loss could be identified; the engine and propeller had both been mechanically sound prior to the accident and the ignition system components had been functional. There was very little evidence of fuel at the accident site and no fuel was recovered from the left wing tank, which was the selected tank at the time of impact. The later test indicated that it was unlikely that any significant volume of fuel had leaked out post impact from this tank. It was therefore considered that one possible cause for a power loss could be related to the operation of the aircraft's fuel system. Also, it could not be discounted that the (unidentified) cause of the loss of power on the flight prior to the most recent maintenance had reoccurred.

Operation of the fuel system

In the absence of detailed records there was no way of establishing how much fuel was onboard the aircraft at any point during the day and, in particular, prior to takeoff on the final flight. Had the pilot of G-BGED complied with the school's routine of refuelling with enough fuel for only two flights, plus a reserve, then the aircraft would have been refuelled after either the first or second flight of the day. Had it been after the second flight, then the aircraft should have departed with sufficient fuel in either tank to conduct the entire flight. However, had the aircraft been refuelled after the first flight of the day then it would still have departed with sufficient fuel for the flight, but this would have been contained in only one of the wing tanks. In this case, the opposite tank would contain some reserve fuel sufficient, theoretically, for about twenty minutes of flight. However, the actual endurance to be expected from this fuel would depend on the exact quantity contained in the tank after re-fuelling, and the actual fuel consumption rate of the engine. (Although the fuel gauges were considered to be inaccurate, the indication from a tank with a very low level of fuel should still have shown as a low quantity in this scenario.)

The refuelling records held by the parachuting school and the aircraft log, did not contain sufficient information on the precise fuel load and its distribution on G-BGED, prior to the accident flight. Whilst no witnesses could be identified who actually saw the aircraft being refuelled, circumstantial evidence suggests it was refuelled at least once during the day. Most notable was the reading on the bowser's fuel gauge which equated to a single uplift for G-ATLT after having completed three flights up to 10,000 ft, at approximately 10 US gallons (38 ltr) per lift. This indicates that the gauge had been zeroed in between the two refuels carried out to G-ATLT that day. As the pilot of G-BGED was reportedly in the habit of zeroing the gauge after refuelling, this also suggests that G-BGED was re-fuelled at some time between midday and about 1430 hrs.

The pilot involved in the accident was known to have operated G-ATLT on the sole flight he conducted on that aircraft that day, with the right fuel tank selected. This was established by the personal fuel record sheet for that aircraft compiled by the other pilot. It is possible, therefore, that when he flew G-BGED, he mentally decided to select the opposite tank on his next flight. If this was so, then he would have departed in G-BGED with the left tank selected, as the position of the tank selection valve found at the accident site would suggest. However, it is possible that the tank selection could have been changed in flight prior to the accident, possibly in an attempt by the pilot to sort out the problem.

The nature of the fuel tanks in this aircraft, being wide and long compared to their depth, means that, as such a tank becomes depleted, small 'packets' of air are initially drawn into the fuel supply as the fuel sloshes about due to turbulence and aircraft attitude changes, particularly if the aircraft were in level flight. This would cause the outlet pipe/stack to be intermittently uncovered. Initially, this is likely to have a minimal effect on the operation of the engine as the collector tanks are likely to remain fairly full but, as the level of fuel in the main tank diminishes further, more air and less fuel would be progressively drawn in, leading to increasing intermittent operation of the engine and finally to complete loss of power.

On the previous reported occasion where engine power was lost suddenly due to exhaustion of the fuel from the selected tank, the aircraft was in the climbing attitude, ie nose high, and this may have reduced the sloshing of the fuel and have led to a more sudden loss of power as the fuel became depleted. Subsequently, due to the height of the aircraft at the time, the engine was able to be re-started but it then ran roughly at reduced power 'missing' and 'coughing', probably due to air/fuel vapour having been introduced into the fuel supply to the engine. The symptoms, described by witnesses towards the end of the accident flight variously as "misfiring, spluttering, revving loudly and cutting out", are similar to those described above after the engine had been re-started. In the absence of any other defects being discovered during the investigation, these symptoms are consistent with the engine being starved of fuel but, on this occasion, after G-BGED turned back, the aircraft had insufficient height from which to glide to the airfield.

Witness evidence also indicated that fuel had been leaking from the right tank immediately after the impact and 15 litres were recovered from this tank. Witnesses were inconclusive as to whether fuel was leaking from the left tank but, as mentioned above, no fuel was recovered from this tank. However, as subsequent testing indicated that there was no significant path for any fuel that may have been contained to drain away, the possibility was raised that it was the left tank that contained little or no fuel at the time of the accident. If this were so then, when considered with fuel selector position as found and similarity of symptoms between this event and that which occurred on 19 August 2000 with G-ATLT, the possibility that the loss of engine power on the accident flight could have resulted from fuel starvation, following depletion of the contents of the left tank, could not be discounted.

Fuel system debris

The fuel system in G-BGED, was found to contain a significant amount of debris of unknown origin in the fuel metering unit filter which, during the previous 50 hour check, was not scheduled to be examined. Therefore, the debris, or a good proportion of it, was considered likely to have been present at the time of the power loss on the flight prior to the most recent maintenance, as the aircraft had only flown for some 1 hour 10 minutes since the check. Post that event, engine runs showed that full power could be obtained and, indeed, the aircraft had flown to and from Exeter Airport and preformed two parachutist dropping flights prior to the accident flight, without any reported engine power problems. Also, operating a new engine with this contaminated filter installed did not cause any performance loss. Therefore, debris in the filter would not appear at first sight to have been responsible for the earlier reported engine problem, and was unlikely to have caused the engine to fail on the accident flight, unless it had built up suddenly during the last flight.

The source of the debris was not established. However, engine test was conducted some weeks after the accident and after the filter had been disturbed by the very act of removal and transportation to the test facility. Thus, the debris might have somehow subsequently changed in nature, or possibly have become redistributed within the filter, changing its flow characteristics. The possibility, therefore, that it was a causal factor in the loss of engine power on the accident flight could not be dismissed.

Auxiliary fuel pump

The auxiliary pump START switch was found in the ON position, although it was possible that it could have moved to this position in the impact. If this were a valid pre-impact setting, then operation of the engine with this selection would result in an excessive fuel/air ratio, resulting in 'rich' running, with a consequent loss of power, or possibly a 'rich cut'. However, it is also possible that the pilot could have intentionally operated this switch when the engine problem first manifested itself, either in an attempt to restart the engine, or to overcome what he could have suspected to be an engine driven fuel pump failure. Operation of this switch could also help to purge air/vapour from the fuel system, should the selected fuel tank have become depleted[2].

Alternator belt

The adjustment of the alternator belt that was believed to have been made following the first flight of the day, was thought to have been carried out by an unqualified person; however, the belt was found to be correctly tensioned and a slack belt would not have caused a loss of engine power.

Aircraft handling

On the day of the accident, the pilot had previously climbed to altitude to the north of the airfield whilst flying G-BGED, and the pilot of G-ATLT expected him to do so again on the accident flight. The weather was such that visibility was good and the pilot of G-ATLT, who was flying just ahead of G-BGED, reported no difficulty with cloud in climbing to altitude. During this period, G-BGED was subject to a reasonably strong tail wind, which increased its relative groundspeed whilst flying towards the east, away from the airfield. It is difficult to determine exactly at which point the engine problem first became apparent to the pilot, although the aircraft's rate of climb was normal for the first 2.5 minutes of the flight. It is possible that the pilot had begun to level off due to the presence of localised cloud, but reports from the pilot of 'LT and witnesses at the accident site indicated that, in the area in which he was flying, cloud cover should not have impeded his ability to climb. Also, data from the GPS receiver showed that at no time, within the resolution of the data, did the aircraft fly level, which might be expected had the aircraft been transitioning under cloud to a clear area in which to continue the climb. The progressive nature of the change in the climb rate to a rate of descent, all of which occurred at around 80 kt, in addition, suggests that a reduction in power had occurred early in the flight, at about the 2.5 minute point.

If indeed the reduction in the climb rate at this point was due to the onset of a problem with the aircraft, rather than a problem with cloud, then the aircraft was

Footnote

[2] Partial or complete interruption of the fuel flow can also be caused, in certain types of aircraft, by the formation of 'vapour lock' in the fuel system, after the aircraft has been parked following a period of operation. Vapour is the result of the more volatile fractions of the fuel boiling off due to heat soak whilst the aircraft is parked, either from the airframe being exposed to warm sunshine, and/or from proximity of the fuel lines to the hot engine. It is more common in aircraft with low set wings (tanks) and with engines using Mogas. In this case, it is thought unlikely to have occurred as the C206 is a high winged aircraft, which results in the fuel lines always being under a positive pressure relative to atmosphere.

reasonably close to the airfield at this time and it should have been possible to complete a circuit and land back on the runway within the remaining time of the 7 min 31 seconds flight. However, the aircraft turned back for the airfield some five minutes into the flight, when it was 5.7 nm from the runway and by this time it was apparently having increasing difficulty maintaining altitude. The aircraft was also now having to fly into a headwind, increasing the time that would otherwise be required to return to Dunkeswell.

Towards the end of the flight, the recorded GPS track shows the aircraft turning away from an area of high ground (Dumpdon Hill) and on to a northwesterly track. This took the aircraft towards another area of high ground at Hartridge. The pilot's comments on the radio that he thought he wouldn't make it back to the airfield were probably made at about this time, as the aircraft was struggling to maintain altitude and terrain clearance from the rising ground. Hartridge runs approximately north-south and is quite flat on the top, and would probably have presented the best area in the immediate vicinity on which to make a forced landing. However, the aircraft was approaching from the east and the pilot would have been presented with quite a short distance in which to land without making a 90º turn. This may have been why the pilot selected full flap (40°) as he became concerned about the aircraft overshooting the chosen landing area ahead. This flap setting would normally only be used when a landing in the desired area is assured, as this degree of flap provides a large amount of drag[3]. It is possible that it was selected late in the flight and the combination of increased drag and rising terrain would likely have induced the pilot to continue to increase the pitch attitude of the aircraft in order to stay airborne. This view is supported by the fact that there was evidence of the aircraft having made contact with the tops of trees immediately before the field into which it crashed, over a distance of approximately 100 m. The impact attitude and final trajectory of the aircraft were both consistent with the aircraft having stalled just prior to striking the ground, probably at about the time the right tailplane made contact with a tree sufficiently hard for its leading edge to be dented.

Footnote

[3] The best glide distance is achieved with a 'clean' aircraft flying at the optimum speed. In this case, delaying the selection of (full) flap would have improved the pilot's chances of gliding to the likely selected landing area.

Operational oversight

It has been common practice over many years, in sporting aviation activities in the UK, that powered aircraft may be flown by pilots holding only a PPL, despite the fact the such operations may have a commercial aspect to them. Generally, this benefits the sports involved as they do not have to pay for the services of professional pilots; indeed it is possible that many sport aviation clubs would become financially unviable if they were required to do so.

The situation, however arises, where members of the public, ie, not regular club members, wish to experience a particular activity and pay to undertake, for example, a tandem-free-fall parachute jump with an instructor. Of importance is the expectation of the standard of operation being received by these members of the public paying for activities for which there is a clear profit motive attached by the provider. It is questionable whether those novices partaking in such activities are aware that, despite paying for their experience, it does not necessarily mean that either the pilot or aircraft are operating to the normal commercial requirements.

The imposition by the CAA of these requirements for commercial aviation activities is not reliant purely on the generation of profit. This might be considered to offer sporting organisations an advantage over other forms of aviation where such commercial activity requirements have been imposed. However, it is accepted that most aviation clubs exist primarily to provide the means of undertaking a sporting activity rather than to provide a business opportunity, but the definition is blurred as to where the boundary between the two lies. It is believed that this position is currently being examined by the European Aviation Safety Agency (EASA) although the outcome is currently unknown.

Both the CAA and BPA believe that, whilst a commercial licence is not required, the additional training required to become a qualified parachuting pilot compensates as the core skills required do not form part of normal commercial pilot training in the first place. This is accepted to a point but, as discussed in other parts of this report, anomalies in aspects of this training and oversight have been noted.

It is accepted by all parties that parachuting operations place a considerable strain on aircraft with frequent take offs, landings and climbs at maximum power followed by descents at reduced power. In more usual commercial operations where fare paying passengers are carried, certain standards are required by the CAA to be met by operators, and these are often embedded in the Air Operators Certificate (AOC). The standards set by an AOC would likely be quite onerous and a financial burden to sporting aviation organisations and, probably, would not be wholly appropriate. The oversight of civil sport parachuting by the CAA and BPA, where aircraft certificated in the Private category may be used, is meant to maintain acceptable standards of civil parachuting activities, an inherent part of which is the operation and maintenance of these aircraft. Whilst the circumstances relating to the maintenance/operation of G-BGED, ie, the absence of detailed fuel records, poor quality of fuel samples, contamination of the aircraft fuel system, and poor quality 'unapproved' maintenance of the alternator, were determined as not being causal factors in this accident, they are perhaps an indication that this aircraft, and possibly others in similar situations, may not be maintained/operated, to a high standard on a day-to-day basis.

Aircraft used in commercial operations, including light single-engine aircraft similar to that involved in this accident, are usually certificated in the Transport (Passenger) Category and hence subject to a more intensive maintenance schedule than aircraft in the Private Category. The parachuting school's own aircraft, G-ATLT was in fact certificated in the Transport (Passenger) Category. However, it should be noted that the basic requirement for maintenance to be managed, with defects being rectified and controlled, are the same for both private and public transport operations.

The circumstances of this accident illustrate an occasional scenario in the operation of light aircraft, where a reduction of available engine power, or complete engine failure, results in an accident instead of a successful forced landing. The particular terrain over which the aircraft might be flying being unsuitable for a successful forced landing, or the lack of experience of the pilot in the particular circumstances to conduct such a landing, are often contributory factors. When training for a PPL, pilots are taught to cope with an engine failure at different stages of flight, be it soon after takeoff (where options are usually limited to landing somewhere ahead), or at altitude (typically 2,000 ft) where sufficient time is usually available to plan a successful landing. However, after a licence is gained, only once in every 24 month period are private pilots required to fly with an instructor as a means of maintaining minimum flying standards, although this should include a review of various emergency situations that might reasonably be encountered.

To minimise the risks to student parachutists, whilst allowing clubs to operate with PPL rated pilots, the CAA and the BPA require, as part of their oversight procedure of parachuting clubs, that they appoint suitably qualified CCPs to specifically oversee the operation of the aircraft and its pilots. Such oversight is expected to ensure, as far as is reasonable, that new pilots are given adequate training and that the currency, abilities and specific knowledge of any pilot approved by the particular club to fly the dropping aircraft, is maintained at an acceptable level. This should, reasonably, include the ability to carry out a forced landing with minimum risk to the aircraft. In addition, CCPs are responsible for ensuring that the aircraft are kept airworthy in accordance with the normal CAA requirements. Maintenance of high standards with regard to fuel storage and refuelling operations is also required under this oversight. In practice, CCPs are not necessarily pilots with professional qualifications.

In the circumstances surrounding the accident to G-BGED, two factors stand out relating to the oversight of the operation of the aircraft, as distinct from the conduct of the parachuting operations. Firstly, there was a lack of positive control over the aircraft refuelling operation. The most direct effect of this was to hamper this investigation, in that the fuel load and distribution on G-BGED prior to the accident flight could not be precisely established from records. This, together with the lack of high quality fuel samples and the debris found in the filters of both aircraft operated by the school, raised questions about the oversight of the club's fuelling operation.

Secondly, given that the takeoff, left turn and initial climb were all apparently normal, the height gained, and hence time available to land the aircraft following the apparent onset of the problem some 2.5 minutes in to the flight, where the flight profile began to deviate from that expected, would have allowed the pilot to recover the aircraft back to the airfield within the time that it subsequently remained airborne. This would have been the most prudent course of action, particularly so as the hilly local terrain did not present many areas in which a forced landing might be made without undue risk. If the power loss had indeed occurred at the 2.5 minute point, it would seem that, in attempting to solve the problem, the pilot did not turn back until the aircraft was some miles downwind of the airfield, five minutes in to the flight and apparently unable to climb or maintain height. Although the pilot of G-BGED was current, within the CAA requirements in terms of flying hours, he had only flown on three other days in the previous six months, all flights being parachutist dropping flights, and before that, since 7 December 2003, only two flights in a Piper Super Cub totalling one hour fifty minutes. This is below the currency requirements of many flying clubs. Again, this raised questions concerning the abilities and recurrent training of pilots when faced with non-normal situations, and hence the oversight of flying operations.

Whilst it would be understandable that a low hours/experience private pilot on a recreational flight might, under similar circumstances, be working to capacity and possibly delay making a prudent decision to return, the oversight of pilots engaged in flying aircraft on parachuting operations should ensure that they make the most appropriate decisions when any flight does not proceed normally. This is particularly so as the pilot must assume total responsibility for the 'passengers', all of whom are paying either directly or indirectly for what is effectively a commercial service. As a result of the above findings, the following safety recommendation is made.

Safety Recommendation 2005-041

It is recommended that the Civil Aviation Authority, in consultation with the British Parachute Association, review their oversight of Parachute Schools, to ensure that the procedure currently in place adequately addresses its original intent, ie the establishment and maintenance of the highest reasonable standards of operation of such schools, including the operational standards for the aircraft and pilots engaged in parachuting operations.

Documentation

General concerns were raised during this investigation in relation to the documentation covering the operating of parachuting aircraft. In particular, the Operations Manual did not detail a training and test syllabus for initial qualification and renewal testing of parachute pilots. The BPA stated that the Pilot's Information Manual is in the process of being re-written, although this was suspended pending the outcome of this investigation. The following two safety recommendations are therefore made.

Safety Recommendation 2005-042

It is recommended that the British Parachute Association revise sections of the Operations Manual relating to the operation of parachuting aircraft, with the intention of clarifying the flying training syllabus and test syllabus required to qualify as a parachute pilot.

Safety Recommendation 2005-040

It is recommended that the British Parachute Association review the contents of the Pilot's Information Manual to ensure that all information contained is accurate, presented clearly in a professional manner and that a procedure is adopted to ensure that any future changes are promulgated expeditiously to all member clubs.

Survivability

The nature of the injuries sustained by the jumpmaster, who was positioned, unrestrained, next to the open door, suggests he was outside the aircraft when he hit the ground. His close proximity to the wreckage suggests that if he did exit the aircraft, it was at a late stage, possibly when the aircraft yawed following the impact with the trees. The yaw may have been sufficiently violent for him to have been thrown out of the open door on the right side of the aircraft. If so, then he would not have had the necessary height or time to deploy his parachute and, indeed, he was found with no apparent attempt having been made to initiate such a deployment.

With the possible exception of the jumpmaster, the parachutists in G-BGED were seated facing aft; this is generally accepted in parachuting operations as preferable to facing forwards, especially if the occupants are adjacent to a bulkhead which can react deceleration forces during any forced or crash landing. In this case, as is also normal in many parachuting operations, particularly those using smaller aircraft, the occupants had neither restraints nor seats and therefore their movement relative to the cabin during the impact was not controlled. Also, the lack of seats prevented any potential attenuation of the vertical impact loads although, in this case, the pilot's seat failed and he also suffered similar injuries to most of the parachutists in addition to striking the instrument panel. The only occupants not to sustain pelvic injuries were at the rear of the cabin and one of these was the jumpmaster whose injuries were consistent with falling to the ground separate from the aircraft. Had the occupants been on seats, it is possible that the severity of the internal injuries might have been reduced due to attenuation of energy and peak loading by the seat structure during the impact, although seats not specifically designed with crashworthiness in mind may themselves cause injuries.

However, the provision of seats for parachutists in a relatively small aircraft such as the Cessna 206 would be impractical and severely limit the freedom of movement within the cabin. This would also pose a threat to the safety of day-to-day parachuting operations, with risk of snagging and deployment of parachutes whilst in the aircraft. The cabin floor, however, has the potential in 'survivable' accidents, to offer a measure of protection if material with an ability to absorb energy were to form part of the floor. The following recommendation is therefore made.

Safety Recommendation 2005-043

It is recommended that the British Parachute Association, in consultation with the Civil Aviation Authority, consider issuing a requirement for appropriate energy attenuating material to be installed as flooring in aircraft engaged in parachuting operations, where the occupants are required to be seated on the floor.

The BPA Operations Manual does not provide guidance on whether tandem jumpers should remain attached during an emergency. If an emergency parachute descent from the aircraft has been discounted and a forced landing is imminent, it seems prudent to disconnect the two jumpers harnesses to aid egress from the aircraft, especially should one or other parachutist become incapacitated. On this occasion, whilst both tandem jumpers survived the immediate impact, it is still unclear if and how the student jumper managed to become free from his instructor. The following recommendation is therefore made.

Safety Recommendation 2005-044

It is recommended that the British Parachute Association include specific advice in their Manuals detailing emergency situations, in aircraft engaged in parachuting operations, concerning when conjoined tandem jumpers should separate from each other.

Although the impact was severe, this was a survivable accident, in that there were two survivors. The lack of any restraint system in the aircraft for the parachutists is an accepted practice as it allows safe and quick egress when jumping from the aircraft without, as mentioned above, the danger of tripping or snagging equipment on any seat structures or floor attachments. However, in the case of an emergency landing, the occupants are afforded little protection from any impact forces.

The BPA Operations Manual states that in an aircraft emergency the jumpmaster should follow the instructions from the pilot where practical. In the BPA's Jump Pilots' Manual it states that in case of an engine failure above 500 ft, the parachutists may decide to jump and, above 1,000-1,500 ft, they will almost certainly jump. This advice does not relate to tandem parachutists who would require significantly more height before jumping. Figure 9 shows that when the aircraft achieved its maximum altitude it was about 1,100 ft above the ground. This should have been sufficient for the three single parachutists to have been able to make an emergency jump from the aircraft. It must be understood, however, that the undulating nature of the ground below the aircraft and the attention being given to resolving the problem, might have affected the ability of both the pilot and jumpmaster to make a timely decision on whether or not the parachutists should jump. Once the aircraft could no longer maintain altitude and started to descend, little time remained for a decision to jump to be made before the aircraft was too low.

On larger aircraft such as the Cessna 208 Caravan, which can accommodate up to 14 passengers, restraint systems for use by parachutists when engaged in parachuting operations are required and fitted. The requirement for restraint is to prevent parachutists from sliding around the cabin floor during aircraft manoeuvring, and possibly causing control difficulties by shifting the aircraft's centre of gravity position. These systems are not necessarily designed to improve survivability in a crash situation. The cabin of the Cessna 206 is relatively small and there are no known control difficulties having arisen from the movement of parachutists. However, the use of a restraint system may have prevented the fall of the jumpmaster from the aircraft and, generally, might reduce injuries resulting from, for example, parachutists towards the rear of the cabin crushing those at the front. The following recommendation is therefore made.

Safety Recommendation 2005-045

It is recommended that the British Parachute Association, in consultation with the Civil Aviation Authority, consider the practicality of installing appropriate restraint systems for parachutists in all aircraft engaged in parachuting operations.

The student tandem parachutist who survived the accident could not recall any information that might have been given before takeoff on the brace position to adopt in case of emergency. It was one of the other parachutists on the aircraft who described the brace position he should adopt with his head on his knees. This would be a suitable brace position in a forward facing 'airline' seat with a lap belt where the occupant is likely to be thrown forward during an impact. Adopting a similar position whilst facing rearwards is probably the worst position to adopt, and is likely to result in the head and upper body being rotated backwards (towards the front of the aircraft) and being brought rapidly to a halt should they strike a fixed structure or the person behind. Ideally, rearward facing occupants should brace their backs against a fixed structure, such as a seat back or a bulkhead, but in this case no such structures were available for all the occupants. It was difficult in this investigation to determine whether the brace position described, and if adopted, adversely affected survivability. However, it would seem sensible to review the benefits of appropriate 'brace' positions for parachutists across the range of aircraft engaged in parachuting operations, and so the following recommendation is therefore made.

Safety Recommendation 2005-060

It is recommended that the British Parachute Association, in consultation with the Civil Aviation Authority, establish an appropriate 'brace' position for each seating position on aircraft engaged in parachuting operations.

G-BGED had been approved by the CAA in 1982 for use in parachuting operations. The CAA supplement to the Owner's manual provided details for the aircraft operation specific to parachute jumping. This included the removal of all seats, with the exception of the front left pilot's seat, and the securing of all loose equipment. Reconstruction of G-BGED's cabin interior, and examination of the other Cessna 206 used by the club, revealed that other further changes had been made; the presence of a wooden box beneath the right side of the instrument panel and a tennis ball fitted over the right control tube stub. Although these additions were intended to improve the cabin interior with regard to the accommodation of the parachutists, they were 'amateur' modifications and thus the aircraft was not configured to an approved standard. However, it should be possible to modify such aircraft interiors in a manner that improves the accommodation of parachutists without degrading its crashworthiness. Had the configuration been submitted to the CAA for approval, they state that the security and crashworthiness of the installations would have been considered. However, with the introduction of EC Regulation 1702/2003, the cabin configuration and the approval of any changes lies with the European Aviation Safety Agency and no longer with the CAA. The following recommendation is therefore made.

Safety Recommendation 2005-061

It is recommended that the British Parachute Association, in consultation with the Civil Aviation Authority and the European Aviation Safety Agency, conduct a review of cabin interiors on aircraft engaged in parachuting operations with regard to improving their crashworthiness.

Availability of recorded data

Witness statements, radar and wreckage analysis did not yield any definitive cause for this accident. Although there are no requirements for aircraft in the Private category, such as G-BGED, to carry any equipment for recording flight parameters or cockpit audio information, on this occasion data retrieval from the Skymap 11 GPS yielded altitude information that would otherwise have been unavailable. This enabled an understanding of the last flight, but not the reason for the aircraft's degraded performance. The investigation of this accident would have been greatly enhanced had audio and basic flight parameter recordings, such as attitude and propeller speed, been available. Thus, in accidents where there is extensive disruption of the aircraft, it may not be possible to determine the causal factors from wreckage analysis and witness evidence alone. This has proved to be the case in a number of investigations, including a recent one into a Hughes 369HS accident, G-CSPJ, the report on which was published in AAIB Bulletin 1/2005.

The circumstances of that accident were that a private pilot had hired the helicopter from a commercial organisation for a private flight. The helicopter was certified in the Transport (Passenger) category and as such would come under the heading of a Commercial Air Transport (CAT) aircraft, but was not required to carry flight recorders as it fell below the weight category where recorders are required. The AAIB has conducted or assisted with many investigations where flight recorders have provided invaluable information which has contributed to the understanding of CAT accidents. As technology now enables lighter, cheaper and more compact electronic devices including, potentially, basic flight recorders, to be made, consideration should be given to encouraging owners, operators and manufacturers to fit such recorders to as wide a range of aircraft, however small, with special emphasis, initially, on those that have a Certificate of Airworthiness in the Transport (Passengers) category. This would increase the proportion of air accidents where the causal factors would be fully understood, thereby improving the aviation community's knowledge of how to minimise the number of future accidents.

Two safety recommendations were made in the report on the accident to G-CSPJ, both to the Department for Transport, one of which stated the following:

'Safety Recommendation 2004-84

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

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

It will be the AAIB's intention to recommend the fitting of appropriate airborne recording equipment, initially most likely a miniature CVR once such equipment becomes available, initially to these smaller CAT aircraft. While recommending such a measure, it is appreciated that the arguments against doing so are financial, technical and operational, but it is envisaged that these arguments will diminish as technological progress reduces the financial burden of installing such recorders. However, in order to design lightweight inexpensive equipment, minimum standards of design will need to be set. The following recommendation is therefore made.

Safety Recommendation 2005-062

It is recommended that the European Aviation Safety Agency develop standards for appropriate recording equipment that can be practically implemented on small aircraft.

ACCIDENT

Aircraft Type and Registration:	Denney Kitfox, G-FOXX
No & Type of Engines:	1 Rotax 532 piston engine
Category:	1.3
Year of Manufacture:	2004
Date & Time (UTC):	2 August 2005 at 1510 hrs
Location:	Upper Harford, Gloucestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - Nil
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	696 hours (of which 13 were on type) Last 90 days - 11 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

After a 50 minute local flight from a private airstrip, the pilot returned for a landing. The airstrip had a surface of dry grass and was approximately 700 m long. For the departure from Runway 26, the pilot had assessed the surface wind as light and variable. However, during the flight he noted that the wind appeared to be gusting and decided to use a touchdown point some ⅓ distance into the strip to avoid known turbulence from nearby trees. For his approach, he assessed the surface wind as 270°/ 5 kt with gusts of 10 to 15 kt.

The pilot reported that he made a steep approach and commenced a flare at about 40 mph for an intended three-point landing. In the flare he was aware of the left wing going down and, with the control column near the rearmost position, he was unable to apply sufficient aileron to correct the roll. He increased power and applied some right rudder in an attempt to raise the left wing. This was successful but resulted in the aircraft heading towards some houses on the right of the airstrip. The pilot then decided to go around so he applied full power and right bank with the intention of passing over a clear area to the right of the houses. However, the right wingtip contacted the ground and the aircraft crashed some 20 to 30 ft from the northern edge of the airstrip.

Pilot's assessment

The pilot considered that the accident resulted from both his lack of experience on type and on the effect of a gusting wind on the aircraft type.

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-AMTV
No & Type of Engines:	1 De Havilland Gipsy Major I piston engine
Category:	1.3
Year of Manufacture:	1935
Date & Time (UTC):	9 August 2005 at 1230 hrs
Location:	Oaksey Park, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - None
Nature of Damage:	Both wings, the rudder and propeller damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	497 hours (of which 28 were on type) Last 90 days - 11 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was refuelled after being flown three times earlier in the day and the pilot then briefed his passenger for the next flight. After a normal engine start, taxi and power checks, the takeoff was commenced on grass Runway 04 which is 30 m wide. The surface wind was estimated to be 320º/5 kt and the temperature 23ºC. Full power was selected and the control column moved fully forward with sufficient left aileron to counteract the crosswind. The pilot became concerned during the take-off roll that the tail was not rising at its usual rate. At approximately 40 kt IAS, with the tail still not properly elevated, the left wing lifted. Although the pilot was able to correct this with full left aileron, the aircraft drifted right towards the standing crop of maize growing by the side of the runway. The aircraft became airborne at 50 kt IAS with the pilot's intention being to gain further airspeed in level flight before climbing away. However, the drift to the right continued and the right main wheel contacted the crop causing a yaw to the right, a decrease in airspeed and subsequent descent into the crop. As the aircraft contacted the crop, it pitched onto its back. The damage to the aircraft was assessed as beyond economic repair.

Both occupants, who were wearing four point harnesses, were able to vacate the cockpit with the pilot suffering from minor cuts and bruises.

ACCIDENT

Aircraft Type and Registration:	Europa (Tri-gear variant), G-PUDS
No & Type of Engines:	1 Rotax 914T turbocharged piston engine
Category:	1.3
Year of Manufacture:	1997
Date & Time (UTC):	7 June 2005 at 1540 hrs
Location:	Curry Rivel, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, nose landing gear and fuselage underside
Commander's Licence:	Private Pilot's Licence
Commander's Age:	69 years
Commander's Flying Experience:	13,700 hours (of which 2 were on type) Last 90 days - 5 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB examination of the nose landing gear components

Circumstances

The aircraft had recently been purchased from the previous owner, who had also built it. A few days prior to the accident the new owner, together with another, more experienced pilot had attempted to fly it from Cumbria to its new base at Curry Rivel in Somerset. A condition of the purchase was that the aircraft came with a renewed Permit to Fly. Whilst the work for this had been completed, the flight test had not been conducted due to the lack of a suitably qualified person: it was therefore decided to accomplish this during the ferry flight. However, the flight test had to be abandoned when it was realised that the engine was developing insufficient power to meet the performance requirements, although the two occupants decided that this would not prevent the continuation of the flight to Somerset. Sometime later, the flight had progressed as far as Herefordshire when the engine temperature was seen to rise suddenly, which necessitated an immediate precautionary landing. Fortunately a farm strip came into view, and apart from the fact that the electrically operated flaps would not deploy, an otherwise uneventful landing was made. Afterwards it was noted that coolant was leaking from a small crack in a radiator joint. The crew were forced to leave the aircraft where it was, and to make alternative arrangements to get home.

Two days later, the new owner, together with the same pilot who had accompanied him on the earlier flight, drove to the Herefordshire airstrip and made temporary repairs to the engine. It was arranged that the owner would drive back to Somerset and meet the aircraft there. After they had satisfied themselves that there were no leaks, the pilot boarded the aircraft and took off, observed by the owner, who noticed nothing untoward.

The flight progressed without incident until arrival at the Curry Rivel circuit, where the pilot found that once again the flaps would not operate. As a result he made three approaches in order to assess the handling prior to committing to a landing. Just before touch down, a gust of wind disturbed the aircraft resulting in a "firm" landing. The pilot was nevertheless surprised when, during the roll-out, the nose dropped and the aircraft subsequently came to rest at the side of the runway, having sustained damage to the propeller and nose underside. The pilot was uninjured and exited the aircraft without assistance.

It was immediately evident that the nose wheel, together with its fork assembly, had become detached; however they were nowhere to be found. The pilot examined the marks made by the aircraft on the grass surface of the runway, which seemed to suggest that the wheel may have been missing before touchdown. This view was also formed by the aircraft owner when he subsequently arrived at the airfield by road. The nose wheel assembly was never found, despite searches of the Curry Rivel and Herefordshire airstrips.

Description of the nose landing gear

The nose landing gear leg on this type of aircraft comprises a length of steel bar attached to the aircraft structure at the rear of the engine compartment. The geometry is such that the leg makes an angle of approximately 30º to the horizontal. The nose wheel fork assembly is attached by means of a shaft to a cylindrical housing welded to the lower end of the leg; - see Figure 1. The shaft is a light interference fit in the top of the fork assembly, with positive location achieved by means of a rolled steel pin inserted into fore-aft drillings in the fork and the lower portion of the shaft. The threaded upper end of the shaft is inserted through a bushed hole within the cylindrical housing and is secured by means of a nut,

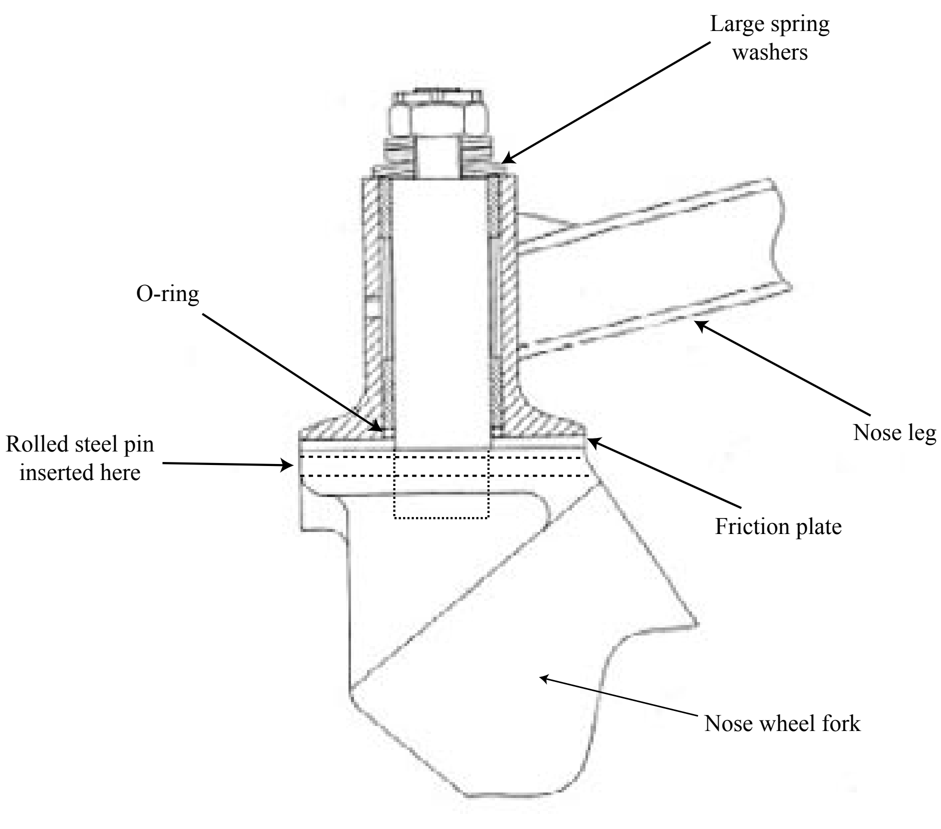


Figure 1

Details of attachment of nose wheel fork to leg which tightens down onto a stack of spring washers. These, in conjunction with a friction plate between the fork and the housing, allow the nose wheel to castor.

Examination of the aircraft

The loss of the nose wheel fork had left the stub of its associated shaft protruding from the bottom of the housing on the nose leg. This had clearly dug into the ground during the landing roll, causing the leg to be bent aft around its approximate mid point. Figure 2a shows the lower end of the leg, complete with the housing and nose wheel pivot shaft. It can be seen that the nut on top of the housing had been secured by a split pin and the lower end of the shaft had sustained considerable distortion in the accident, having been bent in an aft direction. It was also apparent that the lower of the two bronze bushes had partially migrated out of the housing during the failure process. The remains of the rolled steel pin had been retained within the bore of the shaft, both ends having suffered shear failures. Figure 2b shows a close-up view of the end of the shaft, where it can be seen that two holes have been drilled, in the same plane but at 90º to each other. Since the shaft had been supplied by the kit manufacturer in an un-drilled state, it was concluded that the two holes had been made during the construction of the aircraft, the first perhaps being slightly out of position, thus necessitating the drilling of the second hole. Also visible in Figure 2b is one of four cracks emanating from each of the holes and running longitudinally to the lower end of the shaft. It was considered that these occurred as a result of the rearwards distortion, with the sum total of all the damage being entirely consistent with a significant overload, such as could be caused by a hard landing or striking an obstruction.

Flap system

The flaps on this aircraft are powered by a DC electric motor that is supplied from the battery via a circuit breaker. It was subsequently found that an unlabelled toggle switch on the centre console functioned as an isolation switch, which, when moved to the opposite position at which it was found following the accident, allowed the flaps to operate normally. This switch did not appear in the electrical diagram in the Europa Build Manual.

Figure 2a

View of nose leg, showing distortion of lower end of attachment shaft

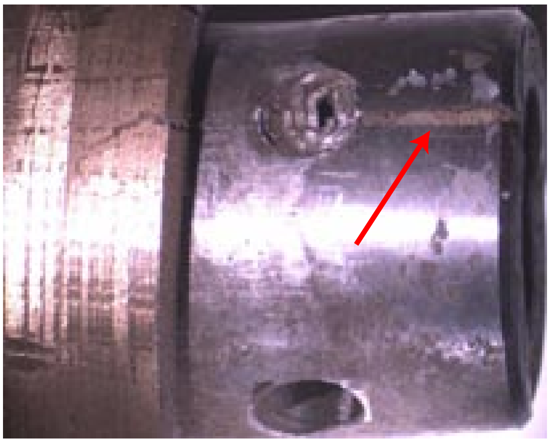


Figure 2b

Close-up view of shaft, showing additional drilling, remains of rolled steel pin and crack (arrowed)

The airworthiness aspects of this class of aircraft are administered by the Popular Flying Association (PFA); changes or modifications can be embodied to the constructor's requirements, subject to some caveats and the authorisation of the local PFA Inspector. The new owner had had no communication with the Inspector concerned with the subject aircraft as had been unable to obtain the necessary contact details from the previous owner. However, it should be noted that all Inspectors' details are available via the PFA. It was later established that the Inspector concerned with this aircraft was unaware of the modification to the flap operating system.

Other information

During the investigation, the aircraft owner indicated a number of features about the aircraft that had led him to become dissatisfied with his purchase. For example, he noted that a narrow bladed propeller was fitted, instead of the recommended broad blade version from the same manufacturer. This may have accounted for the apparent lack of power observed on the test flight (although it is also possible that the turbocharger waste gate was incorrectly adjusted). In addition it was apparent that the nose leg fairing had been the subject of an earlier repair using duct tape. The owner had been unable to establish from the previous owner how and when this damage had occurred. Examination of the fairing, which was non-standard and appeared to be to the previous owner's own design and construction, revealed that it consisted of a foam lined glass fibre moulding that fitted over the cylindrical section of the nose leg: it made no contribution to the strength of the landing gear. The fairing had broken during the accident but it was clear that tape had been applied to two separate areas, although only one area showed evidence of a pre-existing crack: no pre-existing damage was apparent on the leg itself. It was concluded that the damaged fairing bore no relevance to the subject accident. However, this damage, plus the crack in the radiator, the additional hole on the nose wheel fork shaft and the different propeller had led the owner to suspect that the aircraft may have suffered a previous incident, which weakened the fork attachment.

Discussion

Damaged nose landing gears feature prominently among the minor accidents and incidents to general aviation aircraft that are reported to the AAIB. This one was unusual in that the detached nose wheel could not be found after the accident, suggesting that the failure occurred elsewhere. Furthermore the inoperative flap system may have presented difficulties, albeit minor, in landing the aircraft, to a pilot who was inexperienced on type. Ultimately however, the nose wheel fork detached as a result of a simple overload failure of the shaft that attached the fork to the leg. The shaft should have been a light interference fit in the fork; this would normally result in fore-aft loads in the fork placing the shaft in shear. Any looseness in the fitting would give rise to a degree of bending and also produce shear loads in the retaining pin. The extent of the distortion in the bottom of the shaft, plus the absence of the fork, meant that the quality of the fit could not be checked. It could be argued that the additional hole drilled in the shaft caused a slight weakness; this would probably only be significant in the event of a loose fit between the shaft and fork. However it appeared unlikely that it would be weakened to the extent that a failure could result from normal landing loads.

The absence of the nose wheel assembly from the accident site suggests that the damage may have occured at the Herefordshire strip, with some evidence pointing to the possibility of an earlier incident. However, whenever it occurred, the degree of distortion in the shaft to which the fork was attached ought to have made this damage clearly visible, although it seems probable that the nose wheel became detached during or perhaps shortly after the takeoff from Herefordshire.

The apparent problem with the flaps stemmed from an unlabelled switch in the cockpit, which in turn pointed to an inadequate handover briefing when the current owner purchased the aircraft. The reason for the additional switch was not established, but such additions to the electrical systems of kit-built aircraft are not uncommon, and can legitimately be incorporated provided the necessary advice is sought from the PFA Inspector.

Following this incident the PFA expressed concern that the aircraft, which had no Permit to Fly, had been force-landed during a long ferry flight, with the subsequent rectification work and resumption of the flight being undertaken without any reference to them.

ACCIDENT

Aircraft Type and Registration:	Europa XS, G-CGDH
No & Type of Engines:	1 Rotax 912 ULS piston engine
Category:	1.3
Year of Manufacture:	2004
Date & Time (UTC):	27 August 2005 at 1450 hrs
Location:	North Moor, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Port wing to be replaced, propeller damaged, engine shock loaded and fuselage damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	300 hours (of which 13 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Following a normal approach to the grass Runway 27 at North Moor, the aircraft touched down harder than the pilot considered desirable, causing it to bounce and roll to the right. The pilot attempted to correct the manoeuvre by applying power and left aileron, but the right wing continued to drop. The pilot was unable to prevent the right wing from striking the ground, which caused the aircraft to rotate clockwise through 180° and roll to the left. The left wing impacted the ground during this final manoeuvre, which also resulted in two of the three propeller blades braking off. The aircraft came to rest upright, facing east in a field of short cereal crop adjacent to the runway. There was no fire and the uninjured pilot vacated the aircraft unaided. In his comprehensive and frank statement to the AAIB, the pilot attributed the accident to his lack of currency on this type of aircraft. Its landing gear, comprising a single large main wheel, a tail wheel and wing outriggers, is known to produce unusual handling characteristics on touchdown. Also, at low speed following the bounce, the attempt to roll level using aileron probably stalled the right wing, preventing recovery.

ACCIDENT

Aircraft Type and Registration:	Europa XS, G-JAPS
No & Type of Engines:	1 Rotax 914 Turbo piston engine
Category:	1.3
Year of Manufacture:	2003
Date & Time (UTC):	29 May 2005 at 1820 hrs
Location:	Hulam Farm, Co. Durham
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 2 Passengers - N/A
Nature of Damage:	Beyond economical repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	1,364 hours (of which 1,232 were on type) Last 90 days - 50 hours Last 28 days - 22 hours
Information Source:	AAIB Field Investigation

Synopsis

During an endurance test flight, the engine started to run rough and pulse between 2,000 rpm and 4,000 rpm. A forced landing in a field was carried out, but the left wing struck the ground during the flare resulting in the aircraft flipping inverted. Despite a thorough examination of the engine and fuel system, the cause of the engine failure was not determined.

History of the flight

G-JAPS had recently been constructed and, following about 3½ hours of engine ground running, it had been issued with a permit to carry out test flights. The aircraft's first three test flights of 30 min, 50 min and 1 hour 5 minutes, which were all carried out on the morning of the accident flight, were accomplished without incident and, between each flight, the aircraft was thoroughly inspected. The accident occurred on the next flight, which was intended to be a test of the aircraft's endurance, and was carried out by a test pilot with the owner flying as an observer. The aircraft had been fuelled earlier in the day with MOGAS obtained from a local garage and, prior to this flight, there was approximately 46 litres of fuel on board.

After carrying out satisfactory engine runs, the pilot took off from Fishburn and the aircraft and engine both performed as expected for about 1 hour 30 minutes. At this point in the flight, whilst cruising at 1,500 ft, the engine started to misfire and ran roughly with the engine speed pulsing between 2,000 and 4,000 rpm. When the pilot set the throttle to an engine speed of 2,000 rpm, its operation seemed to improve, but on re-opening the throttle in an attempt to achieve 4,000 rpm, the engine speed again pulsed and started to reduce toward 2,000 rpm. The fuel supply valve was cycled from MAIN to RESERVE, even though there was about 12 litres of fuel remaining in the main fuel tank, the auxiliary fuel pump was switched to ON, the electric automatic constant speed propeller system was set to manual and the turbo control unit was briefly selected off, all of which had little effect.

The engine was no longer providing enough power for the aircraft to maintain altitude and so preparations were made for a forced landing. A field was selected close to Hulam Farm and an approach was made with 10º flap with the aircraft trimmed for 75 kt, full flap being selected late on the final approach to the field. The chosen field had an uneven surface and, during the flare, the left wingtip contacted the ground at the same time as the main landing gear. This caused the aircraft to flip inverted before finally coming to rest. There was no fire and both the pilot and passenger, who had been wearing four point harnesses, were able to exit the aircraft, having only suffered minor injuries.

Weather

The observed weather at Fishburn at 1530Z, prior to the departure of the accident flight, was a wind of 290º at 8 kt, a temperature of 13ºC and good visibility. The METAR for Durham Tees Valley Airport at 1650 hrs gave the wind as 260º at 10 kt, a temperature of 17ºC, a dew point of 6ºC and good visibility.

Engine and fuel system description

G-JAPS was equipped with a Rotax 914 Turbo piston engine. This is a four cylinder horizontally opposed engine fitted with two balanced carburettors, each supplying two cylinders, fed with air from a turbo-charger. This is controlled electronically from a 'turbo control' unit which, via a servo and pushrods, controls the turbo-charger waste-gate.

The fuel system on the aircraft consists of a single inverted horseshoe shaped fuel tank in the fuselage, with a 65 litre capacity. One side of the horseshoe is the main fuel tank, with the other side being the 8.5 litre reserve tank. The fuel from both these tanks is fed via three way fuel supply valve selectable by the pilot to either MAIN, RESERVE or OFF. From the fuel supply valve the fuel flows through two electric pumps (main and auxiliary), fuel filters, a fuel flow sensor and a gascolator before finally reaching the carburettors. Unused fuel returns to the fuel tank via an additional fuel flow sensor.

Carburettor examination

Following the accident, the owner removed both the carburettors and took them for a detailed examination to a local facility that specialises in Europa aircraft. Both carburettors contained uncontaminated fuel in their float chambers. Further examination did not reveal any defects with the left carburettor. However, upon examination of the right carburettor it was discovered that the main fuel jet needle was loose within its piston housing, allowing the needle to 'float' up and down by between 4 to 5 mm of travel. There were no other defects found within the right carburettor. Later discussions with the engine manufacturer revealed that a floating main jet needle would result in an enrichment of the fuel air mixture, but should not result in a problem with the engine operation. However, it was not established what effect it might have on the operation of the engine should the needle float cyclically or vibrate up and down in flight.

Engine and fuel system examination

A full examination by the AAIB of the engine and fuel system took place with the aircraft in the owner's hangar. The engine was free to turn and showed no signs of a catastrophic failure and an inspection of the spark plugs, cylinders, ignition system and engine compression checks revealed no evidence of any pre-existing defects. A functional test of the turbo-charger system was also satisfactory.

An inspection of the aircraft's fuel system found both fuel filters to be clean and a test of the system showed that the flow of fuel from the tanks, via the pumps, to the carburettors to be more than adequate for normal engine operation.

The aircraft had been equipped with an R-DAT, a device which records engine speed, exhaust gas temperatures, oil temperature, oil pressure and cylinder head temperature once every six minutes. A review of this data did not reveal any previous exceedences, or any significant variation in the temperatures or pressures.

Discussion

The only anomaly discovered during the investigation was the loose main fuel jet needle in the right carburettor which would likely cause enrichment of the fuel mixture but should not have caused the symptoms that were experienced by the pilot.

These symptoms seem to indicate that fuel starvation to one or both the carburettors had possibly occurred. However, there was sufficient of fuel in both the main and reserve tanks, and later tests did not reveal any system problems which would have restricted the flow of fuel. In addition, the fuel system was found to be clear of contamination and both carburettors contained fuel in their float bowls.

Carburettor icing was considered as another possibility. With the temperatures of the day being given as 17/06ºC, the carburettor icing probability chart places the aircraft in the 'moderate icing at cruise power and serious icing at descent power' area of the chart. However, the aircraft was equipped with a turbo-charger which raises the temperature of the air being induced into the carburettor and, therefore, reduces the likelihood that carburettor icing occurred.

Vapour lock in the fuel system was another possibility considered but, as the aircraft had been in flight for over 1 hour 30 minutes without any difficulties, and the previous flights had been without incident, it was thought that this was unlikely to be the cause of the loss of power.

Conclusions

Despite a thorough inspection of the engine and fuel system the exact cause of the engine failure was not determined. However, the presence of a 'loose' needle in the right carburettor was the only anomaly found during the investigation. This defect was likely to enrich the mixture in two of the four cylinders, but the possibility that it could float cyclically, and affect the normal operation of the engine could, in the absence of any other defects, not be entirely dismissed.

ACCIDENT

Aircraft Type and Registration:	Jodel D11, G-BAPR
No & Type of Engines:	1 Continental Motors Corp PC60 Conversion piston engine
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	15 July 2005 at 1702 hrs
Location:	Wolverhampton Airport, West Midlands
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to landing gear, right wing and propeller
Commander's Licence:	UK Private Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	599 hours (of which 337 were on type) Last 90 days - 4 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was being flown from its base at Oaksey Park, Wiltshire to Wolverhampton Airport. The passenger, himself a qualified pilot, then planned to fly the aircraft solo back Oaksey Park. The flight to Wolverhampton was uneventful and the aircraft arrived in the overhead at approximately 1700 hrs. Runway 28 was in use; it has an asphalt surface and an available landing distance of 880 m. The pilot estimated that the surface wind was north westerly at 10 kts. An aftercast, provided by the Meteorological Office for the time of the incident, indicated that there would have been a surface wind of 320°/10 kt and that the weather was CAVOK.

The aircraft joined overhead, as requested by Wolverhampton radio. The pilot and his passenger commented on rising ground to the east of the aerodrome and discussed the effect that this might have on their perception of height during the approach. The pilot reported that he was established on the final approach at which stage the wind was reported as "light and variable". At the same time the pilot observed that the wind sock was indicating a light north westerly wind, and he was thus expecting a cross wind component during the landing. Judging that he was slightly high the pilot reduced his height using side slip on short finals and prepared for the touch down. The round out was normal, but he reports that he did not hold the aircraft off quite enough and it touched down a little early.

The aircraft bounced slightly, but not enough for him to elect to go around, and the aircraft settled on the ground in a three point attitude. The pilot reported that he was controlling the landing roll when the aircraft veered violently to the right. He attempted to control this with full left rudder and left brake, followed by a burst of power as the yaw continued. These actions arrested the yaw to the right, but initiated a yaw to the left. The pilot applied full right rudder and full right brake and closed the throttle. The yaw continued to increase and the right main undercarriage leg failed. The aircraft then continued to yaw and slide on its left main undercarriage, tail wheel and right wing for a short distance and the propeller contacted the runway. The aircraft came to rest on the runway approximately one third of the way from the threshold having yawed left through approximately 120° from the runway heading. The pilot switched off the engine and he and his passenger vacated the aircraft having suffered no injuries. The fire tender arrived shortly afterwards and offered their assistance. The aircraft was then removed from the runway without inflicting any further damage.

The pilot attributes the accident to a loss of control following a gust of wind from the right.

An assessment of the damage, by the repair agency found that the right main undercarriage had failed inboard and the right wing was damaged. The propeller had suffered impact damage and the engine was shock loaded; the aircraft was thus deemed to be beyond economic repair.

ACCIDENT

Aircraft Type and Registration:	Piper PA-18-150 Super Cub, G-BGWH
No & Type of Engines:	1 Lycoming O-320-A2B piston engine
Category:	1.3
Year of Manufacture:	1961
Date & Time (UTC):	6 September 2005 at 1000 hrs
Location:	Great Oakley Airstrip, near Harwich, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	The underside of the fuselage was dented
Commander's Licence:	Private Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	100 hours (of which 9 were on type) Last 90 days - 9 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft departed from Clacton Airfield at 0935 hrs for the flight to Great Oakley. Before setting course for his destination the pilot flew three circuits at Clacton, which he judged to be satisfactory. The weather was fine on arrival at Great Oakley, with good visibility and a light and variable surface wind. The pilot flew a normal approach to Runway 09, and touched down within the first third of the 900 m grass strip at between 50 and 55 kt. The pilot applied what he believed to be even and not excessive braking. Almost immediately after commencing braking, the aircraft veered to the right and the pilot was unable to prevent the aircraft from performing a 'ground loop'. The aircraft left the prepared surface and came to rest with its tail in a ditch adjacent to the runway, causing damage to the underside of the rear fuselage. The pilot secured the aircraft and vacated with his passenger without further difficulty.

The pilot later stated that he may have commenced braking too early when he could have used the remaining runway length to decelerate without braking. This view was shared by a flying instructor familiar with the aircraft and pilot, who stated that the general advice to pilots on this type was to avoid the use of brakes where possible.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181, G-BORS
No & Type of Engines:	1 Lycoming O-360-A4M
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	23 July 2005 at 1239 hrs
Location:	6 miles west of Dalmally, near Oban, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to propeller, nose wheel, left main landing gear detached, creasing to wingtip and skin buckling in tail cone area
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	260 hours (of which 140 were on type) Last 90 days - 5 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further telephone enquiries by the AAIB

The flight was planned from Fowlmere in Cambridgeshire to Oban (North Connel) in Scotland, the exact routing being dependant on the weather. It was a journey the pilot had conducted on a previous occasion and he expected to carry out the trip non-stop in approximately 3½ to 4 hours, with the option to stop en-route should he or his passenger need a break.

He took off from Fowlmere at 0755 UTC with both fuel tanks full giving an endurance of 5½ hours with normal cruise procedures. The fuel was carried in two 94 litre wing tanks, with tank selection ('left', 'right' or 'off') being made via a selector located on the left hand side panel forward of the pilot's seat. He followed his normal routine which was to depart with the left fuel tank selected and after approximately one hour he changed to the right tank. His route took him along the East Coast past Newcastle and Edinburgh. He decided to land at Cumbernauld for a break and landed there at 1110 hrs, having flown the final 1¼ hours with fuel selected to the left fuel tank.

Prior to departure from Cumbernauld the pilot visually checked both fuel tanks and noted that the right tank had approximately half its contents remaining, with the left containing a lower quantity. His flight to Oban was estimated to be 45 minutes duration and so he concluded that the fuel remaining following the 3¼ hour fuel burn on the first leg of the trip was sufficient to complete the flight. He mentally noted that he would carry out the flight using the contents of the right fuel tank.

In order to depart Cumbernauld the aircraft was required to backtrack along the runway, following another aircraft, prior to lining up for takeoff. The pilot was expecting a departure clearance after the aircraft ahead had taken off; however he was asked if he would depart first. The pilot lined the aircraft up for departure and power checks were completed on the runway; the engine power was then increased for takeoff. The pilot subsequently commented that he may have missed an intended fuel selection at this stage as he felt the need to expedite his departure to avoid delaying the other aircraft.

The aircraft took off at 1205 hrs and departed to the west. The pilot carried out his en-route checks shortly after and later commented that this was another opportunity when the left tank may have been inadvertently selected. His route to Oban was via Loch Lomond; low cloud on the tops of mountains up to 2400 ft amsl to the west of the Loch forced him to route to the south. However, on passing south of the Prohibited Area P611 the weather cleared allowing him once again to route direct to Oban. He took the opportunity to fly VFR on top of clouds at 5,500 ft for a short while before descending over Loch Fyne to 3,500 ft.

Shortly after having levelled at 3,500 ft the aircraft experienced a loss of power; the pilot reported that the engine surged, coughed and then stopped. Carburettor heat had been selected during the earlier descent and he felt sure that carburettor icing was not a contributory factor to the loss of power. His position was midway between Loch Fyne and Loch Awe where the height of the ground is up to 1932 ft amsl. Due to the mountainous nature of the terrain he immediately set up a glide towards the shores of Loch Awe. He attempted to restart the engine however this was unsuccessful. He commented that the fuel tank selection was changed during the restart attempt. At around 1,200 ft he made a MAYDAY call to Scottish Information. The pilot was anxious to extend the aircraft glide to Loch Awe and, given the unforgiving nature of the terrain, ditch close to the shore. While coasting out over the Loch he saw a slight break in the tree line where there was a small clearing. He carried out a tight 180º turn and touched down firmly in a very small grass area and the nose and left main landing gear collapsed. After a short ground run the aircraft approached a rising bank where it was brought to a halt. Both occupants were uninjured and exited the aircraft unaided and received immediate assistance from people who had witnessed the landing and alerted the rescue services.

The Chief Flying Instructor of the club visited the site in order to recover the aircraft; he noted that the left fuel tank was empty and approximately 30 litres of fuel were drained from the right fuel tank. This fuel state was consistent with having flown the second leg selected to the left fuel tank. The fuel selector was found selected to the right fuel tank. The accident occurred at 1239 UTC, having completed 34 minutes flying time since departing Cumbernauld. From this flight and the previous leg, the aircraft would have flown 2¾ hours using the left fuel tank contents, half the calculated endurance.

ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200T, G-BEJV
No & Type of Engines:	2 Teledyne Continental TSIO-360-EB piston engines
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	30 March 2004 at 1810 hrs
Location:	Oxford Airport, Oxfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to bulkhead aft of nose wheel
Commander's Licence:	Commercial Pilot's Licence, with Instrument and Instructor ratings
Commander's Age:	68 years
Commander's Flying Experience:	12,300 hours (of which 5,100 were on type) Last 90 days - 102 hours Last 28 days - 45 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional AAIB enquiries

Circumstances

During final approach following an NDB let-down procedure, both the student and commander confirmed the 'three greens' indication of the landing gear assemblies being locked down. There was a 10 kt crosswind component which caused the student to take some time to align the aircraft with the runway and reduce airspeed. Touchdown was made slightly to the left of the runway centreline. After touchdown, the nose was lowered in the normal manner and the commander immediately became aware that the aircraft attitude was excessively nose-down. He thought that this could have been due to a deflated nosewheel tyre, or a collapsed oleo; however the nose continued to drop until its underside contacted the runway surface. Both propellers also struck the runway, stopping the engines. The aircraft was brought to a halt using the wheelbrakes, following which the fuel and electrical systems were turned off and the occupants vacated the aircraft.

Description of the landing gear

The landing gear on this type of aircraft is operated by means of hydraulic actuators. Hydraulic pressure is supplied from a "power pack" consisting of an electrically driven hydraulic pump with an integral fluid reservoir. When the gear is retracted, a pressure switch signals the pump to operate if the hydraulic pressure falls below 1,800 psi.

The nose landing gear of the Seneca is of the forward retracting type which, when extended, has the wheel axle forward of the oleo pivot. When retracted, the gear is held up by hydraulic pressure in the actuator and, when extended, it is held in the down position by a geometric downlock mechanism. When the nose landing gear is extended and under load the primary brace against collapse is the drag link assembly. When the landing gear is fully extended, the drag link centre pivot should be offset below the line between its two end pivots and, in this position, the fixed stops of the drag link centre joint, which limit the over-centre travel of these links, should be in abutment. (See Figure 1 Details, next page.)

The overall geometry of the landing gear is such that aircraft weight on the nose-wheel applies a compressive load to the drag link assembly, which tends to drive it more firmly into the safe 'over-centre' condition when the gear is properly extended. Conversely, if the load is applied when the drag link assembly is in an 'under-centre' condition, it will tend to cause the drag link to fold and the gear to retract.

The downlock assembly, which forms the geometric lock to keep the drag links in the extended position, also acts as an integral part of the retraction/extension mechanism. The retraction actuator attaches to the centre pivot bolt of the two part, articulating, downlock linkage. During the retraction cycle, the first movement of the actuator causes the downlock linkage to pull the drag link out of the over-centre condition; during the extension cycle the final movement of the actuator causes the downlock assembly to push the drag link into the fully over-centre position. There is a downlock spring, which pulls the downlock centre pivot rearwards, assisting the downlock assembly into the 'gear locked down' position, particularly during 'free fall' extensions.

The lower part of the downlock link assembly is a spring strut (see Figure 2, below) which has a spring force of about 2-3 lbs and is compressible by about 0.06 inch. The sprung travel is limited by a cross-pin, fitted through the shank of the lower eye fitting, running in a control aperture in the barrel of the lower downlock link body. This aperture is described in the Service Manual as a 'slot'. The length of the lower downlock link is adjustable and is correct if, when the drag link assembly is driven to the fully over-centre position, the lower downlock link is almost fully compressed. The clearance of the cross-pin from the upper end of the slot, established by the rigging procedure, is a half turn of the adjustment thread, which is about 0.018 inch.

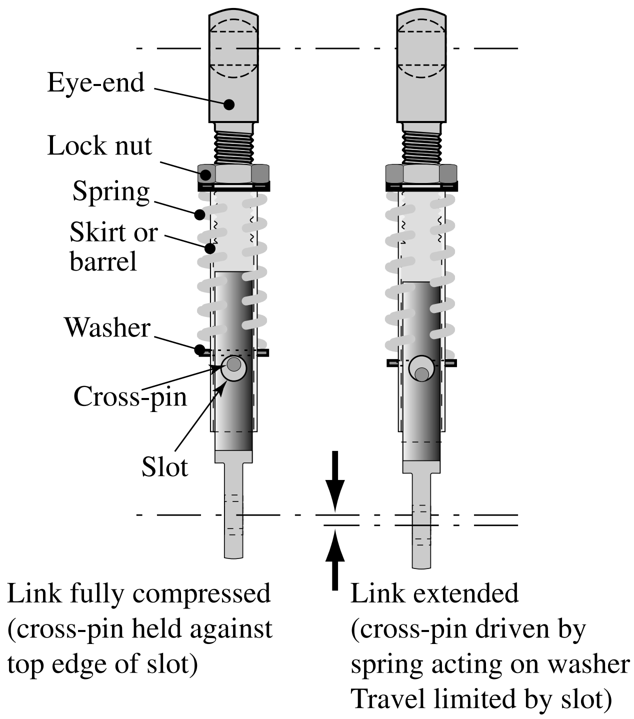


Figure 2

Downlock link
Sectioned assembly)

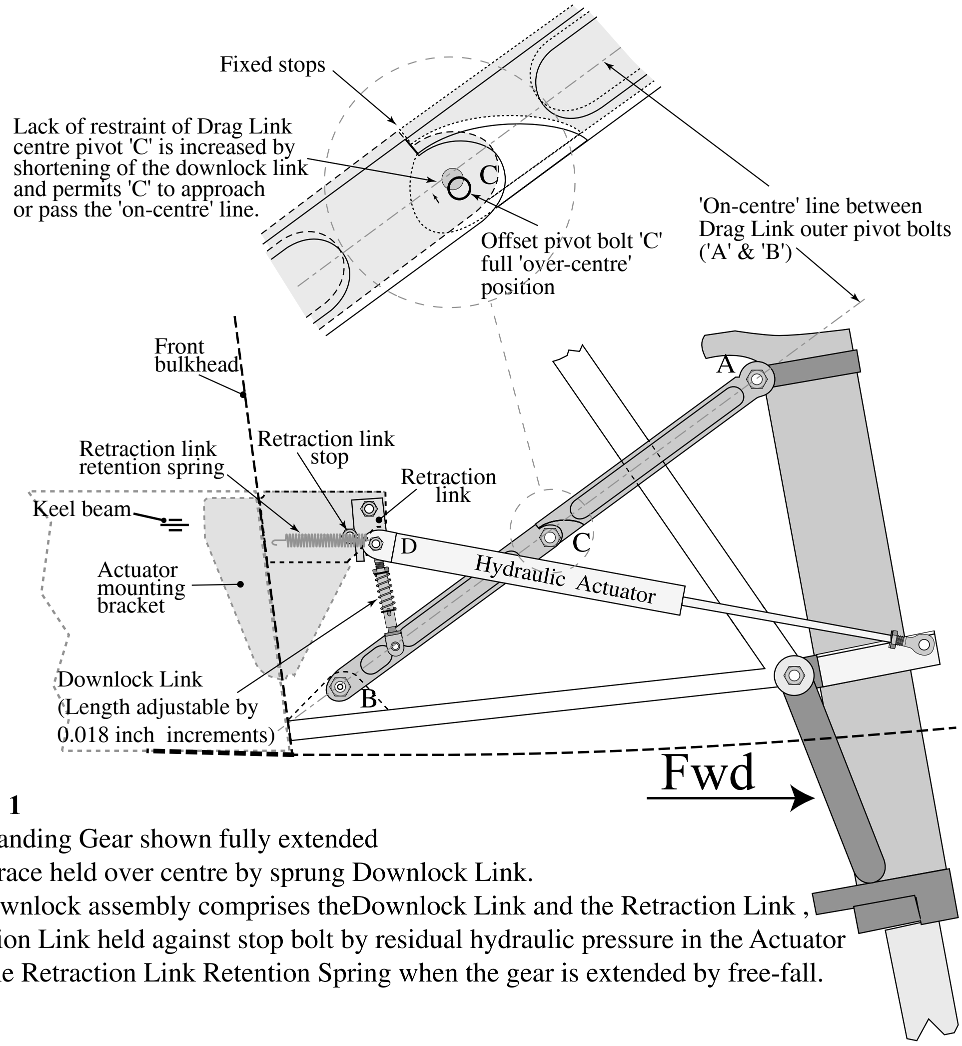


Figure 1
Nose Landing Gear shown fully extended
Drag Brace held over centre by sprung Downlock Link.
The Downlock assembly comprises theDownlock Link and the Retraction Link , Retraction Link held against stop bolt by residual hydraulic pressure in the Actuator or by the Retraction Link Retention Spring when the gear is extended by free-fall.

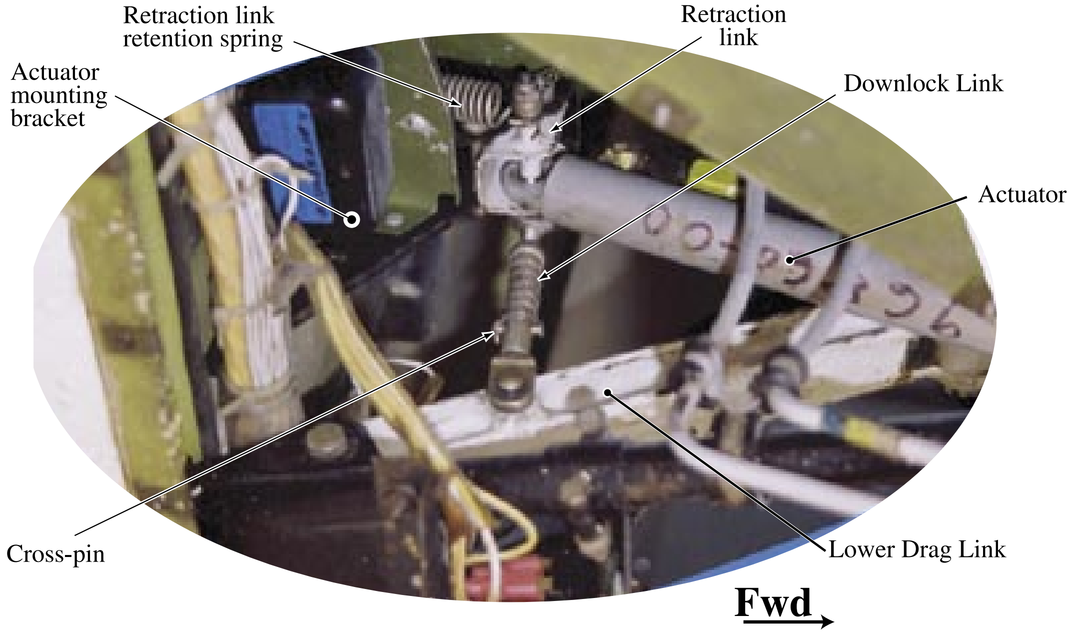


Figure 1a
PA-34 nose landing gear - view from below and right side showing lateral stagger of downlock linkage components.

The procedure for rigging the nose landing gear drag links, retraction actuator and downlock mechanism is laid down in the PA34-200-T (Seneca II) Service Manual, Chapter VII (Landing gear and brake system), Paragraph 7–11d.

Examination of the aircraft

Apart from that to the propellers, the damage associated with the collapse of the nose leg was mainly confined to cracks and distortion in the fuselage front bulkhead close to the attachment of the actuator. In addition, a number of sheared rivets were observed on the actuator mounting structure which was attached through the bulkhead to the keel structure on the bottom of the fuselage. This damage could only have occurred as a result of an excessive load transmitted to the bulkhead/keel area through the actuator itself. Such a load path would be created only in the event that the drag link was not in its locked, over-centre position.

The downlock link had suffered some distortion in its upper eye end, and the aperture, or slot, had been slightly elongated to the extent that a burr had been raised at the upper end, with the result that the spring-end washer rested on the burr, rather than the shank of the pin (see Figure 3, right). It was not clear if the slot elongation had occurred over a number of landings, or as a result of this incident.

It was considered that a hydraulic system failure could result in the landing gear not achieving the downlock position, ie with the nose gear drag links remaining in an 'under-centre' position. However, this would not result in the green 'down and locked' indication reported by the crew. Nevertheless, a test of the hydraulic pump was conducted, with satisfactory results. The associated pressure switch was also found to function within its permitted limits, and the hydraulic reservoir was found to be full after the incident. Therefore, it was concluded that a failure in the hydraulic system had not occurred. Accordingly, attention was once again focused on the downlock mechanism.

Similar events

The AAIB is aware of around seven incidents to UK registered Piper Seneca aircraft which involved uncommanded nose landing gear retraction. These, together with others around the world had caused the manufacturer to issue, in May 2003, Service Bulletin (SB) 1123. The purpose of the SB was described as follows:

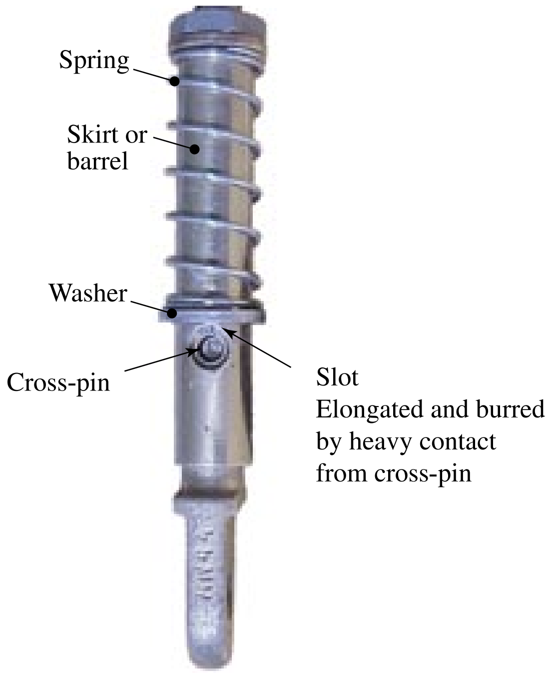


Figure 3

Damaged Downlock link showing distortion of slot and washer jammed on burr

"A review of the service difficulty report concerning PA-34 Nose Landing Gear failures and inadvertent retractions indicates a need to emphasise and expand upon the periodic inspection requirements currently listed in the applicable PA-34 series Maintenance Manuals. In addition, a design review of the installation identified a few components that could be modified to improve their long term service life. This publication introduces the revised inspection requirements and identifies those parts that have been modified to improve their service life. Also included are corrections and clarifications of the rigging procedures pertaining to the Nose Gear installation."

The inspections detailed in SB 1123 had been performed on G-BEJV at its annual inspection 180 flying hours prior to the incident.

Whilst the exact mechanism of failure of the nose landing gear in this accident is different in detail from that reported on in the next Report in this Bulletin (G-BNEN), both have been the result of a failure of the downlock mechanism to retain the drag link in an 'overcentre' condition. The 'Discussion' and subsequent sections of that report have, therefore, been used to draw conclusions and make Safety Recommendations relevant to both accidents.

ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200T Seneca II, G-BNEN
No & Type of Engines:	2 Teledyne Continental TSIO-360-EB piston engines
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	22 February 2003 at 1230 hrs
Location:	White Waltham Airfield, Berkshire
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear collapsed, damage to underside of nose, nose gear doors and engine cowlings, all propeller blades bent and engines shock loaded
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	1,300 hours (of which 800 were on type) Last 90 days - 125 hours Last 28 days - 40 hours
Information Source:	AAIB Field Investigation

Synopsis

During takeoff, the nose landing gear collapsed and the pilot was unable to prevent the propellers and nose of the aircraft from striking the runway. Investigation showed that the upper eye end of the Sprung downlock link had failed and that there was considerable wear in the upper and centre pivots of the drag brace.

The geometric downlock mechanism had recently been adjusted to correct an inability of the nose landing gear to free fall. There was no procedure available in the aircraft maintenance manual for correcting an inability to lower the landing gear by free fall.

Two new safety recommendations are made and reference is made to three earlier recommendations.

Account of the accident

The aircraft was being used for a passenger flight from White Waltham to Cambridge. After start-up the aircraft was taxied to the holding point where the pilot completed the pre-takeoff vital checks and waited for another aircraft to land. After this aircraft had landed, G-BNEN was lined up on the grass runway and, when the landing aircraft had cleared the runway, the take-off run was initiated. The aircraft accelerated normally to about 50 kt when the nose began to drop. The pilot was unable to stop the nose-down pitching with elevator and he realised that the nose landing gear had retracted. Although he then closed the throttles, both propellers had already struck the runway. The aircraft slid to a halt supported on the main landing gear and the undersides of the nose and the engine cowlings. The pilot remarked that he had heard no unusual noises during the take-off run before the nose had started to pitch down.

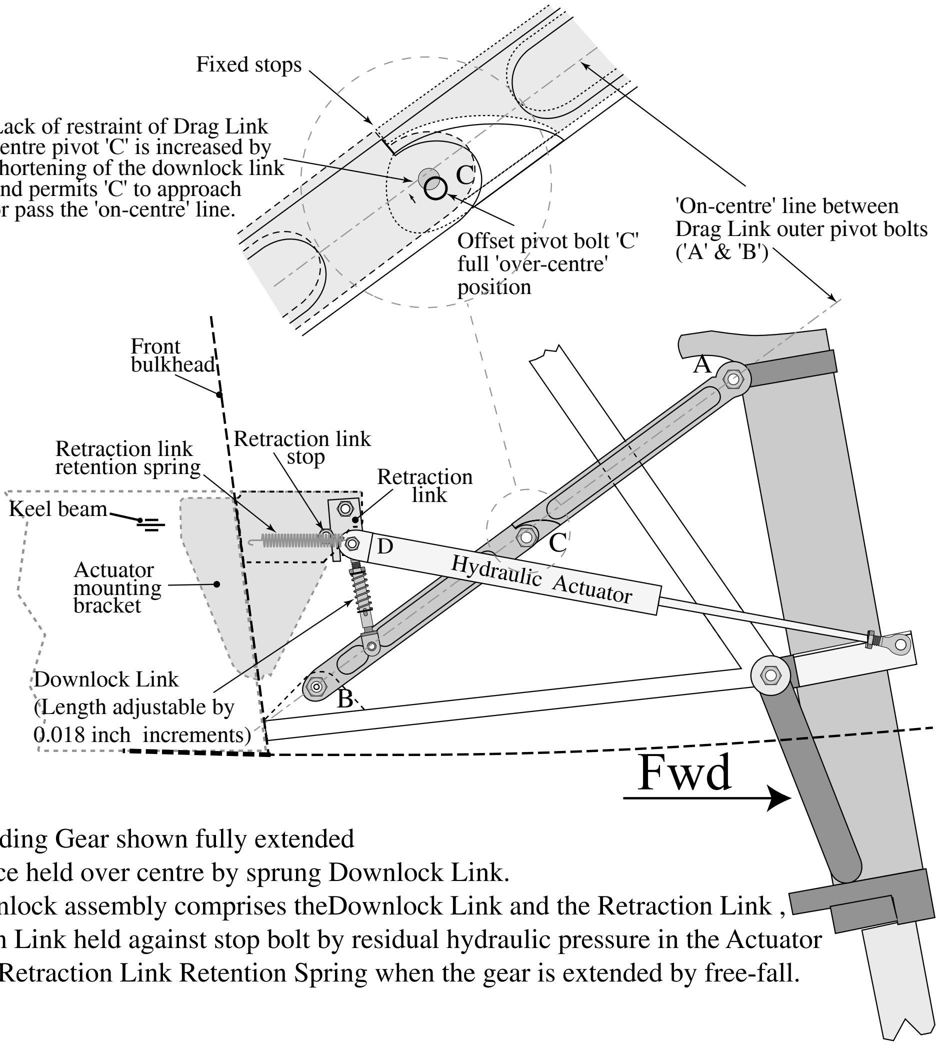
Recovery and examination of the aircraft

The aircraft was towed from the runway after lifting its nose, pulling the nose landing gear down and bracing its drag strut in the over-centre condition. Preliminary inspection, in the maintenance area, revealed that both blades of both propellers had suffered severe damage and that the forward undersides of both engine nacelles had been abraded by contact with the runway. The nose landing gear doors and the underside of the nose fairing back to the front bulkhead of the main cabin structure were also badly damaged and the forward cabin had been distorted, resulting in side and upper skin wrinkling forward of the windscreen. Initial inspection of the nose landing gear mechanism revealed that the threaded stem of the upper eye-end of the downlock link had bent and fractured.

After the aircraft had been placed on jacks and the downlock link removed, the nose landing gear was checked for freedom of movement. The drag link was found to articulate freely but it was also noted that considerable lateral play could be induced at the centre joint. The failure of the downlock link eye-end precluded any determination of the downlock adjustment before the accident. The drag link assembly was removed for more detailed examination. Inspection of the downlock link revealed that, in addition to the failure of the upper eye-end, the slot in the link had been crushed and distorted by the cross-pin at its upper end. This indicated that it had experienced a high compressive load. The crushing distortion was measured to be approximately 0.02 inch.

Inspection of the drag link after its removal from the aircraft showed that there was considerable wear in the upper and centre pivot joints ('A' & 'C' on Figure 1, next page) but the lower joint ('B' on Figure 1) of the lower link exhibited very little wear. Before dismantling the assembly, the 'over-centre' dimension of the drag link assembly was measured to be 0.310 inch which was greater than the specified minimum.

The upper joint, attaching the link to the landing gear leg, was the most severely worn. Measurement of the individual components showed that the bolt itself was unworn and dimensionally correct. The steel sleeve (Part No 9061-29) which runs in the upper link bush was found to have no significant wear on its outer suface. However, the bore of this sleeve, for which wear limits are given in the Aircraft Maintenance Manual (AMM), had been worn bell-mouthed at both ends. Although at its mid-point the bush bore was measured as 0.001 inch smaller than the lower limit given, resulting in a bolt clearance of only 0.003 inch on the measured bolt diameter, at the ends the clearance was 0.006 to 0.007 inch; the greatest wear being 0.001 inch above the maximum limit. The inside diameter of the bronze bush at the upper end of the upper drag link, within which the steel sleeve worked was also measured and also found to be bell-mouthed. There were no established wear limits for this bronze bush at the time of this accident. In the bore of this bush it was found that the wear was oval and more severe along the axis of the link. Similarly to the steel sleeve, the bore of the bronze bush also was very little worn near the middle of the bush and most worn on the left side which had been adjacent to the landing



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Drag Brace held over centre by sprung Downlock Link.
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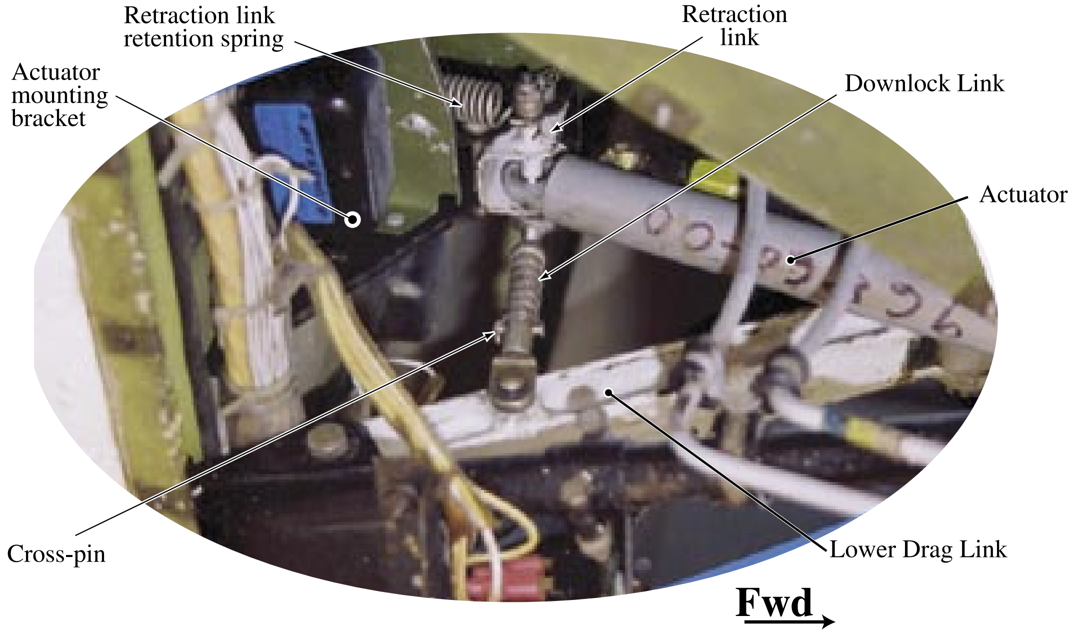

Figure 1a
PA-34 nose landing gear - view from below and right side showing lateral stagger of downlock linkage components.

gear leg when installed in the aircraft. If the minimum measured internal diameter of the bronze bush was taken as nominal, the maximum wear was 0.012 inch with an ovality of 0.008 inch. (See Figure 2, right, for typical bush wear shape.)

At the centre joint, the paired outer lugs of the lower drag link are not bushed because the pivot bolt should not turn relative to the lower link whilst the joint is articulating; neither lug was found to have measurable wear. However, the bronze bush of the single lug of the upper link element of this joint was moderately worn. The wear pattern on this bush was similar to that of the upper joint but in this case the wear was predominantly on the left side with the same tendency to be more severe in the link axial direction than across it. The bore on the right hand side of the bush was near circular and close to nominal size.

Recent aircraft utilisation and history of maintenance on its nose landing gear

The aircraft was in regular use for charter work and had a consistent utilisation of about 50 hours per month in the period running up to this accident. It had, on six occasions in the very recent past, landed and taken off using the grass runway of White Waltham Airfield without incident. All regular maintenance work had been conducted by the same company for some time and, consequently, they were familiar with this aircraft. At the time of this accident it had flown for a total of approximately 6,950 hours.

There is an FAA Airworthiness Directive (FAA AD 93-24-12) which requires the nose landing gear upper drag link forward pivot bolt to be renewed at 500 flight hour intervals. In October 2002, whilst carrying out a 50 hour check about 200 flight hours before the accident, the maintenance organisation complied

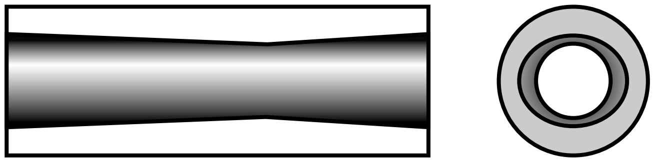

Figure 2

Section through bushes at 'A' and 'C' conical and oval wear

with this Directive. Whilst doing so it was observed that there appeared to be some free play at the drag link centre stops. The assembly was removed, cleaned and the 'overcentre' measurement checked and found to be correct. It was then refitted and the downlock link extended slightly to correct its adjustment. Subsequent retraction and extension tests were satisfactory. Additionally, at the next 150 hour check, about two months later, both normal and emergency (free-fall) extension tests were performed satisfactorily.

On 12 February 2003, the operator's Chief Pilot, whilst familiarising a newly recruited pilot with the aircraft, observed that a 'down and locked' indication was not obtained for the nose gear when he demonstrated the emergency lowering of the landing gear, although both main gear indications were obtained. However, when he recycled the landing gear normally with the hydraulics, all three gears indicated 'down and locked'. This fault was reported verbally to the maintenance organisation and it was arranged that it would be addressed at the next 50 hour maintenance check which was due about a week later.

At the 50 hour check the fault in the emergency lowering of the nose landing gear was confirmed. It appeared that the downlock link was slightly too long to allow the retraction spring to pull the retraction link onto the downlock stop (see Figures 1 & 3). After lubrication of the downlock mechanism, the link was shortened by a small amount

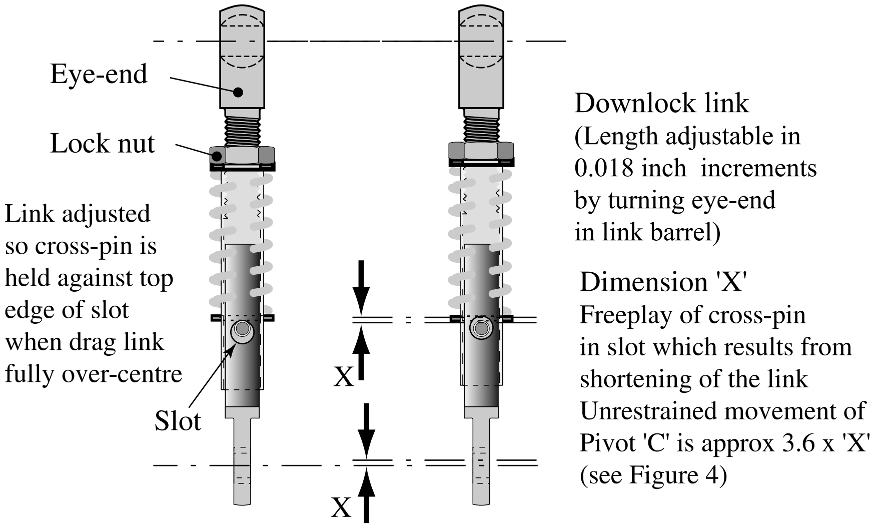

Figure 3

Downlock link, details
Relationship of cross-pin to slot and adjustment of eye-end

and the nose gear would then free-fall to the locked position. The free play at the drag link centre stops was not considered to be excessive after this adjustment and the general condition of the gear mechanism was assessed as normal. Following this maintenance the aircraft had taken off twice from a hard runway and landed once on the hard runway and the second time on grass. It was during the subsequent takeoff from the grass runway that the nose landing gear collapsed.

Analysis (refer to Figures 1, 3 and 4)

The instructions for rigging the downlock link state that after having set its length, initially, to hold the drag link at its maximum 'overcentre' position, the final step calls for it to be shortened by one half-turn of the eye end (0.018 inch). Consideration of the geometry of the lock and link mechanism indicates that every half-turn shortening adjustment of the length of the downlock link permits about 0.065 inch of unrestrained movement of the centre joint of the drag link towards the 'on centre' position by allowing movement of the pin in the downlock link slot (Dimension 'X'). Since it is only possible to adjust the link length by increments of half a turn, it is possible for the unrestrained movement to approach twice this value and for the lock to be correctly rigged in accordance with the setting-up procedure in the AMM. Any subsequent shortening (necessarily by half-turn steps) would relax the restrained 'overcentre' state of the drag link a further 0.065 inch.

The occurrence of the nose landing gear collapse so soon after an adjustment had been made to the length of the downlock link strongly suggests a connection between the two events. Whilst there is no doubt that shortening the downlock link would have made it easier for the retraction spring to draw the downlock linkage into the position required to hold the retraction link against its stop, it would reduce the distance by which the drag link was forced 'overcentre'. This solution to the problem of the failure of the gear to 'free-fall' into the locked position is not proposed in the AMM. Moreover, neither the normal adjustment instructions nor the 'Troubleshooting' table in the AMM appear to give any guidance on what to do in this eventuality.

Consideration of the way in which the lock mechanism works during 'free-fall' extensions indicates that the hydraulic actuator acts, to some extent, as a damper against violent deployment and that the downlock spring draws the retraction link fully up to its stop. When the nose landing gear is extended but the aircraft's weight is not on the wheel, the weight of the forward raked strut tends to pull the drag link straight (ie off its full overcentre stop), against the gravitational pull on the drag link assembly itself which is tending to drive it

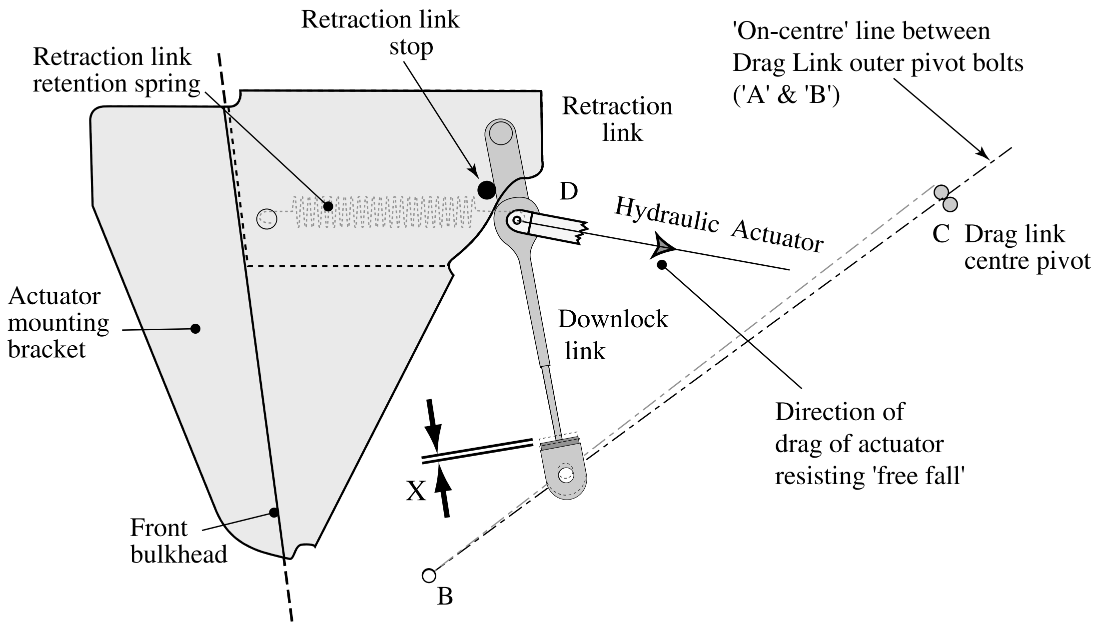

Figure 4

Schematic diagram of locking linkage
showing effect of free play in Downlock Link on restraint at pivot 'C'

to full 'overcentre'. Thus the action of the downlock spring, whilst pulling the retraction link onto its stop, has to overcome any resistance in the (unpowered) actuator, friction in the linkages and the force resulting from the weight of the strut, augmented by any aerodynamic drag loads on the extended gear. These latter two factors will be greater on drag link assemblies with larger 'over-centre' measurements.

From the above it would appear that the most likely prime reason for the failure of the nose landing gear to extend fully and lock, when extended by 'free-fall' in flight, was the insufficient strength of the retraction spring to overcome the combination of forces resisting it. No untensioned length, no minimum break-out force and no minimum force/extension relationship are specified for this spring. Judgement of its fitness to remain in service on strength grounds appears to be subjective.

Discussion

The AAIB has investigated a number of nose landing gear collapses on this aircraft type. Nearly all of these have involved the downlock link suffering either fracture or bending of the upper eye-end threaded portion and crushing/tearing damage to the link 'slot'. Those instances when the collapse has not resulted in the failure of the upper eye-end have characteristically involved damage to the actuator mount bracket and the structure surrounding its attachment to the fuselage front bulkhead and keel beam (as was the case in the preceding report in this Bulletin, concerning the collapse of the nose landing gear of G-BEJV). In all cases the damage has precluded accurate determination of the pre-failure adjustment of the downlock mechanism and, consequently, any quantifiable determination of maladjustment. Additionally, it is not possible to be certain that some crushing of the link 'slot' has not occurred as a result of 'hammering' in use; any such damage would result in increased freedom of the drag link centre joint.

Typically, all the damage has been of an overload nature with no evidence of progressive deterioration of strength. In all cases the loading which has led to the damage and subsequent collapse could only have arisen if the drag link had been in an 'under-centre' condition when weight came onto the nose wheel. A considerable proportion of the occurrences have happened soon after an adjustment or reassembly of the nose gear downlock mechanism. They have also occurred in mechanisms which have been in service for a considerable period without renewal of any of the drag link pivot bushes. None of those investigated by the AAIB has involved the failure or significant wear of the upper drag link pivot bolt which has to be changed, in accordance with an Airworthiness Directive, at 500 hour intervals.

In general, it would appear that several factors, either singly or in combination, can lead to reduced constraint of the free movement of the drag link centre pivot under dynamic loading, for it to be able to move to a vulnerable, 'undercentre' position. These are:

(a) Downlock link adjustment

If the link is adjusted too short, free movement of the crosspin in the slot will occur.

(b) Bush and pin wear

The resulting slack will allow increased movement in, and at right angles to, the plane of the mechanism.

(c) Structural flexibility

This may be exacerbated by degraded fastening of the actuator mounting bracket at the fuselage front bulkhead.

As a result, if weight comes onto the nose wheel when the landing gear mechanism is in this undercentre condition, the downlock link has to resist the forces tending to cause the landing gear to fold in the retracting sense, which it is insufficiently strong to do, unless there is any weakness in the attachment of the actuator mount bracket to the front bulkhead/keel beam structure, in which case the bracket and its mounting structure become severely disrupted.

Having occurred during the take-off run, this particular accident is of considerably greater concern than the more usual occurrence of nose landing gear collapse during the landing run. When on the ground, the PA-34 has a relatively small propeller tip clearance and the propellers are close to the longitudinal position of the nose wheel. Any collapse of the nose landing gear will most probably result in the propellers striking the runway.

In this instance, the collapse occurred at a speed when the pilot was not ready to take the aircraft into the air. If a collapse were to occur immediately before the pilot started to rotate, the danger would exist that a brief propeller strike on the runway might fracture a blade pitch control mechanism just as the aircraft became airborne, with unpredictable results. It should be noted that at take-off rpm, each propeller blade would strike the runway at a rate of 43 times per second, leading to a high potential for propeller disruption in a very short period of time.

Previous Recommendations

As a consequence of the investigations into several previous nose landing gear collapses on PA-34s, the AAIB has made three previous Safety Recommendations. These were:

Safety Recommendation 2000-45 (FAA 00-327). It is therefore recommended that the New Piper Aircraft Company should review and amplify the instructions for rigging the nose landing gear downlock mechanism contained in the Piper PA-34 Maintenance Manual.

Safety Recommendation 2000-46 (FAA 00-328). The FAA and the CAA, in conjunction with the New Piper Aircraft Company, should investigate the causes of reported cases of Piper Seneca nose landing gear collapse. Consideration should be given to design modification which should minimise movement of the drag brace resulting from loads applied to the nose landing gear, and to ensure sufficient force is applied to the drag brace to retain it in the locked condition.

Safety Recommendation 2004-07 (FAA 04-019). It is recommended that the Federal Aviation Administration, as the primary certificating authority for the Piper PA-34 Seneca aircraft series, should require the aircraft manufacturer to provide a clear and unambiguous description of the operation of the nose gear downlock spring link, its installation and its correct rigging by both narrative and pictorial means.

Safety action

In May 2003 the manufacturer produced a Service Bulletin (SB 1123) in response to a number of Accident Prevention Recommendations made by the US National Transportation Safety Board (NTSB), as well as the first two AAIB Recommendations mentioned above. This addressed the issues, in part, and was approved by the FAA.

In recognition of what were seen as deficiencies in SB1123, the Civil Aviation Authority, with the co-operation of AAIB, sent a letter in May 2004 to the manufacturers, which was copied to the FAA, detailing those parts of the Bulletin which were considered not to address the concerns sufficiently. In particular, with the exception of correcting the 'over-centre' dimension of the drag link for Seneca II aircraft, there was no clarification of the rigging procedure for the downlock mechanism.

Additionally, and as a result of the AAIB investigation of another PA-34 nose landing gear collapse, the AAIB made the third of the Recommendations mentioned above (2004-07). As a result, the aircraft manufacturer has issued Revision A of SB 1123, approved by the FAA in November 2004, which, in the main, addresses the concerns raised in AAIB Recommendations 2000-45 & 2004-07. It does not, however, fully address the concerns raised in the letter from the CAA to the manufacturer, nor does it fully meet the intent of Recommendation 2000-47.

These Service Bulletins had not been issued when the maintenance organisation last serviced and adjusted the nosegear downlock mechanism of G-BNEN.

Conclusions

A detailed description of the operation of the PA-34 nose landing gear can be found in the AAIB report on a previous incident (G-EXEC at Stapleford on 28 October 1999; see AAIB website). This description includes the susceptibility of the effectiveness of its downlock mechanism to misrigging, slack in the pivots and flexibility of the structure. Although SB 1123A specifies acceptable wear limits within the drag link pivot bushes, it does not indicate the likelihood that the internal wear of both the bushes and the steel sleeves will be conical, towards their axial centres, nor that it will probably be oval. These concerns, amongst others, were expressed in the letter from the CAA to the manufacturer.

This accident appears to have been triggered by the adjustment which was made in order to ensure that the nose landing gear would 'free-fall' to the locked down position. Although the mechanism appeared to operate satisfactorily in normal operation, its failure to extend by 'free-fall' had to be addressed. In the absence of any specific advice in the Maintenance Manual on how to rectify this deficiency, or its most likely causes, the maintenance organisation made the only adjustment of the landing gear which was available to them, in accordance with the Manual. Although they considered that the condition and free play of the mechanism was 'normal' after this adjustment, in combination with the deflections induced in the local structure under dynamic loading was sufficient to allow the drag link to move to an 'under-centre' condition which the mechanism was not robust enough to resist.

Safety Recommendations

Since it is considered that the primary contributory factor to this accident was the lack of guidance in the Aircraft Maintenance Manual relating to ensuring correct 'free fall' extension of the nose landing gear it is recommended that:

Safety Recommendation 2005-106

The Federal Aviation Administration of the USA should ensure that the New Piper Aircraft Company includes, in the appropriate Maintenance Manuals, clear advice on the factors affecting 'free fall' extension of this landing gear and a more precise definition of an 'acceptable' nose landing gear 'Retraction Link Retention Spring'.

Although the Piper Service Bulletin 1123A improves the clarity of the instructions for rigging the nose landing gear, it is considered that some issues, which are identified in the CAA letter to Piper, and the issues of uneven wear in the bushes and sleeves, still need addressing. Furthermore, it is considered that the information contained in the Service Bulletin rightly belongs in the Maintenance Manual, thereby relieving maintenance engineers of the need to reconcile two documents. The intent to put the content of the Bulletin into the Manual at some future date is stated in the Bulletin. It is therefore recommended that:

Safety Recommendation 2005-107

The Federal Aviation Administration of the USA should ensure that the New Piper Aircraft Company reviews the content of Service Bulletin 1123A and expedites embodiment of the resulting instructions into the Maintenance Manual.

ACCIDENT

Aircraft Type and Registration:	Piper PA-38-112 Tomahawk, G-BMXL
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	31 May 2005 at 1942 hrs
Location:	Farm strip near Chepstow, Monmouthshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	104 hours (of which 4 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, aircraft inspection, site inspection and further AAIB enquiries

History of the flight

The pilot and his passenger were both members of a group which owned the aircraft. They were in the process of conducting an aerial inspection of a newly prepared farm strip prior to its later use by the passenger, using the same aircraft. The pilot reported that the aircraft had departed from Wycombe Air Park at 1810 hrs, and that the flight was expected to terminate at Wycombe once the inspection was complete. The aircraft had been refuelled after a previous flight; prior to departure the fuel load was checked visually and seen to be at a level approximately equivalent to 76 to 78 litres. Total fuel capacity was 121 litres. Once at the farm strip the aircraft flew two visual circuits, each to a low go-around, which were flown by the passenger from the right hand seat. The pilot took control for a third circuit, intended to be the last before returning to Wycombe. However, as the pilot applied full power to go-around, the engine began to run roughly. The pilot sensed a reduction in power, though he noted that the engine was producing maximum rpm. As a precaution, he reduced power and carried out a landing on the farm strip. The landing was uneventful, with no further abnormal engine indications or unusual throttle position; the engine idled normally prior to shutdown. The pilot reported that he had been using carburettor heat regularly during the flight and did not associate the fault with induction system icing. He also stated that he had changed fuel tanks at least twice during the flight.

The pilot inspected the engine and aircraft, and although there was a slight oil quantity anomaly that was attributed to the uneven ground, no faults were apparent. The pilot and his passenger then prepared to depart from the strip. Flaps were set to one notch, which is the procedure recommended in the Pilot's Operating Handbook (POH) for a soft or short field takeoff. As the aircraft taxied to the take-off point the pilot conducted two power checks, and again conducted a power check immediately before commencing the take-off roll. Carburettor heat was used in accordance with the procedures for the type. Engine indications were normal and the aircraft seemed to accelerate normally down the strip, which initially had a marked down slope in the direction of takeoff. As the aircraft neared the bottom of the slope prior to the final upward sloping section of the strip, the aircraft achieved 55 to 60 kt and became airborne normally in response to slight backwards pressure on the control stick. However, the engine immediately began to run rough again and the pilot sensed a sink developing. He waited a moment before initiating a further backward movement of the stick, but the apparent loss of power persisted and the aircraft sank back again. The pilot aborted the take-off attempt and closed the throttle. The aircraft landed heavily on the upward sloping part of the strip, and bounced at least once. It then passed through the boundary fence into the field beyond, where it collided with a calf which later had to be destroyed. The pilot recalled that the propeller was turning when the aircraft passed through the fence, but that it had stopped by the time the aircraft came to a stop. The pilot carried out a normal sequence of shut-down checks, including raising the flaps, and the two occupants vacated the aircraft by both doors. The aircraft had suffered substantial damage and was later written off.

Aircraft inspection

Photographic evidence taken within 48 hours of the accident was available, as was information from the specialist recovery organisation. The aircraft came to rest upright, with the left main gear missing and the left wing in contact with the ground. The aircraft was heading about 30º to the left of the take-off heading, and was situated 130 m beyond the fence marking the end of the strip. Witnesses from the recovery organisation noted a lack of obvious ground marks.

The aircraft was returned to the group's maintenance organisation at Wycombe Air Park, where it was subsequently examined by the AAIB. Both wings had suffered substantial damage to the leading edges, the worst occurring to the left wing at its outboard end. The left wing tip showed an abrasion pattern and scoring on its rear underside and the rear most section of the tip had detached. The right wing suffered less severe damage, which included a cracked wing tip assembly and damage to the outboard aileron. Both wing skins were buckled, though the majority of the upper skin damage is believed to have been caused by cattle which occupied the field whilst the aircraft was awaiting recovery. The left main undercarriage assembly had detached from the wing as a result of two retaining bolts failing. At the rear of the fuselage there was a cracked frame at the base of the fin, deforming the outer skin and indicative of a heavy load transmitted through the tail skid.

The centre 'carry through' spar, which incorporated the rear wing spar attachment points was buckled where it passed through the fuselage. The port tail plane had a large hole in both upper and lower skins at approximately mid span, just aft of the leading edge. One propeller blade was bent backwards about 20º from about mid-span, whilst the other blade was undamaged. Apart from two very small burrs on the extreme propeller tip, and one witness mark centrally on the damaged blade face, there were no other scratches or score marks on either blade. Both flaps exhibited minor buckling. There were no obvious signs of the reported engine problems. Spark plugs were removed and showed no signs of sooting or fouling. Fuel was present in the aircraft and at the engine; 69 litres were drained from the tanks prior to recovery.

The aircraft had been subject to a number of verbal reports from group members concerning an intermittently rough running engine, though there was no factual data to support this since no related defect had been raised. The aircraft's maintenance company had a long association with the aircraft dating back to when it had been a club aircraft. There was no recorded history of engine problems on this aircraft, and the company was unaware of the reports concerning an intermittently rough running engine, having been neither asked to investigate the reports nor asked for advice or opinion on the matter. The reports themselves varied from occasional mis-firing to rough running similar to that associated with carburettor icing, or to excessive 'mag drops' during power checks which were cleared prior to takeoff. As far as was ascertained, the reports of rough running were confined to less experienced members of the group.

The farm strip

The strip had recently been prepared for use by the land owner in liaison with the passenger of the accident aircraft with whom he was acquainted. The strip spanned parts of three fields which were in use for cattle grazing. In preparing the strip, parts of two tree lines which separated the fields had been removed. The ground was then filled and lightweight electric cattle fencing installed. The surface of the strip had not received special attention and was generally rough or very rough in areas. Some isolated trees had been removed, leaving uneven ground and small rocks in places.

The strip was orientated 07/25, with a main take-off direction of 066º(M), though the initial part of the take-off run had a direction of 085º(M). When the aircraft landed, it did so in a westerly direction on the central field with both fences rigged, giving a landing strip length of 315 m. For the takeoff, which was to the east, the westerly fence was lowered, giving an available strip length of 495 m. The easterly field, in which the aircraft came to rest, could be made available for use but held cattle at the time of the accident.

The strip was situated on undulating ground. From the take-off point the ground had a significant downward slope for about 350 m before sloping upwards to the end fence. The ground then sloped away once again in the 'over-run' field. The ends of the strip were approximately level and there was a gradual fall in the ground from left to right when viewed in the direction of takeoff used.

The westerly field from where the takeoff commenced contained a number of large trees which dictated the slightly angled initial take-off run. The main field was bounded by a tree line to the north (left side, in the direction of takeoff), with isolated trees to the south where the ground started to fall away. The 'over-run' field was bounded on all sides by trees, but only those on the south side were adjacent to any likely aircraft manoeuvres. The strip width was approximately 50 m, being established by the gaps in the tree lines where trees had been removed. Mean field elevation was 475 ft amsl.

Pilot experience

The pilot, with 104 total flying hours, had learnt to fly on Warrier aircraft and had recently converted to the PA-38 to enable him to fly the group's aircraft. He reported that he had experienced some strip operations whilst flying in the USA but had not undergone formal training and none of this flying had been recorded. The passenger had about 160 hours total fixed wing time, with an additional 60 hours rotary wing. The passenger's recent flying had mostly been rotary wing with limited recent fixed wing experience. Prior to the accident flight neither pilot had met nor flown with each other and each had only a broad idea of the other's experience.

The passenger, intending to fly to the strip himself in the same aircraft, had originally intended to visit the strip with either a flying instructor known to the group, or the group's leader who was an experienced Tomahawk pilot. On the day of the flight he had tried to book the aircraft, but when it was clear that it had already been booked, he approached the pilot, whom he did not then know, to see if he could fly with him. The pilot agreed, and agreed to visit the strip area with a view to conducting an aerial inspection of the site and to take some photographs.

Witness information

The land owner said that he had spoken with the aircraft passenger on the afternoon of the flight and been told that a landing was planned if all appeared well. He saw the aircraft land, and noted that it stopped comfortably within the length of the centre field. Both crew men appeared relaxed, and he did not recall either mentioning that there had been any aircraft problems. He could not recall the crew carrying out a protracted inspection of the aircraft.

The land owner and his wife observed parts of the take-off, but not the final seconds of the flight. The aircraft was seen to accelerate down the initial part of the strip, and to get airborne before the down hill part of the strip ended - a distance of about 300 to 325 m. However, at about 25 to 30 ft the aircraft was seen to roll to the left and it was clear that all was not well. The aircraft was then seen to "veer" from the left to the right, though it is not known how much the aircraft deviated from the strip centre-line. Neither witness heard unusual engine noises or saw the aircraft strike the ground.

Meteorological information

En-route to the farm strip, the pilot obtained a weather report from RAF Brize Norton, which reported calm conditions, good visibility and no significant cloud. The conditions in the accident area were observed to be very similar, with a negligible surface wind. Information from the Met Office shows that the 2,000 ft gradient wind over the Chepstow area at the time of the accident was approximately 280º(T) at 5 to 10 kt. This suggests a general surface wind in the same area of approxima tely 250º at 5 kt. The temperature and dew point in the area at the time were approximately +13ºC and +09ºC giving a relative humidity of 77% and a 'serious' risk of carburettor icing at all power settings.

Aircraft performance

The aircraft was subject to a maximum take-off mass of 757 kg. The pilot and passenger weighed a combined total of 162 kg, including an allowance for clothing and equipment. The 69 litres of fuel drained from the aircraft weighed 49 kg, giving a total payload of 211 kg. With a basic mass of 546 kg, the aircraft's take-off mass at the start of the take-off roll is estimated to have been at the maximum allowed.

Sources of information available to pilots to calculate takeoff and landing performance include among others; the aircraft's POH, the CAA's General Aviation Safety Sense leaflet 7b '*Aircraft Performance*' and Aeronautical

Information Circular 67/2002 '*Take-off, climb and landing performance of light aeroplanes*'. Neither the pilot nor his passenger knew accurate distances available at the strip for takeoff and landing, nor had they made any performance calculations for the strip. The pilot believed a safe takeoff would be assured, based on his experience of the airplane's performance from the 695 m grass runway at Wycombe Air Park.

Performance data is produced in the POH for the PA-38 at maximum mass of 757 kg. Data is given only for operations from paved level dry runways and represents the performance achieved with a new aircraft and engine, in ideal conditions and flown by a highly experienced pilot. The data is not factored to include any safety margins.

Utilising this data the take-off ground roll with one notch of flap, lifting off at 53 kt, is 245 m. For a 5 kt tailwind, the take-off roll increases to 317 m. The above figures require adjustment for the actual conditions. The CAA states in its leaflet General Aviation Safety Sense 7B - '*Aeroplane Performance*' that a factor of 20% should be added for dry grass. Rough ground is not considered as such, since it is presumed that the strip is prepared to a minimum standard in this respect. Applying the factor for grass, the take-off ground roll increases to 294 m in still air and 380 m with a 5 kt tailwind.

Whereas public transport flights are legally required to apply specified safety factors to performance data, private flights are not. However, the CAA states in its leaflet General Aviation Safety Sense 7B - '*Aeroplane Performance'* that it is *'strongly recommended'* that private flights apply the same factorisation as applicable to public transport flights. If this factor of 1·33, is applied, the take-off roll is increased to 391 m in still air and 505 m in a 5 kt tailwind. The available strip length was 495 m. The effect of down slope for takeoff is not normally considered.

Discussion

As well as the accident sequence itself, the investigation was concerned with how an inexperienced pilot with no recorded strip training found himself operating from a new and unproven farm strip in an aircraft at maximum allowed mass, with no prior preparation and with doubts over the engine's reliability.

For the pilot, the visit to the strip was a change of plan. A key factor is whether or not a landing at the strip was raised by the passenger prior to the flight. Were it not, as the pilot and passenger reported, then there would be no reason for the pilot to raise any concerns or to seek more information about the strip, other than its location. The passenger stated that his original intention was to fly to the strip that evening with a more experienced pilot, in which case a landing was a possibility, and he believes it may have been with this in mind that he mentioned the possibility of a landing to the strip owner. However, the strip owner thought the conversation had taken place that afternoon only a short while before the flight. Given the passenger's intention to use the strip and his status as a full group member, it is surprising that he was not in possession of accurate data or performance information for the strip.

Reports of the engine rough running and power loss prior to landing were not sufficiently detailed to point to a possible cause. No mechanical reason was found, though conditions were conducive to carburettor icing. The pilot reported that he had made normal use of carburettor heat during the flight and that his normal fuel management had included changing tanks twice during the flight from Wycombe. Given that the aircraft was positioned on short finals, the decision to land appears reasonable. However, this must be weighed against the destabilising effect of selecting full power to go-around, the inevitable time delay to recognise the problem, the time to make a decision and the mental re-adjustment that would be necessary. Given that the go-around was initiated from a relatively low height, these effects would tend to cause the aircraft to land beyond the ideal touchdown point, with an increased risk of over-running the available strip length.

It is to the pilot's credit that he was able to carry out a successful precautionary landing from a critical position into the restricted field. Although the aircraft had already flown two approaches, this was the pilot's first approach as handling pilot. However, having landed successfully, it could be expected that the pilot would then seek to establish the cause of the rough running and power loss. Apart from the inspection of the aircraft and engine, no detailed investigation was carried out and no advice was sought. It is surprising therefore that both pilot and passenger subsequently boarded the aircraft for takeoff just a short time later.

The condition of the strip was very poor in places and could have caused handling difficulties as well as adversely affecting take-off performance. It is difficult to quantify the latter, and to some extent the adverse effect on performance would have been offset by the significant down hill slope on the take-off portion of the strip. The pilot's account of the takeoff and eye witness information indicates that the aircraft became airborne after a ground roll of about 300 to 325 m, which is not markedly beyond that expected on a grass strip.

The final position of the aircraft was some 300 to 325 m beyond the point at which it was believed to have become airborne - about the same distance as the take-off roll. Had the aircraft lost power and touched down immediately after taking off, it would not have had the energy to cover this distance, particularly as part was uphill. Furthermore, the passenger recalled that the aircraft stopped very quickly after it had touched down. Moreover, the aircraft would not have run straight for this distance if, as the pilot believed, the left main undercarriage had detached at this point and the left wing had contacted the ground.

Similarly, the extensive damage suffered by the aircraft was difficult to reconcile with the reported occurrence. Abrasion damage and score marks to the underside of the left wing tip indicates that it contacted the ground at a relatively high forward speed. Although this is presumably connected with the loss of the left undercarriage, the possibility remains that it could have occurred on takeoff. The right wing also contacted the ground at some stage, and damage to the right aileron suggests that it was deflected downwards in a 'roll left' sense at the time. Additionally, the left wing was subject to a rearwards and upwards force sufficient to buckle the centre 'carry through' spar. The pilot's recollection that the aircraft landed heavily in a nose up attitude on its main wheels is supported by the damage to the aft structure and the limited damage to the nose gear, which was subject to a rearwards force but did not collapse. The damage to the tail could have been caused by the left main undercarriage leg puncturing the tailplane, though there were no signs of paint or marks on the leg to corroborate this. The main damage to the propeller was to one blade only, and not associated with rotation. Apart from the very small burrs on one tip, there was no evidence that the propeller had struck the ground. One possible reason for the blade bend could have been the collision with the cow, but the pilot believed that it was struck by the right wing.

A further discrepancy concerned the fuel state. A total of 69 litres was drained from the aircraft, though the expected fuel on board should have been between 45 and 55 litres. This discrepancy remained unexplained.

Eye-witness information suggests that the aircraft became airborne in a recognisable manner and that the pilot appeared to be experiencing some difficulty with control. Given the rough surface and the chance of encountering an unexpected tailwind, it is possible that the aircraft became airborne at an abnormally slow airspeed. The POH techniques call for acceleration immediately after lift off towards the best angle or best rate of climb speed, as applicable. The significant upslope ahead of the aircraft may have caused the pilot to inadvertently maintain too high a nose attitude to allow this to happen. Combined with the possible low or reducing airspeed and the probability of climbing into a light tailwind, a scenario can be envisaged which includes both the sink felt by the pilot and the apparent erratic flight path described by witnesses. Any loss of power at this stage, which could conceivably be due to carburettor icing, would have made a successful recovery from the situation unlikely.

Summary

The reported engine problems which necessitated the precautionary landing and preceded the accident could not be accounted for, though conditions were conducive to carburettor icing. The pilot then attempted to takeoff from an unfamiliar strip, which was poorly prepared and for which he had no accurate performance information, and with an engine whose performance had already precipitated the precautionary landing. The damage to the aircraft, its final resting place and eye-witness accounts were inconsistent with the pilot's account of the accident and suggested that the aircraft had been airborne for longer than the pilot recalled. The rough ground, the slope of the strip and probable light tailwind component during or immediately after lift off may have contributed to the accident.

ACCIDENT

Aircraft Type and Registration:	Pulsar (kit-built aircraft), G-CCBZ
No & Type of Engines:	1 Rotax 582 two-cylinder two-stroke piston engine
Category:	1.3
Year of Manufacture:	2000
Date & Time (UTC):	2 July 2005 at 1134 hrs
Location:	Approximately 0.5 miles south-west of Deanland Airfield, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage to fuselage and separation of nose leg
Commander's Licence:	National Private Pilot's Licence (NPPL)
Commander's Age:	47 years
Commander's Flying Experience:	225 hours (of which 70 were on type) Last 90 days - 10 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The aircraft was an amateur-built Pulsar, a low-wing two-seat monoplane of composite construction powered by a Rotax liquid-cooled engine. The aircraft had been constructed in the United States and later imported into the UK. The pilot, who was also the owner, was one of a group flying from Deanland Airfield, near Lewes, to the PFA Rally at Kemble. The surface wind was light and the pilots used Runway 26 for takeoff.

The pilot of G-CCBZ reports that, shortly after takeoff and at about 300 ft agl, the engine 'popped' abruptly and then stopped completely. He lowered the nose and attempted a re-start of the engine, including use of the primer. The engine appeared to start but then promptly stopped again. At about 150 ft agl the pilot trimmed the aircraft for landing into the only field of sufficient size for a forced landing, noting that, although large, the field contained a tall crop.

The pilot considers that the descent rate and approach speed into the field were reasonable but, as the wing contacted the crop of oilseed rape, the aircraft decelerated rapidly and pitched nose down, coming to a stop within a few metres of the first contact with the crop. The fuselage was extensively damaged and the nose leg separated: there was no fire and the pilot was not injured.

Causal factors

The pilot suspected fuel starvation and later removed the two carburettor float bowls, both of which contained sediment. He considered that there was a sufficient amount of sediment in the bowls to have restricted the supply of fuel (which was automotive MOGAS) into the engine. The larger items of sediment appeared to be small flakes of red paint, which matched the fuel cans from which he habitually filled the aircraft. It was not apparent how the sediment had reached the float bowls but further inspection showed that the replaceable element in the Purolator fuel filter assembly (Figures 1 and 2) had not been fully screwed home and could therefore 'rock' in place, allowing the flow of dirty fuel past the filter element.

The pilot also considered that, in retrospect, he should have refuelled through a proper external strainer to filter the fuel into the tank, rather than using a simple 'jerry can' and siphon-tube arrangement. He also noted that the filter assembly did not indicate that the replaceable element should be screwed fully home and that, in this aircraft, the fuel supply to the engine primer is drawn from the fuel tank 'sight glass', which is not filtered.

Figure 1

G-CCBZ - fuel filter assembly

Figure 2

G-CCBZ - fuel filter components

ACCIDENT

Aircraft Type and Registration:	Rockwell Commander 112TC, G-SAAB
No & Type of Engines:	1 Lycoming TO-360-C1A6D piston engine
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	22 August 2005 at 1530 hrs
Location:	Gamston Airfield, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller severely damaged. Abrasion damage to the flap hinges, front gear doors, steps and to the under surface of the fuselage. Engine damaged and shock loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	142 hours (of which 42 were on type) Last 90 days - 12 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that he approached the airfield in squally conditions and became distracted by the weather. He lowered the flap in stages as he turned onto the final approach, but did not carry out the downwind or final checks, and did not lower the landing gear. The aircraft touched down with the landing gear retracted, sustaining damage. The pilot vacated the aircraft without difficulty and there was no fire. The aircraft was not fitted with any landing gear warning system, and although there was a placard in the cockpit referring to a 'Red, green, blue' check (a final check of the position of the red mixture control, green landing gear indicators and blue propeller control), the pilot did not carry this check out either. The pilot commented that the majority of his flying experience was on aircraft with fixed landing gear, and whilst this may have contributed to his omission it did not explain why he failed to complete routine checks.

ACCIDENT

Aircraft Type and Registration:	Silence Twister, G-TWST
No & Type of Engines:	1 Jabiru 2200A piston engine
Category:	1.3
Year of Manufacture:	2004
Date & Time (UTC):	27 February 2005 at 1256 hrs
Location:	Aylesbury (Thame) Airfield, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Landing gear collapsed, engine and front cowling detached, broken propeller blades, damage to aircraft underside
Commander's Licence:	Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	420 hours (of which 5 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

History of the flight

The newly built aircraft was on a local test flight out of Wycombe Air Park and this was its second flight of the day and its seventh flight overall. It was cruising at approximately 4,000 ft amsl over the Oxford Plain near Thame, when the engine started to run roughly and reduce in power. The pilot selected the carburettor heat on and decided to remain in the vicinity of Aylesbury (Thame) Airfield as a precautionary measure. He then turned the electric fuel pump on, switched fuel tanks, reduced the power setting and changed magnetos but none of these actions remedied the engine problem. The engine was producing only sufficient power for the aircraft to maintain level flight or climb very slowly. He then informed Wycombe ATC by radio that he had a suspected carburettor icing problem and was planning on carrying out a precautionary landing at Aylesbury Airfield. The pilot carried out a high approach to Runway 06 using full flap and the aircraft landed two-thirds of the way down the 1,000 m grass runway. He then taxied back to the downwind end of the runway during which time the cylinder head temperature rose (as is normal) and the engine seemed to clear. The pilot then shut down the engine to carry out some checks. He visually inspected the fuel tanks and found that the right tank was approximately two thirds full and the left tank was one third full. He then checked the engine air intake, checked the carburettor heat mechanism, and drained a fuel sample from both wing tanks and from the gascolator. The fuel samples were clear of contamination. The pilot believed that the engine had either been suffering from carburettor ice and that the carburettor heat was not sufficient to clear it, or the fuel had been contaminated. He started the engine again, checked both magnetos at idle, and then made an extended full power run before reducing to 75% power and then idle. The engine ran normally with no indication of the earlier rough running. Consequently, the pilot then switched tanks, turned the electric fuel pump on, selected 10º of flap, and carried out a short field takeoff.

The aircraft climbed normally and then at a height of 400 to 500 ft agl the engine started to run roughly again. Because there was insufficient runway remaining to land straight ahead and because he expected to be able to maintain height, he levelled off and turned left to carry out a short circuit. Once the aircraft was established on the downwind leg the engine ceased producing power. The pilot estimated his tailwind to be 10 to 15 kt but he did not think he had sufficient height to turn back into wind so he decided to land downwind on a recently ploughed rough field. He did not have time to retract the landing gear so when the main wheels hit the ground the aircraft nosed over onto the propeller. The landing gear collapsed and the fuselage-to-engine mount fittings failed, causing the engine to separate. The remainder of the aircraft continued over the engine and came to rest erect. The pilot immediately turned off the ignition and switched the fuel to SHUT OFF. There was no fire and he was experiencing back pain so he remained seated for a few minutes.

A pilot flying a Robinson R44 helicopter saw the aircraft at the accident site and landed in the field to assist. A man walking his dog also arrived on the scene to help. The pilot was able to exit his aircraft in the normal manner and received a ride back to Wycombe in the helicopter. His aircraft was later recovered to his workshop. It was later determined that the pilot had suffered from a fractured vertebrae.

Weather

There was no weather reporting station at Aylesbury Airfield but the conditions at three surrounding airports within 24 nm of Aylesbury at the time of the accident, are listed in Table 1 below.

These reports indicate that the air near Aylesbury at the time of the accident was relatively dry. According to the chart in the Civil Aviation Authority's Safety Sense Leaflet on piston engine icing, the temperature/dewpoint spread placed the risk of carburettor icing in the 'Light icing at cruise or descent power' category - the lowest risk of the four categories.

Airport and Time	Temperature	Dew Point	Humidity	Wind
Brize Norton 1300 UTC	2.5ºC	-6.7ºC	51%	13-25 kt from 050º
Benson 1300 UTC	2.6ºC	-6.0ºC	53%	15 kt from 030º
Northolt 1300 UTC	2.3ºC	-8.4ºC	45%	11-25 kt from 040º

Table 1

Weather conditions at local airports at the time of the accident

Description of the aircraft

The Silence Twister (as shown, Figure 1) is a light weight, all-composite, low-wing, kit-build aircraft with a tailwheel configuration and retractable main gear. It has a maximum take-off weight of 420 kg and is powered by a four-cylinder, four-stroke Jabiru 2200A engine, driving a fixed pitch propeller. The aircraft has a fuel tank within the inboard section of each wing with a combined total fuel capacity of 80 litres.

Figure 1
Silence Twister

Examination of the aircraft

The pilot, who was also the aircraft's builder, examined the aircraft in his workshop. He stripped the carburettor but found no fault. The right wing fuel tank had ruptured and a large quantity of remaining fuel escaped when it was moved. The left fuel tank was intact and contained approximately 20 litres of fuel. An examination of the electric fuel pump revealed small particles of resin on the inlet side of the pump. Both fuel tanks also contained particles and flakes of resin. Some particles were also found in the fuel filters inside each tank. However, the filter inside the gascolator downstream of the electric fuel pump was clean apart from a plug of dirt that had become embedded during the forced landing. No other anomalies were found.

Fuel tank construction

The fuel tanks were made by an individual who specialised in composite manufacture. The tanks were constructed from glass reinforced plastic (GRP) wrapped around a plug. A wax releasing agent was applied to the plug to enable the plug to be removed once the GRP had cured. Any remaining wax was then cleaned from inside the tank. Two internal ribs and a closing end-rib were then bonded to the fuel tank using a Derakene Vinyl Ester resin, developed for usage in underground fuel storage tanks. The completed fuel tanks were then pressure tested and shipped to the aircraft kit manufacturer. The aircraft build manual instructed the builder to flush the tanks with water to remove any deposits.

Determination of the origin of the resin particles

The pilot contacted the aircraft kit manufacturer and the Popular Flying Association (PFA) to report his discovery of resin particles in the fuel system. He then travelled to Germany to meet the kit manufacturer and the fuel tank manufacturer. Together they determined that the fuel tank manufacturing process was not ensuring adequate removal of all the wax releasing agent from inside the tank. When the ribs were bonded to the tank using the resin, some resin was bonding inadequately to residual wax deposits inside the tank.

The pilot had flushed his tanks out using water but when the tanks were subsequently filled with fuel the fuel probably helped to remove the poorly bonded resin from the wax, leaving the resin free to enter the fuel lines. It was determined that four other aircraft, three in the UK and one in the USA, had fuel tanks that could have been affected by the same manufacturing problem.

Analysis

The cause of the rough running engine and its eventual complete power loss could have been carburettor icing, but this was unlikely as the air was relatively dry and according to the carburettor icing chart the risk was low, particularly at high power settings. The more likely cause was a restriction in fuel flow caused by the resin particles found in the fuel system. No resin particles were found downstream of the electric fuel pump, but sufficient particles could have built up within the fuel pump to cause a flow restriction or blockage. However, this does not explain why the engine ran normally during the ground run at Aylesbury and then only failed during the takeoff. It is possible that during the ground taxi, with the engine running near idle with a low fuel demand, the fuel restriction was not sufficient to cause a problem and during this period the fuel gascolator was replenished. During the high power engine ground run the fuel demand would have been high but the fuel contents of the gascolator may have been sufficient for the ground run despite a flow restriction at the fuel pump. The aircraft then possibly departed with a low fuel level in the gascolator and insufficient fuel flow to power the engine at takeoff power. Alternatively, the fact that the tanks were switched just prior to takeoff could have introduced some additional resin from that tank causing a fuel flow restriction or blockage.

Safety action

The aircraft kit manufacturer has notified the four other Twister owners of the potential problem with their fuel tanks. Similar problems of contaminated tanks were found. They have been advised to flush their tanks out thoroughly using fuel rather than water. The Twister build manual has also been revised with a note in red text stating:

> *'Important: Before flying, clean the fuel tanks with gasoline properly. Open the fuel tanks after the first five flight hours and control the tanks and filters if there are any particles.'*

In addition the build manual has been revised with instructions to bore six holes of 3 mm diameter into the inlet end of the plastic tube of the filters inside each fuel tank. This is to reduce the potential of a fuel flow blockage at the filter. Furthermore, the fuel tank manufacturer has revised his manufacturing process to more thoroughly remove all wax releasing agent from inside the tank prior to bonding the ribs. The Popular Flying Association has stated that they are satisfied with the safety action taken.

The owner of G-TWST modified the aircraft's fuel system by fitting a new type of fuel pump and adding two new fuel filters which are visible through the landing gear leg mounting holes.

ACCIDENT

Aircraft Type and Registration:	Tri Kis, G-BVTA
No & Type of Engines:	1 Continental Motors Corp O-240-E piston engine
Category:	1.3
Year of Manufacture:	1996
Date & Time (UTC):	17 July 2005 at 1100 hrs
Location:	Dunkeswell, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Minor damage to fuselage and undercarriage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	345 hours (of which 73 were on type) Last 90 days - 6 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The main undercarriage collapsed following a slightly firm landing.

History of the flight

The pilot reported that following a normal approach to Runway 23, the aircraft made a slightly firm landing with a small bounce. After the aircraft had taxied for approximately 50 yards, the main undercarriage collapsed rearwards and the aircraft came to a stop in a nose up position. The failure of the undercarriage was caused by the two forward undercarriage securing bolts and washers pulling through the fibreglass structure. The damage to the aircraft was assessed as minor. The pilot assessed the weather at the time as good with a wind velocity of 210º/5 kt.

The pilot, who built the aircraft from a kit imported from the USA, confirmed that the assembly of the undercarriage conformed to the designer's plans. Since the accident the pilot has submitted a modification request to the Popular Flying Association to strengthen the area of the fuselage to which the undercarriage is attached.

ACCIDENT

Aircraft Type and Registration:	Zenair CH 601HD (Modified), G-BUTG
No & Type of Engines:	1 Continental Motors Corp C90-14F piston engine
Category:	1.3
Year of Manufacture:	1993
Date & Time (UTC):	14 August 2005 at 1955 hrs
Location:	Upper Wellingham Farm, Near Lewes, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller and nosewheel broken, minor damage to port wing tip
Commander's Licence:	Private Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	288 hours (of which 16 were on type) Last 90 days - 4 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft had landed uneventfully on a wet grass surface, and was taxiing towards a concreted area opposite the hangar, when it hit a small concrete obstacle close to the edge of the hardstanding. This resulted in the collapse of the nose landing gear and damage to the propeller tips and left wing tip.

The pilot reported that due to the grass surface being wet, the effect of the aircraft's brakes was significantly reduced. He also reported that the concrete obstacle was obscured from view by long grass and that this prevented it being seen from far enough away to take avoiding action, given the degraded braking performance.

ACCIDENT

Aircraft Type and Registration:	Enstrom F-28A-UK, G-BAAU
No & Type of Engines:	1 Lycoming HIO-360-C1A piston engine
Category:	2.3
Year of Manufacture:	1972
Date & Time (UTC):	15 December 2004 at 1559 hrs
Location:	Corporation Lane, Coton Hill, Shrewsbury, Shropshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	105 hours (all on type) Last 90 days - 14 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB

Synopsis

The pilot was on the return leg of a solo flight from Manchester to Nottingham when the engine suddenly cut out. He entered autorotation but the aircraft sustained extensive damage in the ensuing forced landing. On inspection it was found that the aircraft had run out of fuel. Investigation revealed that there was no appropriate data on fuel consumption rates in the helicopter's Flight Manual although some information existed in the Lycoming engine manual. The pilot did not possess a copy of the engine manual and had incorrectly based his fuel planning on the consumption rate witnessed on the aircraft's fuel flow gauge during previous flights.

History of the flight

The pilot planned to fly solo from the helicopter's home base at Barton Airport, Manchester, to Nottingham and then to return to Barton. The entire flight had a planned distance of 156 nm. The pilot intended to cruise at 80 mph indicated airspeed (69.5 KIAS) with a planned airborne time of two hours and twenty-four minutes. The weather forecast was good with only light north-westerly winds predicted. Before departure the pilot positioned the helicopter at the airport's refuelling point and asked the attendant to fully refuel both of the helicopter's fuel tanks. He then departed at 1150 hrs for the flight to Nottingham, flying at an altitude of about 1,500 ft and at his planned cruise speed of 80 mph. During the cruise the pilot noted that the fuel flow gauge indicated that the helicopter was consuming about 54 lbs/hr of AVGAS. He arrived at Nottingham Airport at 1312 hrs, having taken two minutes less than the planned flight time for this leg. On landing the fuel gauge showed three-quarters full.

Prior to his return flight the pilot again checked the forecast weather conditions and confirmed that he still had enough fuel on board, without refuelling, to complete the flight ba ck to Barton safely.

The pilot took off for the return flight at 1449 hrs and found himself flying into sun in hazy conditions. He had planned to use a mast situated on Carlton Moor as a navigational reference point. However, under the prevailing conditions, shortly after takeoff he mistakenly started to fly towards a different mast, situated on Darley Moor. The pilot realised his mistake some way into the flight and took several minutes to regain the correct track. When he had done so he recalled checking the fuel gauge which showed a quarter of a tank remaining. The pilot was then concerned that he might not have sufficient fuel on board to complete the remainder of the flight and he decided the safest option was to make a precautionary landing in order to allow him to re-calculate his fuel requirement. If necessary, he could then either plan to fly to a suitable diversion or organise for the helicopter to be refuelled where it was.

The pilot began heading towards an area of open fields in which he planned to land and had descended to a height of about 800 ft agl when, without warning, the engine stopped. The pilot immediately entered autorotation and looked for a suitable place to land. His choice of landing area was limited by his relatively low altitude plus numerous surrounding buildings and obstacles. The pilot identified what he considered the most suitable area, although it was relatively small and had power lines in the undershoot and some trees in the overshoot areas. As he got lower it was also apparent that the chosen landing area was in fact a small bowl and once over the wires, when flaring the helicopter for touchdown, the tail struck rising ground behind the machine. This tail strike broke off the tail rotor and rear portion of the tail boom, whereupon the remainder of the helicopter then struck the ground heavily, coming to an immediate halt. The pilot estimated his speed just prior to touchdown was 30 mph (26 kt). The helicopter remained upright, but the force of the landing was sufficient to burst open both cabin doors and to cause extensive damage to the rest of the machine.

The pilot injured his left shoulder during the impact, but otherwise he was unscathed. He made sure all the electrical switches were safe and in the absence of any fire, he remained in the helicopter whilst contacting the emergency services on his mobile telephone. He then climbed out of the helicopter to await their arrival.

A subsequent inspection of the helicopter could find no apparent mechanical faults which may have caused the engine to stop. It also revealed an absence of fuel in the fuel tanks and in the remainder of the fuel system.

Fuel capacity

The FAA (Federal Aviation Administration of the USA) approved Flight Manual produced by the helicopter manufacturer for the F-28A states in its description of the fuel system that the helicopter is fitted with two fuel tanks, each with a capacity of 15 US gallons. The Manual makes no mention of an unusable fuel quantity, but it does state that the mixture control should be pushed in (the fully rich position) during all flight operations. In the weight and balance section the Manual indicates that 30 US gallons of fuel weighs 180 lbs.

Performance data

The '*Performance Data*' section of the Flight Manual does not contain any fuel consumption data. The '*F-28A Specifications*' section of the same manual states a specific fuel consumption for the engine of '*0.5lb/hp/hr'* (pounds per horsepower per hour) and a '*normal'* power output of 205 HP. The fuel consumption at this '*normal'* power output equates to 102.5lb/hr, giving a maximum flight duration of one hour and forty-five minutes. There was no data equating horsepower with cruising or climb speeds to support any calculation of typical fuel flow rates.

However, the engine manufacturer's manual for the Lycoming HIO-360-C1A contains a chart comparing fuel flow with percent rated power. This indicates that the fuel consumption is about 72 lb/hr at 65% power and 86 lb/hr at 75% power. The 72lb/hr rate at 65% power equates to a maximum flight duration of two and a half hours.

Helicopter manufacturer's statement

The Enstrom F-28 model aircraft was certified under CAR 6 (not under the Federal Aviation Regulations) and continues to be subject to those recommendations. The Flight Manual for the F-28A was directly approved by the FAA in 1968 and was re-printed in 1972.

The helicopter manufacturer agreed that the only references to fuel consumption in the current revision level of the F-28 Rotorcraft Flight Manual (Revision 10 dated 22 May 1998) was the '*0.5lb/hp/hr'* consumption rate and the total fuel capacity of the tanks. Later model production aircraft have a manifold/fuel pressure gauge marked with pounds per hour along with the fuel pressure scale on the fuel pressure side of the gauge. The same instrument on early production models has only the fuel pressure scale. Moreover, because the unusable quantity of fuel in the F28A is less than 1 US gallons, neither the fuel quantity indicator nor the Flight Manual were required to provide unusable fuel quantity information.

Analysis

The pilot realised he was running low on fuel but the engine stopped when the tanks emptied before he completed the precautionary landing. The only source of fuel consumption data available to him in the Flight Manual was unusable unless all operations were conducted at '*normal'* power. The meaning of '*normal'* in this context is not stated but it is likely to mean the maximum power output at full throttle under ISA conditions for this version of the fuel-injected engine running at 2,900 rpm. Full power may not be appropriate during the cruise but no information is contained in the Manual which would allow any pilot to calculate the expected fuel consumption at the lower power settings experienced during a transit flight.

Slightly more useful fuel consumption information was available in the engine manufacturer's Operator's Manual, but being generic it was of little use without data relating power output to manifold pressure or a combination of weight, temperature and airspeed. Moreover, the pilot did not possess a copy of the engine manual and therefore did not have even this generic information available to him.

The pilot relied for his pre-flight fuel planning on the indicated fuel consumption he had previously witnessed on the helicopter's fuel flow gauge of approximately 55lb/hr in the cruise. Based on the pilot's assumed fuel consumption this would give a maximum flight endurance of three hours and sixteen minutes. The return flight to Nottingham had a total planned flight time of two hours and twenty-four minutes which, if his assumption was correct, would have given a reserve of some fifty-two minutes. Despite the divergence from the planned track, the forced landing took place 65 track miles from Nottingham which was less than the 78 nm distance between the two airports.

Conclusion

The helicopter's engine lost power due to fuel exhaustion. The pilot had departed with what he believed to be sufficient fuel on board based on an incorrectly assumed fuel consumption figure. This belief was reinforced by indications on the helicopter's fuel flow and fuel quantity gauges.

The flight time between the helicopter refuelling and the engine cutting out was approximately two and a half hours. This appears to be the endurance equivalent to cruising at 65% power but the difference between the observed fuel flow of 55 lb/hr and the 72lb/hr predicted at this setting could not readily be explained. Historically, the fuel quantity indications on many light aircraft have proved to be inaccurate. The effect of relying on such indications is, ultimately, that the aircraft might unexpectedly run out of fuel.

Whilst many pilots take precautions against inaccurate quantity gauges by dipping their tanks or by only filling them completely full, they still require accurate fuel consumption figures to be able to determine the expected duration that the fuel on board will allow. This position is potentially made worse by the contrast found in the accuracy of modern car fuel gauges. Not only do most cars now display low fuel contents warnings, but some cars also allow average fuel consumption figures to be displayed. The temptation is for the same level of confidence to mistakenly be transferred by a user to a potentially less accurate helicopter system, with obvious results.

It was surprising that the FAA approved Flight Manual did not contain any suitable information on fuel consumption. Certainly there was no information available that would have allowed the pilot to calculate the fuel requirement for his flight with any level of accuracy. The relationship between fuel pressure and fuel consumption is established on later model production aircraft.

The absence of useful fuel consumption data from the Flight Manual may have been a causal factor in this accident. Therefore, it was recommended to the FAA that:

Safety Recommendation 2005-059

The Federal Aviation Administration of the USA should instruct the Enstrom Helicopter Corporation to include useful information on fuel consumption rates in all their Rotorcraft Flight Manuals.

Response to Safety Recommendation 2005-059

The helicopter manufacturer decided not to act independently upon the safety recommendation because (quote):

> *'in accordance with the applicable regulations under which the aircraft was certified, ie CAR 6.743, Performance Information, fuel consumption rates are not "required" to be included as part of the performance information in the Flight Manual'.*

In March 2000 the manufacturer issued a Service Directive Bulletin (SDB 0092, Fuel Quantity System Calibration) which required annual checking/calibrating of the aircraft's fuel quantity system. Subsequent enquiries by the AAIB revealed that the last time this SDB had been carried out on G-BAAU was on 10 June 2001. There was no record in the aircraft logbooks of it being carried out during any of the subsequent annual inspections. This factor may explain inaccurate fuel quantity indications on G-BAAU.

A response from the recommendation addressee, the FAA, has not yet been received. The FAA's response will be reported in the AAIB's annual review of Safety Recommendations.

ACCIDENT

Aircraft Type and Registration:	Robinson R44, G-SYTN
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Category:	2.3
Year of Manufacture:	2002
Date & Time (UTC):	8 May 2005 at 1220 hrs
Location:	Swansea Airport, West Glamorgan
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - 2
Nature of Damage:	Tail broken off and main rotor destroyed. Skids detached
Commander's Licence:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	58 hours (of which 7 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While hover taxiing the helicopter in a moderate tailwind towards the apron at Swansea Airport, the pilot initiated a right turn which developed into an uncommanded and uncontrollable yaw to the right. The pilot was unable to regain control of the helicopter before it hit the ground and came to rest on its left side, with substantial damage to the tail and rotors. There was no fire. The pilot was able to vacate the aircraft unaided and assist the two passengers, who exited the aircraft without major injury. In the absence of evidence of a pre-existing mechanical fault, the investigation determined that the most likely cause of the accident was a loss of tail rotor effectiveness while hover taxiing at low speed with a tailwind.

History of the flight

After completing two circuits on Runway 28 at Swansea Airport, the pilot brought the aircraft to a hover beside a taxiway intersection and hover taxied clear of the runway on a north-easterly heading. The helicopter then turned right onto an easterly heading in order to enter the apron for parking. Surface wind was reported as 300º/14 kt. As it turned from the taxiway onto the apron, the aircraft continued in an uncommanded turn to the right, which the pilot tried to correct with a left yaw pedal input. Despite full left pedal input, however, the aircraft continued to yaw to the right. During this manoeuvre the nose pitched down and the main rotor struck the ground. The tail struck the ground and broke off during the subsequent violent yaw to the right.

The pilot has no clear recollection of the control inputs he made at this point. The aircraft came to rest on its left side with substantial damage to the tail and rotors. There was no fire. The pilot was able to climb out unaided before reaching back into the cockpit to shut off the fuel. The passenger in the left rear seat was trapped briefly by her clothing but was freed without great difficulty and helped out of the aircraft by the pilot. The passenger in the left front seat was able to vacate the aircraft unaided. Paramedics and the airfield fire and rescue service were in attendance quickly.

Engineering inspection

A subsequent engineering inspection did not reveal any evidence of a pre-existing mechanical fault that could have caused the accident.

Loss of tail rotor effectiveness

A loss of tail rotor effectiveness (LTE) is said to occur if the tail rotor does not provide sufficient thrust to maintain directional control, allowing an uncommanded yaw to develop which, if not corrected, results in loss of control of the helicopter. LTE will cause a yaw in the opposite direction to the rotation of the main rotor. The yaw will be to the right in the case of the Robinson R44, whose single main rotor rotates counter-clockwise when viewed from above. LTE is likely to occur while hovering or moving slowly with a quartering tailwind from more than 30° behind dead abeam and may be initiated by an intentional turn. Full opposite yaw pedal input may not be sufficient to arrest the yaw unless it is applied positively and without delay. Any increase in power applied to the main rotor will increase the yaw tendency and complicate recovery. Conversely, reducing power to the main rotor will assist with recovery, but usually this is not practical during a hover taxi.

Previous occurrences

AAIB Bulletin 1/2004 contains a report (reference EW/C2003/05/07) into the accident to helicopter G-BAML. LTE was considered a possible cause and two safety recommendations were made.

Relevant extracts from the report of the investigation into the accident to G-BAML

In 1995, and in response to a number of helicopter accidents in the USA involving LTE, the FAA issued Advisory Circular (AC) 90-95 on the Subject of '*Unanticipated Right Yaw in (US Manufactured) Helicopters*'.

The report identifies four possible relative wind directions and resultant aircraft characteristics that can, either singularly or in combination, create an environment conducive to LTE:

1. Main rotor disc vortex interference occurs with a relative wind of 285º to 315º and involves changes in tail rotor thrust as the airflow experienced at the tail rotor is affected by the main rotor disc vortex.
2. Tailwinds from a relative wind direction of 120º to 240º will cause the helicopter to yaw into wind and may accelerate an established rate of yaw.
3. Tail rotor vortex ring state can occur with a relative wind of 210º to 330º. With the relative wind in this region, vortex ring state can cause tail rotor thrust variations.
4. Loss of translational lift with the relative wind in all azimuths results in an increased power demand and consequent increase in anti-torque demand from the tail rotor.

The recommended recovery technique, if a sudden unanticipated yaw occurs, is to apply full pedal to oppose the yaw whilst simultaneously moving the cyclic forward to increase speed. If altitude permits, power should be reduced. The AC also makes the point that the tail rotor is not stalled and full pedal to oppose the yaw should be maintained until rotation stops.

In the UK there has been little emphasis on the phenomenon, but most of the factors that can lead to LTE should be known by most UK helicopter pilots. However, the relationship of the various factors to the performance capability of Part 27 helicopters is probably less widely known. The pilot involved in this accident had been trained to cope with tail rotor failures, but he had not received training nor was he aware of the LTE phenomenon."

Safety Recommendations made in report EW/C2003/05/07(1/2004) and related CAA responses

Safety Recommendation 2003-126

The CAA should publish, as widely as possible within the UK, information on the Loss of Tail Rotor Effectiveness (LTE).

CAA response

The CAA has taken action to publish this information. This publicity has included inclusion of LTE at the helicopter flight instructor examiners (FIE(H)) seminar held in October 2003, the issuance of training communication to all helicopter flight instructors (FI(H)), and information on the provision of the appropriate training materials identified by the report for use at FI(H) seminars. In addition, all UK FIE(H) have been briefed to include LTE and tail rotor malfunctions in the mandatory section of the FI(H) rating revalidation process. Further to promulgate information on LTE, the CAA published Flight Operations Department Communication (FODCOM) 1/2004 on 9 January 2004. A comparable article for the general aviation community will be published in the first 2004 issue of the General Aviation Safety Leaflet (GASIL).

Safety Recommendation 2003-127

The European Aviation Safety Agency (EASA) should ensure that information on Loss of Tail Rotor Effectiveness (LTE) is included in helicopter pilot training syllabi.

CAA response

Although not specifically a recommendation for the CAA, the UK has, through its involvement with formulating the Joint Aviation Requirements for Flight Crew Licensing - Helicopter (JAR-FCL 2), gained the agreement of the other JAA Member States to an amendment to the helicopter pilot training syllabi to include LTE. The amendment will be subject to the Notice of Proposed Amendment procedure during 2004. It is anticipated that JAR-FCL 2 will form the basis of European requirements for flight crew licensing scheduled for adoption during 2005.

The full text of GASIL 1 of 2004 and FODCOM 1/2004 is available on the CAA website www.caa.co.uk. Previous AAIB bulletins are available online at www.aaib.gov.uk.

Conclusion

The helicopter was hover taxiing in a light quartering tailwind. Such conditions make a loss of tail rotor effectiveness more likely. Having initiated a right turn, the pilot did not maintain positive control of the aircraft, and an uncommanded yaw developed which could not be brought under control before the helicopter hit the ground.

ACCIDENT

Aircraft Type and Registration:	X'Air 582(5), G-CBOC
No & Type of Engines:	1 Rotax 582/48-2V piston engine
Category:	1.4
Year of Manufacture:	2002
Date & Time (UTC):	22 June 2005 at 2100 hrs
Location:	Pomeroy, Co Tyrone, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Damage to aircraft nose, propeller and landing gear
Commander's Licence:	None
Commander's Age:	48 years
Commander's Flying Experience:	20 hours (of which 10 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The pilot and a friend were carrying out a flight from Blackhill, Draperstown to the general area of the village of Pomeroy before returning to Draperstown. The weather was good with a light wind from the east. The flight down to Pomeroy was uneventful and the microlight aircraft was descended to low level in the area of Crocknagaran, 2 nm north-east of Pomeroy. The aircraft made an orbit of a private property and as a second orbit was commenced, power was applied but the engine did not appear to respond and the aircraft failed to climb. The main landing gear wheels struck some trees close to the property. The pilot managed to maintain control but he was forced to land immediately in an adjacent field. The landing gear collapsed and the propeller contacted the surface stopping the engine. Both persons vacated the aircraft, the pilot having isolated the fuel and electrical power. The emergency services attended the scene and pilot and passenger were taken to hospital.

Pilot's assessment of the causal factors

The pilot considered the cause of the accident was possibly due to carburettor icing or the climb performance being reduced by the weight of the additional person.

FORMAL AIRPORT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2003

1/2003 Hughes 269C, G-ZAPS
at Hare Hatch, near Twyford,
Berkshire on 8 March 2000.

Published February 2003.

2/2003 Shorts SD3-60, G-BNMT
near Edinburgh Airport
on 27 February 2001.

Published April 2003.

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

Published July 2003.

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

Published November 2003.

2004

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

Published February 2004.

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

Published April 2004.

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

Published June 2004.

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

Published July 2004.

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

Published August 2004.

2005

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

Published February 2005.

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