CONTENTS

COMMERCIAL AIR TRANSPORT

FIXED WING

Airbus A320-214	G-BXKD	15-Jan-05	1
Boeing 747-436	G-CIVB	18-Jun-05	17
Fokker F27-500 Friendship	G-BVOB	22-Mar-05	20

ROTORCRAFT

Aerospatiale AS355F1	G-FFRI	19-Jul-04	24

GENERAL AVIATION

FIXED WING

Avid Speedwing Mk 4	G-BUFV	10-Jun-05	29
Cessna 152	G-IRAN	03-Jul-05	32
Cessna 180K Skywagon	G-BETG	15-May-05	35
DA40D Diamond Star	G-HASO	29-Jun-05	36
Druine D.31A Turbulent	G-ARLZ	17-Jul-05	46
Grob G115 D2	G-BVHF	06-Jun-05	47
Maule M6 Super Rocket	N6130X	06-Aug-05	50
Piper PA-28-140	G-BTVR	11-Jun-05	51
Piper PA-28-181	G-MERI	10-Jul-05	52
Piper PA-32R-300	G-BSYC	25-Jun-05	54
Pitts S-1E	G-LITZ	08-Jul-05	55
Staaken Z-21 Flitzer	G-ERIW	16-Jul-05	57

ROTORCRAFT

Agusta Bell 206A Jet Ranger	G-OJEF	27-May-05	58
Enstrom 280FX	G-MHCK	21-May-05	60
Robinson R44 Clipper II	G-SHAN	10-Jun-05	64

SPORT AVIATION / BALLOONS

Cameron Z-250 Balloon	G-CDIN	12-Jun-05	66
Rans S6-ESD	G-MWTT	26-Jun-05	76

ADDENDUMS and CORRECTIONS

CORRECTION

Cessna F177RG Cardinal	G-TOTO	09-Feb-04	78

List of recent aircraft accident reports issued by the AAIB 80

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	Airbus A320-214, G-BXKD
No & Type of Engines:	2 CFM56-5B4/P turbofan engines
Category:	1.1
Year of Manufacture:	1997
Date & Time (UTC):	15 January 2005 at 1635 hrs
Location:	London Gatwick Airport, West Sussex
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 177
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left nose wheel detached from aircraft
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	6,200 hours (of which 4,400 were on type) Last 90 days - 113 hours Last 28 days - 55 hours
First Officer's Flying Experience	4,392 hours (of which 2,566 were on type) Last 90 days - 82 hours Last 28 days - 36 hours
Information Source:	AAIB Field Investigation

Synopsis

The left nose wheel detached from the aircraft during the takeoff from London (Gatwick) Airport. Airport staff saw the wheel fall off and the flight crew were notified by Air Traffic Control (ATC). After holding for two hours, to burn off fuel and reduce the landing weight, the aircraft landed safely at Gatwick. The nose wheel detached as the result of the partial seizure of the outer wheel bearing, most probably caused by water contamination of the grease in the bearing. Four safety recommendations have been made.

History of the flight

The flight was scheduled to depart from London (Gatwick) at 1400 hrs for Sofia, Bulgaria, with an estimated flight time of 2 hours 40 minutes. The taxi and subsequent takeoff at 1434 hrs were apparently uneventful but one minute after the aircraft was airborne ATC advised the crew that they had lost a wheel on departure. The aircraft was given a radar heading and clearance to climb to maintain 3,000 ft initially and was subsequently re-cleared to climb to 6,000 ft and to hold at the nearby Mayfield VOR.

Ten minutes later ATC informed the crew that it had been confirmed that it was a nose wheel that had detached from their aircraft. With the aircraft now in the holding pattern the crew considered the options available to them. They decided to reduce the fuel load until the aircraft was at its maximum landing weight of 64,500 kg and then to carry out a landing. At first, following consultation with their company operations and engineering departments, the crew planned to divert the flight to Manchester Airport. However, on receipt of an unfavourable weather report from Manchester they decided to remain at Gatwick and complete a landing in daylight in the better weather conditions available there.

The crew, uncertain of the reason for the loss of the wheel and unable to ascertain the integrity of the nose landing gear, reviewed all the various possible consequences of making a landing. They decided to plan for the worst case, which was the nose landing gear collapsing on landing. There were no Electronic Centralised Aircraft Monitor (ECAM) messages or any other indications of a failure displayed so they reviewed the Quick Reference Handbook (QRH) and the Flight Crew Operating Manual (FCOM) looking for any procedure related to the unusual configuration of their aircraft. They eventually decided to apply the 'LDG WITH ABNORMAL L/G' procedure from the QRH. They briefed the cabin crew for an emergency landing and informed the passengers of the nature of the problem.

Although the crew now knew that they had lost one nose wheel, in order to confirm the existing condition of the nose landing gear they arranged with ATC to carry out a low approach and go-around. This was to allow company engineering personnel, positioned near the threshold of Runway 08R, to make a visual inspection of the landing gear. At 1557 hrs a flypast was carried out down to 200 ft agl, following which a normal go-around was flown but with the landing gear remaining down. After the flypast, engineering personnel advised the crew that the left nose wheel was missing but that the right nose wheel was in place.

The aircraft returned to the hold and following a further review of the QRH and the FCOM the crew decided that they were ready to make an approach. A normal approach was completed until just before touchdown when the first officer shut down both engines, as the crew had pre-planned, in accordance with the QRH procedure. A gentle touchdown followed at 135 kt with an attendant pitch attitude of 6º. The commander applied the brakes, being careful not to brake too hard since the anti-skid system was not available, and kept the aircraft rolling straight along the runway. The nose gear touched down normally. The commander experienced some difficulty in maintaining directional control, needing to brake harder on the right side to keep straight. One right main gear tyre burst but the aircraft maintained the runway centreline until just before coming to a stop, when the nose swung left through approximately 30º. The aircraft stopped having used some 2,300 m of the available runway length.

After the aircraft came to a stop the commander consulted with the Airport Fire Service (AFS) as to the condition of the aircraft and decided that a passenger evacuation would not be necessary. A wheel jack and spare nose wheel were brought out to the aircraft and once they were positioned and fitted the aircraft was considered to be secure. Steps were brought out and the passengers disembarked normally.

Runway marks

A set of tyre marks leading back from the nose and main wheels indicate that after landing the aircraft continued down the runway with each of the main wheels approximately equidistant from the runway centre line. During approximately the last 8 ft of the ground roll, the tyre marks from the right hand nose wheel tyre indicates that the nose wheel had turned approximately 60º to the left, resulting in the aircraft stopping on the runway at an angle of approximately 30º to the runway centre line.

Airport operations

Runway 08R at Gatwick has a Landing Distance Available (LDA) of 2,766 m (9,075 ft).

The AFS were already prepared for the emergency landing and the first vehicle arrived at the point where the aircraft came to a stop within a few seconds.

Following the landing the aircraft remained on Runway 08R thereby closing the operational runway at the airport. However the protected area for the standby Runway 08L was not infringed and therefore operations were quickly switched to Runway 08L. There were six diversions away from the airport before it reopened.

Meteorological conditions

The weather report received by the crew for Manchester Airport, which had been observed at 1450 hrs, was as follows: Surface wind from 150º/11 kt, visibility 5 kms, cloud overcast at 600 ft, temperature 10ºC, dewpoint 9ºC and QNH 1019 hPa.

Gatwick ATIS information 'X', valid at 1620 hrs was as follows: Surface wind from 140º/3 kt, CAVOK, temperature 8ºC, dewpoint 4ºC and QNH 1023 hPa.

The crew wished to complete the landing in daylight and verified that the local time of sunset was at 1623 hrs.

Operational decisions

Electronic Central Aircraft Monitor

The ECAM presents data to the flight crew. In the case of a failure or problem where there is no ECAM message generated the crew may be able to refer to procedures in the QRH. Further information may also be available in the FCOM which the crew should review if there is time available.

'LDG WITH ABNORMAL L/G' procedure

The diagram at Figure 1 below is included within the 'LDG WITH ABNORMAL L/G' procedure in the FCOM. It shows that in the event of a collapse of the nose landing gear both engine nacelles would contact the runway.

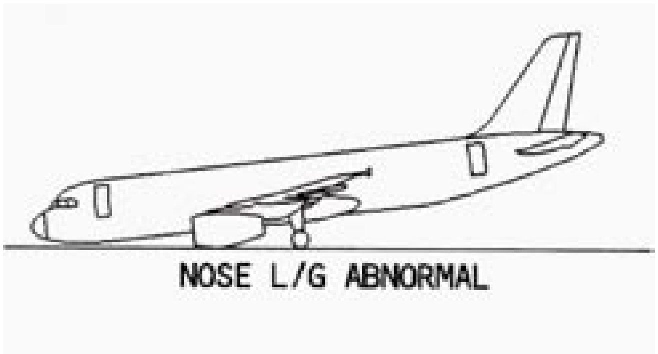


Figure 1

Nose Gear Down

The QRH procedure is reproduced below at Figure 2

Expanded information is provided in the FCOM in the form of notes within the procedure.

The procedure requires the engines to be shut down before or during the landing roll. The loss of electrical power, (without the APU running) renders some services associated with stopping distance and directional control unavailable, notably the ground spoilers, the antiskid system and nose wheel steering. Further effects due to the decay of hydraulic pressure over time are; loss of hydraulic brake pressure and loss of flight controls.

LDG WITH ABNORMAL L/G

PREPARATION

- CABIN CREW .... NOTIFY
- ATC .... NOTIFY
- GALLEY .... OFF
  - *Consider fuel reduction to a safe minimum.*
- **If NOSE L/G abnormal**
  - CG location (if possible) .... AFT
    - *10 PAX from front to rear + 4 %.*
    - *10 PAX from mid to rear + 2.5 %.*
- **If one MAIN L/G abnormal**
  - FUEL IMBALANCE .... CONSIDER
    - *Open the fuel X-FEED valve and switch off the pumps on the side with landing gear normally extended.*
- OXYGEN CREW SUPPLY .... OFF
- SEAT BELTS/NO SMOKING .... ON
- CABIN and COCKPIT .... PREPARE
  - *Loose equipment secured.*
  - *Survival equipment prepared.*
  - *Belts and shoulder harness locked.*

APPROACH

- GPWS SYS .... OFF
- L/G LEVER .... CHECK DOWN
- GRVTY GEAR EXTN handcrank ..... TURN BACK TO NORMAL
- AUTOBRAKE .... DO NOT ARM
- EMER EXIT LT .... ON
- CABIN REPORT .... OBTAIN
- **If one or both MAIN L/G abnormal**
  - A/SKID & NW STRG .... OFF
  - MAX BRAKE PR 1000PSI
  - GROUND SPOILERS .... DO NOT ARM

BEFORE LANDING

- RAM AIR .... ON
- BRACE FOR IMPACT .... ORDER

Cont'd

LDG WITH ABNORMAL L/G (cont'd)

FLARE, TOUCHDOWN AND ROLL OUT

Engines should be shut down sufficiently early to ensure fuel is shut off before the nacelles impact, but sufficiently late to ensure adequate hydraulic supplies for the flight controls. Engine pumps continue to supply adequate hydraulic pressure for 30 seconds after first engine shutdown.

- REVERSE .... DO NOT USE
- **If NOSE L/G abnormal**
  - NOSE .... MAINTAIN UP
    After touchdown, keep the nose off the runway by use of the elevator. Then, lower the nose onto the runway before elevator control is lost.
  - BRAKES (compatible with elevator efficiency) ..... APPLY
  - ENG MASTERS .... OFF
    Shutdown the engines before nose impact.
- **If one MAIN L/G abnormal**
  - ENG MASTERS .... OFF
    At touchdown, shut down both engines.
  - FAILURE SIDE WING .... MAINTAIN UP
    Use roll control, as necessary, to maintain the unsupported wing up as long as possible.
  - DIRECTIONAL CONTROL .... MAINTAIN
    Use rudder and brakes (maximum 1000 psi) to maintain the runway axis as long as possible.
- **If both MAIN L/G abnormal**
  - ENG MASTERS .... OFF
    Shut down the engines in the flare, before touchdown.
  - PITCH ATTITUDE (at touchdown) .... NOT LESS THAN 6°

WHEN A/C STOPPED

- ENG (all) and APU FIRE pushbutton .... PUSH
  Pressing the ENG FIRE pb shuts off the related hydraulic pressure within a short time.
- ENG (all) and APU AGENT .... DISCH
- EVACUATION .... INITIATE
  Announce : "PASSENGER EVACUATION" via the P.A. system, and press the EVAC COMMAND pushbutton.
  All emergency and passenger doors may be used to evacuate the aircraft.

Figure 2

It was following an accident to an Airbus A340 aircraft at London Heathrow, reported on in AAIB Aircraft Accident Report 4/2000, that changes to Airbus QRH procedures were made which allowed for consideration of the best timing for engines to be shutdown when landing in an abnormal configuration. The changes were made with the intention of:

> *'preserving essential electrical and hydraulic services for the maximum time consistent with the reduction of risk to the aircraft.'*

Flypast

The initial idea for a flypast was suggested by company engineering personnel and passed on to the crew by ATC. The crew readily complied with the suggestion. There was not any procedure or training for how to carry out a flypast so the crew discussed beforehand how they would fly it. Initially they planned to go down to 500 ft agl in the landing configuration and then to fly level past the runway threshold. However once they had descended to 500 ft agl on the approach they realised that it would not be low enough for anything to be seen, so they continued down to 200 ft agl. The go-around was flown as a standard procedure with the exception that the landing gear remained down.

Approach and landing

The crew followed the QRH procedure (Figure 2) and completed the actions as required. There were two variations made to the procedure, firstly they applied the 'GROUND SPOILERS..............DO NOT ARM' action, applicable for when one or both main landing gear are abnormal and secondly the engine masters were selected to 'OFF' just before touchdown.

Landing distance

The procedure provided for calculating landing distance requires a base figure to be determined and then correction factors are applied according to the nature of the failure. Correction factors for a number of different failures or combination of failures can be obtained from the QRH but there were none directly applicable to these particular circumstances. The factor to be applied for a loss of green and yellow hydraulic systems (ie for accumulator braking only) is 2.6 times the normal landing distance, which in this case would have given a figure of 2,500 m.

Damage to the aircraft

Apart from the missing left hand nose wheel, the only apparent damage to the aircraft was a burst starboard main wheel tyre and scuffing to the outboard edge of the remaining nose wheel tyre. The axle for the missing nose wheel and the wheel nut securing threads were undamaged, with no signs of overheating. There were minor scratches on the sleeve that covers the axle, which most probably occurred during routine maintenance operations. The operators maintenance staff inspected the nose wheel bay and adjacent structure in accordance with instructions from the manufacturers and found no damage. The nose undercarriage leg was replaced as a precautionary measure. Detailed examination of the burst main wheel tyre and anti skid system was not carried out as the action of shutting down the engines rendered the anti skid system inoperative and the tyre was seen to burst half way through the landing ground run.

Aircraft Information

Nose Wheel Assembly

The nose wheel assembly consists of two wheels each running on an inner and outer bearing that sits on a sleeve fitted over the axle (Figure 3). A circlip secures the bearing in the wheel hub during transportation. Grease seals are fitted on the outside face of both bearings and the wheel is secured to the axle by the nose wheel securing nut, which has a right hand thread. Secondary locking of the nose wheel securing nut is achieved by two locking bolts fitted with castellated nuts and split pins. The hub cap is secured by three securing bolts.

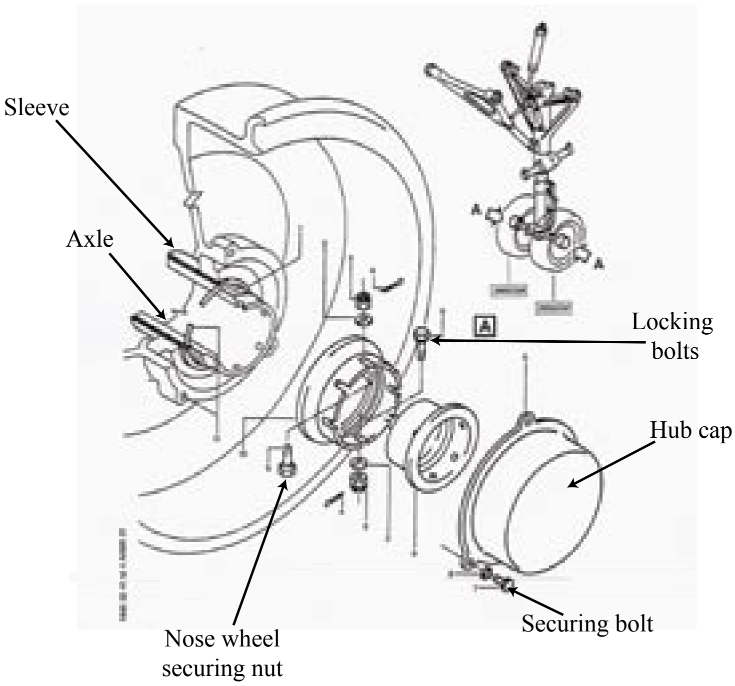


Figure 3

General Arrangement of Nose Wheel Assembly

Bearing

The nose wheel bearing consists of a cone, taper roller, cup and cage (Figure 4). The cup is fixed to the hub and is not normally replaced at wheel overhaul unless there is any evidence of physical damage. The tapered rollers are spaced and retained on the cone by the cage. The radial and side forces on tapered roller bearings are reacted primarily by the tapered races and roller bodies, and also by the roller large end and cone large rib faces.

Detailed Examination

Definition of Roller End Scoring

Roller end scoring results from metal to metal contact between the roller large end and cone rib face. In normal operation the roller body rolls along the face of the cone, whilst the roller large end moves with a sliding and rolling motion across the cone large rib face. However, if the load between the roller large end and rib face is too high, or there is insufficient lubrication, then metal to metal contact between the roller large end and rib face could occur. This contact may result in the micro-welding and tearing of metal causing excessive heat to be generated. The increase in friction at the roller large end would cause the rollers to start to skew and slide along the cone face, causing the softer cage pockets to be distorted. A further increase in temperature might be sufficient to cause the rollers to weld to the cone and 'bearing lock up' to occur.

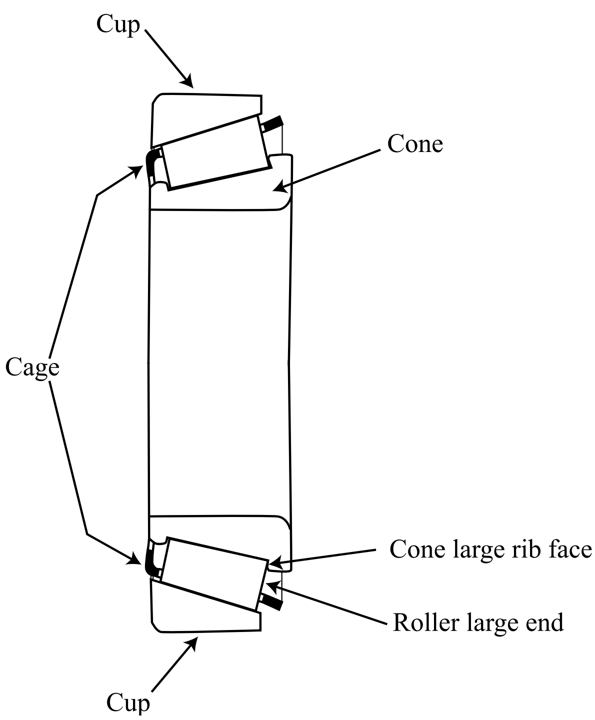


Figure 4

General Arrangement of Nose Wheel Bearing

Examination carried out at incident site

The left nose wheel, which was found near the runway, appeared to be in good condition with no evidence of either scuffing of the tyre, or damage to indicate that it had fallen from the aircraft. Whilst the inner bearing cone and securing circlip were missing, the inner bearing cup was still attached to the wheel. The hub cap was still in place and the three securing bolts were correctly wire locked. It was noted that a small quantity of grease had been thrown out from under the hub cap across the outer face of the wheel. On removing the hub cap it was observed that the grease under the hub cap and on the bearing was a chocolate brown colour rather than the normal bright red. The nose wheel securing nut was stuck to the grease seal and, apart from slight damage to the last thread, the nut was found to be undamaged. The tails and one head of the two nose wheel securing nut locking bolts, which had failed in shear, were found in the grease. The split pins in the locking bolts were still in place and correctly fitted. Slight damage was found on the castellation of the nose wheel securing nut consistent with it having sheared the locking bolts. The bearing was rotated through approximately 180°; whilst it was free to rotate the bearing felt very rough and required a moderate amount of force to keep it moving. Both nose wheels were subsequently taken to the operator's wheel overhaul agents to be stripped and examined under AAIB supervision.

Examination carried out at wheel overhaul facility

The outer bearing assembly, on the recovered left nose wheel, had been correctly fitted and the circlip was still in place; the quantity of grease in the bearing was considered to be adequate. The bearing cup was removed and grease samples were taken at a number of positions through the hub. It was noted that the colour of the grease gradually changed from the chocolate brown at the outside face of the bearing towards the more normal reddish colour on the inner face of the bearing. Fitters experienced in handling this type of wheel indicated that the grease was normally chocolate brown on returned wheels. From the bearing (Figure 5) it could be seen that the rollers had been forced under the bearing cage and that the softer cage had been distorted, with metal transfer having occurred between the cage and bearing cup. Metal smearing was discovered around the circumference of the bearing cone in a position consistent with the distortion and damage to the bearing cage. Apart from localised bluing at the large end of the bearing rollers and a light straw colour on part of the cone, there was no indication that the hub, axle or other wheel components had been subjected to high temperatures. Because of distortion to the outer bearing seal it was not possible to check the dimension of the seal using the seal gauge. The inner bearing cone was removed, inspected and found to be in a good condition.

Figure 5

Left hand wheel outer bearing

The bearing assemblies and associated components in the right nose wheel were all found to be serviceable. Again, the colour of the grease appeared to change through the hub, with the grease on the inner bearing much closer in colour to that of new grease. Both bearing seals marginally failed the seal check, which is not surprising given that the wheel was half way through its anticipated overhaul life and the test is designed to check that the seals are suitable for reissue.

Examination at bearing manufacturer

The outer bearing from the left nose wheel was stripped and examined by the manufacturer under AAIB supervision. It was established that the bearing had the correct part and hardness number. The bearing and grease seals were measured and, as far as could be ascertained, were considered to be manufactured to the correct dimensions. The outer grease seal and securing nut were separated and it was observed that there was wet grease between the contact surfaces. An inspection of the contact faces between the grease seal, securing nut and cone indicated that fusion between the cone and grease seal was caused by cold welding and between the securing nut and grease seal by melted paint from the grease seal.

The cage, which was distorted, was cut open to allow the bearing to be inspected. (Figures 6 and 7) The cage pockets were skewed and metal transfer had occurred between the cage and cup, approximately 5 to 10 mm from the roller large end. Four of the rollers were welded to the race at an angle of approximately 16º and there were marks around the remainder of the circumference indicating that the remaining rollers had been spot welded to the cone race. The roller large ends were slightly deformed with metal smearing and signs of bluing, which indicates temperatures above 815ºC. A number of the rollers also exhibited metal smearing and a flat spot within 10 mm of the roller large end, which indicates that the rollers had skidded for a short period. The cone large rib face exhibited signs of plastic deformation and bluing around its circumference. The cup displayed evidence of light straw discolouration, indicating temperatures of approximately 238ºC, and metal smearing 5 mm deep around the circumference of the race, which matched the metal smearing on the cage.

The cup from the left nose wheel inner bearing was assessed to be in good condition and suitable for further service. The inner and outer right nose wheel bearings were also assessed as being serviceable for further use.

Grease Examination

The quantity of grease recovered from the bearings was relatively small and, therefore, limited the number and types of tests that could be carried out. A test to establish the water content revealed that in the bearings fitted to both nose wheels, the amount of water present in the grease in the outer bearings was significantly higher than in the grease in the inner bearings. See Table 1.

Figure 6 (left)

Rollers welded to cone

Figure 7 (right)

Distortion of cone large rib face

Sample	Water Content %
Sample of fresh Grease of Mobil Grease 28	0.07
Left hand wheel – under hub cap	22.5
Left hand wheel – Under outer seal on outer bearing	15
Left hand wheel – Outer bearing, on bearing surface	22.6
Left hand wheel – Outer bearing, inner race	22
Left hand wheel – Inner bearing, on inner cone	2.1
Right hand wheel – Outer bearing under outer seal	18.3
Right hand wheel – Outer bearing under outer seal	25.1
Right hand wheel –Inner bearing under outer seal	2

Table 1

Water Content in Grease Samples

A further 6 grams of grease from the left outer bearing was analyzed by Fourier Transform Infrared spectroscopy and the spectra were compared to a sample of Mobil Grease 28, batch number B98259 manufactured in December 2004. It was concluded that the grease in the bearing was Mobil Grease 28 and that there was no sign of oxidization. Oxidization occurs when grease is subjected to elevated temperatures; however it is possible that grease exposed to localised high temperatures might have boiled off leaving no detectable trace of oxidization.

Further grease samples were taken from the nose wheels of ten A320 aircraft of four different operators that had operated in similar conditions in Northern and Southern Europe over the winter period. The grease taken from six aircraft from the same fleet as the incident aircraft had a water content of 0.6% to 5.3% with an average of 2.6%. The water content on the remaining aircraft was less than 1% with an average of 0.43%. The four airlines used three different types of grease.

Research

Effect of water on the lubricating properties of greases

The QinetiQ Fuels and Lubrication laboratory have previously undertaken work into the effect of water on the lubricating properties of greases. A Cone Penetration, Mean Hertz Load and Welding Load tests were undertaken to determine the effect on the properties of grease with a water content of 18% to 25%. Mobil Grease 28 has a clay (Bentonite) thickener and the consistency of the grease measured by the Cone Penetration Test, after working the grease by 60 double strokes, revealed that the hardness had increased by 38 units, which took it outside the limitations detailed in the Defence Standard. The Mean Load Test recorded a decrease in the load carrying capability by 36% and the Welding Load Test recorded a reduction in the extreme pressure lubrication ability of 20%. The studies concluded that the contamination of grease within a bearing by water can have a significant effect on some of its important physical and mechanical properties such that bearing failure may occur.

Landing mass and fuel burn

The aircraft actual take-off mass was 70,268 kg which included 10,200 kg of fuel. The maximum landing mass for this aircraft was 64,500 kg and the actual landing mass of the aircraft was 63,568 kg with 3,500 kg of fuel remaining on board.

A flight simulator was programmed with a similar aircraft weight and environmental conditions and at holding speeds at 6,000 ft the following fuel burn figures were observed (see Table 2):

Autopilot engaged, no spoiler	2,500 kg/hr
Autopilot engaged, half spoiler deployed	3,000 kg/hr
Manual flight, full spoiler deployed	4,000 kg/hr
Landing gear extended	3,600 kg/hr
Landing gear and spoiler extended, autopilot engaged	5,000 kg/hr

Note 1. With autopilot engaged only reduced spoiler deflection is available
Note 2. With APU running fuel burn increased by approximately 50 kg/hr
Note 3. An increase in speed was required when spoilers were extended

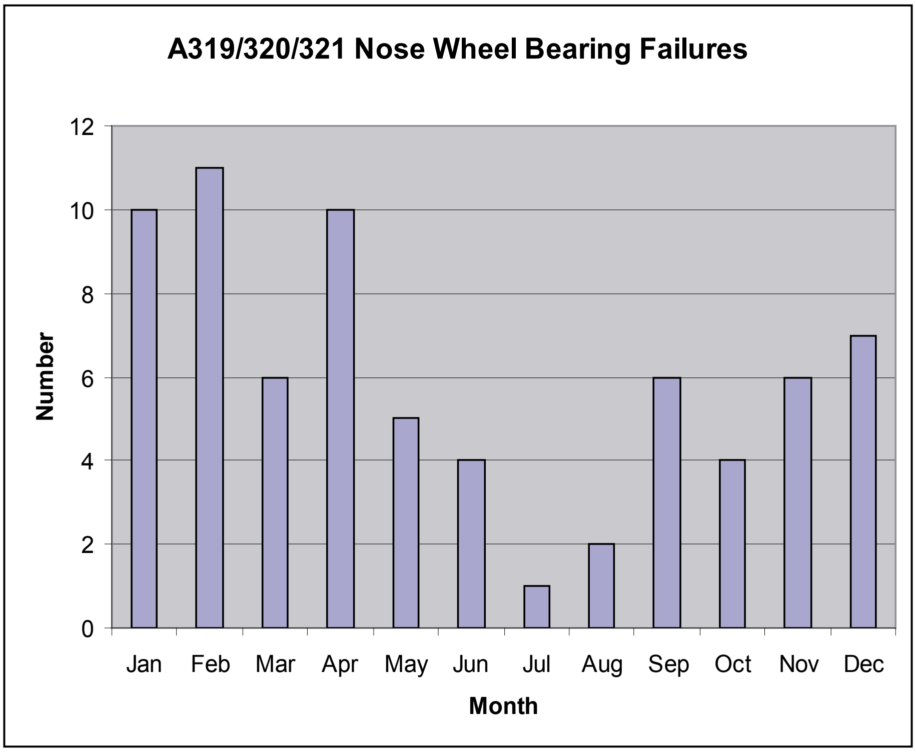
Table 2

Fuel burn at various configuarations

Previous Incidents

Data provided by the aircraft manufacturer indicated that there had been 74 reported occurrences of problems with the nose wheel bearings on the A319/320/321 family of aircraft since 1989, which resulted in seven nose wheels coming off aircraft operated by six different airlines. Four of the incidents involved the left wheel. Approximately 44% of the occurrences involved the new wheel assembly (3-1531), of which 28% involved the outer bearing. The majority of the airlines that have reported problems operate in the Northern Hemisphere and it would appear from the data that there might be a seasonal connection. However, given the size of the fleet and the number of cycles flown since 1989 care must be taken in how this relatively small number of occurrences is interpreted. (See Graph 1.)

Following the early failures an investigation was undertaken by the aircraft, wheel and bearing manufacturers who determined that the failure mode of the bearing was roller end scoring, resulting from excessive rib stress. In the subsequent years a number of measures were introduced such as increasing the bearing preload and reducing the aircraft speed when undertaking sharp turning manoeuvres. A number of modifications to the wheel assembly were also made including the introduction of a new improved wheel (PN 3-1531), which featured bigger bearings and improved spacers and grease retainers. A new grease seal inspection criteria was also introduced, by a Service Bulletin, in July 2004, which the wheel manufacturer believed would help ensure that fully worn grease seals were not refitted in nose wheel assemblies. Since this incident the wheel manufacturer has introduced an improved grease seal, which they believe makes the ingress of contaminants and the leakage of grease more difficult.



Graph 1

However, water ingress tests, undertaken by the wheel manufacturer, produced inconsistent results and it was not possible to determine if the new seal was any better at preventing the ingress of water.

Not only did the last three occurrences of wheels coming off aircraft involve the improved wheel, but the manufacturer's tests did not demonstrate that the new seal is any more effective at keeping out water than the seal fitted to the incident wheel. This suggests that the fundamental causes of the bearing failures might not have been resolved.

Flight Recorders

CVR

The aircraft was fitted with a digital cockpit voice recorder (CVR) capable of recording the P1, P2 and cockpit area microphones on a 2-hour continuous loop when AC power was available. As the flight duration was greater than 2 hours, the recordings during the take-off were over-written; the recorder stopped when the AC power supply was interrupted when the engines were shut off about three seconds after the aircraft touched down at Gatwick Airport. The subsequent landing roll was thus not recorded. Interruption of the power supply to the CVR and FDR is discussed later.

FDR

The aircraft was fitted with a digital flight data recorder (FDR) capable of recording a comprehensive range of parameters on a 25-hour continuous loop. Like the CVR, the FDR stopped recording when the AC power supply was interrupted after the engines were shut off.

From the available parameters on the FDR, there were no unusual occurrences such as fast or extreme manoeuvring on the ground in the recorded sectors preceding the incident. Similarly, the start-up, taxi and incident take-off appeared normal.

The approach, landing and touch-down were also normal. The flight recorders stopped recording when AC power was interrupted about three seconds after touch-down.

Recorders Power Source

The recorders installation has a protection system that is designed to stop recordings automatically on the ground five minutes after the aircraft electrical AC2 system is energised after both engines have been shut down. The CVR and FDR are both connected to the same AC power source and did not have an independent power supply. The recorders thus ceased to record after the aircraft reverted to the emergency electrical configuration following engines shut-down, and denied accident investigators information that could have been vital had the outcome of the landing been different.

Analysis

Operational

The crew reduced the weight of the aircraft and carried out a landing at Gatwick, having planned and configured the aircraft to allow for the possibility of the nose landing gear collapsing on touchdown. In the event a successful landing was carried out. The commander was able to maintain the runway centreline until just before coming to a stop when the aircraft suddenly veered to the left; nevertheless, the aircraft remained on the runway.

Choice of landing field

The crew were familiar with Gatwick Airport and although they at first considered a diversion to Manchester, once they discovered the weather conditions there were less favourable they decided to land at Gatwick. The crew commented that planning and conducting the approach at a familiar airfield reduced their workload considerably.

Approach planning

The crew decided to land at the maximum authorised landing weight as they considered that this was the best compromise between landing in daylight and landing at the lightest weight whilst retaining some fuel reserves. The aircraft was airborne for two hours while the fuel load was reduced, giving the crew plenty of time in which to consider their actions. Had they wished this time could have been reduced by increasing the drag of the aircraft while maintaining the holding pattern, but in fact their only constraint on time was the local time of sunset.

Once the landing gear was successfully extended for the flypast the crew decided to leave it down in case it did not retract normally; this had the added benefit of increasing the rate of fuel burn. From the recorded flight data the fuel burn in level flight before the flypast was around 2,500 kg/hr and with the landing gear extended was 3,600 kg/hr.

Use of QRH procedure

The crew found themselves with an obvious technical problem with the aircraft but one for which there were no ECAM actions or other established procedures. They could not be sure that the existing condition of the nose landing gear would be maintained throughout a landing roll. They considered the various consequences of the other nose wheel coming off on touchdown and/or the nose landing gear strut contacting the runway, and decided to prepare for a possible collapse of the nose landing gear. The most appropriate procedure they were able to find to deal with this was the 'LDG WITH ABNORMAL L/G' procedure from the QRH. They reviewed this procedure and decided how they would conduct the landing, in particular that the engines would be shutdown over the threshold before touchdown. At a later stage they did obtain some further information, for example that one nose wheel was still in place, but did not see any reason to change the original plan.

Presentation of QRH

The QRH procedure has a number of either/or options which are identified by a black dot, for example 'PREPARATION' (Figure 2) contains an option for NOSE or MAIN L/G abnormal. Within the option there may be subheadings, indicated by a short black line. Once the option has been completed the common part of the procedure continues, either at the next short black line for example -OXYGEN CREW SUPPLY or alternatively, in some cases at a boxed heading, APPROACH. The definition between part of an option and the resumption of the common procedure can easily be confused with this method leading to inappropriate actions being carried out. In this case the crew correctly actioned the procedure with the exception that they applied the 'GROUND SPOILERS.............DO NOT ARM' procedure from the main landing gear abnormal subsection (Figure 2).

Despite having plenty of time to review the procedures, including the expanded version from the FCOM, and being reasonably experienced on the type, it is possible that the crew did not appreciate the full intent of some elements. In particular the intention of the amendments to earlier versions of the QRH was for the engines not to be shutdown at least until touchdown, and in the case of the nose landing gear, not until just before nose touchdown. That this was not understood was felt to be indicative of a less than optimal presentation of the procedure rather than any lack of attention by the crew.

The crew action of shutting down the engines before touchdown left the aircraft on emergency electrical power, which deprived them of significant systems and retardation devices, causing a long landing roll with a reduced directional control capability. A possible option, which could have provided electrical power through the landing roll, would have been to have run the APU, but this did not feature in the QRH and its use was not considered by the crew.

Landing performance

The aircraft landed in a degraded status leading to a long landing roll with limited retardation and directional control being available. In fact the actual stopping distance was very close to that provided by the QRH for loss of the green and yellow hydraulic systems (accumulator braking only). Had the engine shutdown been delayed until after touchdown the stopping distance and time would have been reduced.

Engineering Analysis

Both nose wheels, complete with bearings, were fitted to the aircraft at the same time. However, whilst the water content in the grease in the outer bearings on both wheels was similar, the right wheel bearings were assessed as being serviceable and fit for further use. The condition of the inner cup on the left nose wheel indicates that the inner bearing was also serviceable. The damage to the left outer nose wheel bearing roller large end and rib face indicates that the initiating action was roller end scoring. As the roller end scoring developed, friction between the roller large end and rib would cause the rollers to start to skew, forcing the cage upwards between the rollers and cup race. The increased friction between the rib and roller large end, the skewed rollers and the contact between the cage and cup race would combine to increase the torque significantly across the bearing. This would also increase the axial load into the adjacent seal case and nose wheel securing nut. The resulting increased torque and axial force would have been sufficient to cause the interfaces between the cone back face, seal case and securing nut to fuse together. This enabled the torque from the rotating wheel to be transferred to the securing nut causing the two locking bolts to shear and the securing nut to unwind from the axle. The localised signs of overheating suggest that this sequence of events occurred over a relatively short period of time.

Roller end scoring could have been initiated by excessive bearing end load or a break down in the lubrication film. There is no evidence that excessive torque was applied when the wheel and bearing were fitted to the aircraft. The high water content in the grease and the research previously undertaken by QinetiQ suggests that the most likely cause of the failure of the nose wheel bearing was a break down in the lubrication film. Consideration was given as to how the water entered the bearings. The operator's maintenance organisation hand-wash the undercarriage and have a procedure in place to ensure that pressurised water is not applied to the wheel areas; moreover, none of the wheels sampled from six of the other aircraft in the operator's fleet had excessively high levels of water in the grease. The handling and storage of the wheel was also considered, but there was no obvious means by which the bearing could have become contaminated with water. Whilst the washing and handling process can not be discounted, it seems unlikely that this was the source of the water contamination. However, the aircraft had been operating to several European destinations during a particular wet period and it is possible that it was during this period that the bearing grease was contaminated with water.

Whilst the number of bearing failures on the A320 fleet is relatively small, the loss of a wheel during takeoff and landing has the potential to present an immediate danger to other aircraft and ground personnel. Moreover, landing and taking off with one nose wheel increases the chance of the aircraft departing the runway during the ground roll. A number of modifications have been made to improve the integrity of the nose wheel assembly; however, subsequent incidents of nose wheels coming off in flight suggest that the modifications have not been entirely successful. This incident also appears to be the first occasion when high water content in the grease has been attributed to causing the failure of an A320 nose wheel bearing. Whilst the wheel manufacturer has introduced an improved seal, its ability to prevent the ingress of water has yet to be determined, though the manufacturer does believe that it will better at preventing grease from leaking out of the bearing. Whilst there was evidence of some grease having washed out of the bearing, it was assessed that there was still sufficient grease in the bearing to allow it to function normally. It is considered that further investigation into the failure of the nose wheel bearings on the A320 series of aircraft is required and, therefore, the following safety recommendations are made:

Safety Recommendation 2005-072

The European Aviation Safety Agency should ensure that Airbus undertakes a further investigation into the failure of the nose wheel bearings on the A319/320/321 series of aircraft.

Safety Recommendation 2005-073

The European Aviation Safety Agency should ensure that the preventive measures identified by Airbus are introduced into the A319/320/321 series of aircraft to a timescale commensurate with the risk.

Performance specification for flight recorders

The European Organisation for Civil Aircraft Equipment document ED-112, Minimum Operational Performance Specification for Crash Protected Airborne Recorder

Systems, addresses the issues surrounding continuation of recording in the event of power interruptions. In most modern aircraft, the FDR monitors data through the aircraft data busses. If power to a particular sensor is lost, then FDR information related to that parameter will also be lost. Additionally, if power is lost to the avionics controlling the data busses, every parameter transmitted on that bus will be lost. Thus, to continue recording flight data parameters in the event of a power interruption, many avionics systems will be required to continue to be powered and operate in addition to the FDR itself. This contrasts with the requirements to continue the audio recording from an area microphone which is itself solely powered from the CVR. ED-112 thus specified that, as a minimum, the CVR and cockpit area microphone should continue to be powered for short periods regardless of the availability of normal aircraft electric power. In an enhancement to previous specifications, ED-112 added the requirement (and minimum performance specification) for a 10 minute Recorder Independent Power Supply (RIPS) for the CVR and cockpit area microphone.

Previous instances of premature recording cessation

There have been other previous instances of loss of CVR and FDR data due to interruption of power supply to the flight recorders, including, for example, the Transportation Safety Board of Canada' (TSBC) investigation into the Swissair Flight 111 in-flight fire and loss-of-control accident that occurred of the Nova Scotia coast on 2 September 1988. As a result of that investigation, on 9 March 1999 the TSBC issued a recommendation that:

> *"As of 1 January 2005, for all aircraft equipped with a CVR capable of recording for at least 2 hours a dedicated independent power supply be required to be installed adjacent or integral to the CVR to power the CVR and the cockpit area microphone for a period of 10 minutes whenever the normal power sources to the CVR are interrupted"*

In the same report, TSBC made a further recommendation that:

> *"Aircraft required to have two flight recorders be required to have these recorders powered from separate generator busses"*

In response to the above recommendations, Transport Canada supported the latter recommendation, provided that the Canadian regulations and those of the USA were harmonised.

Developments in CVR and FDR Regulations in the USA

In response to the concerns of accident investigators, the regulations regarding flight recorders have been reviewed and, in the USA, new proposals have been promulgated.

The Federal Aviation Authority (FAA) has published proposed revisions to the regulations related to CVRs and digital FDRs in a document titled "14 CFR part 23, 25 et al. Revisions to Cockpit Voice Recorder and Digital Flight Data Recorder Regulations: Proposed Rule" dated 28 Feb 2005. The document quoted additional accidents where the loss of critical flight and cockpit voice data had hampered the investigations. The changes include proposals to improve the reliability of the power supply to both the CVR and FDR and increase the potential for retaining important information needed during accident or incident investigation.

In summary, the document proposes, amongst other improvements, that, for newly manufactured aircraft required to be fitted with a CVR, the installation includes an independent 10 minute back-up power source for the CVR in the event that normal power to the CVR is interrupted. For aircraft required to be fitted with a CVR and an FDR, the document additionally proposes that, for newly manufactured aircraft, the recorders should be powered from the supply calculated to provide the maximum reliability and that a single supply failure should not result in the disabling of both CVR and FDR. There is an additional, proposed requirement for the CVR to operate continuously from the initiation of the checklist before starting the engines for the purpose of flight until completion of the checklist at the termination of the flight. Aircraft would have to comply with these requirements within defined time periods from the acceptance of the proposal, depending upon whether they were of new manufacture or already in service. It is noted that the European Aviation Safety Agency already addresses the need for reliable flight recorder power supplies within Certification Specification CS 25.1457 and CS 25.1459, but does not provide requirements with regard to separation of CVR and FDR power sources.

In the case of the incident to G-BXKD, the landing was carried out successfully with minimal damage to the aircraft. However, had the damage to the aircraft been more severe (for example if the noseleg had been compromised when the wheel fell from the aircraft), then the information that would have been provided by the CVR and FDR could have been vital. For this reason, and to harmonise European regulations with the intent of the FAA, the following safety recommendations are made:

Safety Recommendation 2005-074

For newly manufactured aircraft, the European Aviation Safety Agency should require that no single electrical bus failure terminates the recording on both cockpit voice recorder and flight data recorder.

Safety Recommendation 2005-075

For newly manufactured aircraft, the Joint Airworthiness Authorities should require that the cockpit voice recorder and cockpit area microphone are provided with an independent 10 minute back-up power source, to which the cockpit voice recorder and cockpit area microphone are switched automatically, in the event that normal power is interrupted.

INCIDENT

Aircraft Type and Registration:	Boeing 747-436, G-CIVB
No & Type of Engines:	4 Rolls-Royce RB211-524G2-19 turbofan engines
Category:	1.1
Year of Manufacture:	1993
Date & Time (UTC):	18 June 2005 at 1200 hrs
Location:	London Heathrow Airport, London
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 17 Passengers - 334
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose wheel tyres and nose landing gear torque link
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	12,560 hours (of which 4,212 were on type) Last 90 days - 215 hours Last 28 days - 64 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following an uneventful pushback, ground ATC requested that the aircraft move forward to clear a parking stand. At the time the tug was partially disconnected, and was in the process of being reconnected when the parking brakes were released and the aircraft rolled forward. This resulted in damage to the right nose wheel tyre and nose gear torsion links. The incident was attributed to a breakdown in communication between the headset operator and the aircraft's commander.

History of flight

G-CIVB was parked on Stand 408 at London Heathrow's Terminal 4 where the aircraft was prepared for a passenger flight to Boston, Figure 1. A towbarless tug was attached to the aircraft's nose gear and the headset operator connected his headset into the aircraft communication system in order to talk to the aircraft's commander.

Once the aircraft was fully loaded and the doors were closed, a request to push back was made to ground ATC, who subsequently gave clearance for G-CIVB to be pushed off the stand and positioned to face north. The commander relayed this clearance to the headset operator, who in turn communicated to the tug driver using hand signals, to indicate that he may commence the pushback and to face north.

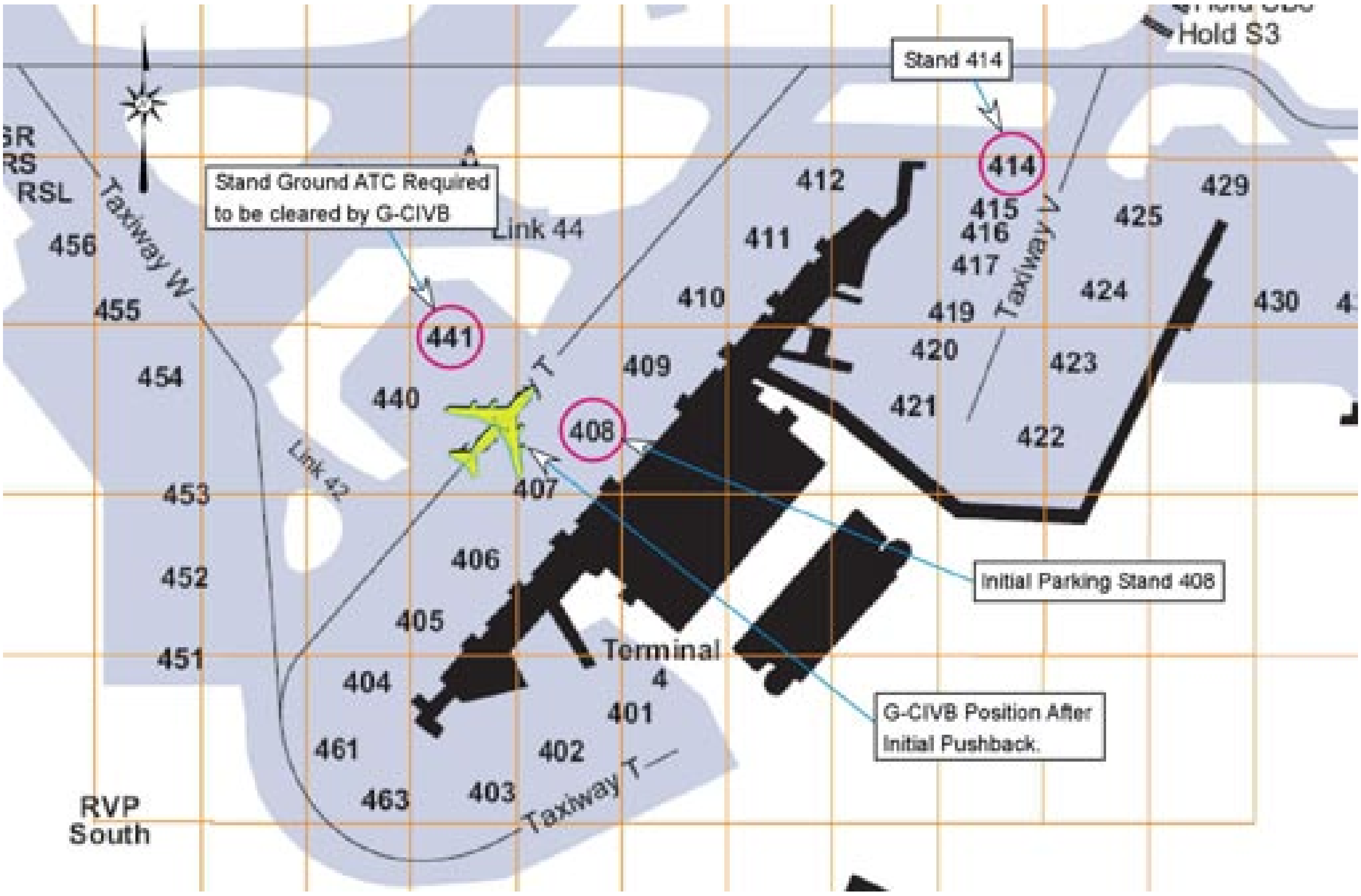


Figure 1

The initial pushback was commenced without incident; the commander started the engines during this process. Once the aircraft was positioned on the taxiway, pointing north, the parking brake was applied and the commander said to the headset operator, "brakes set to park". The headset operator, again using hand signals, relayed this to the tug driver who, using standard procedure, began to disconnect the tug. G-CIVB was now abeam, and to the right of, Stand 441, Figure 1. The commander was about to say "engines running, awaiting visual clearance", as detailed in the standard procedure, when ground ATC requested that they clear Stand 441. The commander contacted the headset operator and asked if the tug was still attached, to which the headset operator replied "standby". The commander mistakenly thought the reply was "affirmative" and then said "do not disconnect and to standby". The headset operator then spoke with the tug driver, who was still in the process of disconnecting the tug. The tug at this time was away from the nose leg but not far enough to allow a chock to be placed under the nose wheels. The headset operator and tug driver continued their discussion, which was mainly about whether they needed to move the aircraft to clear Stand 414 or 441.

In the meantime, the commander requested whether ground ATC required them to move forward or push back. Ground ATC replied with "pull forward". This was passed to the headset operator but he appeared confused with the instruction. After three of four repeats of the information he then understood the request, the confusion being mainly about which stand needed to be cleared. The commander then asked "are we connected?", to which the reply from the headset operator was "we are connecting". After this, the commander asked "release parking brakes?", to which the headset operator replied "hold on". However, the commander thought he heard a positive response and released the parking brake. The aircraft then moved forward and struck the tug.

The headset operator spoke to the commander and informed him that the aircraft had struck the tug and requested that the park brakes be set. The aircraft was inspected and later towed back to the engineering base for repair.

There were no injuries and the damage was limited to the nose gear upper and lower torsion links and the right nose gear tyre.

The replay of the Cockpit Voice Recorder (CVR) revealed that this incident had been overwritten by the time the circuit breaker (CB) had been pulled.

Discussion

The accident occurred clearly due to a lack of communication between the flight and ground crew. However, this was compounded with having the additional requirement to manoeuvre the aircraft after the initial pushback in accordance with ground ATC instructions. The ground crew procedure allows them to disconnect the tug as soon as the parking brake is set without consulting the flight crew. At this point the flight crew may have thought that the tug was still attached and when the ground crew were asked, the reply of "we are still connecting" seems to have been misconstrued as the expected answer of 'we are still connected'. This may also have been true when the commander asked for the release of the parking brake, expecting a positive response, but actually getting the response "hold on".

This move away from the standard push back procedure meant that non standard phrases had to be employed between the flight crew and the ground crew, leading to mis-interpretation and confusion.

The operator has undertaken a review of the ground operations during the push back of aircraft and will be introducing updated standard phraseology to be employed during these manoeuvres. The operator is also considering introducing an item to their checklist to pull the CVR CB following a ground incident.

ACCIDENT

Aircraft Type and Registration:	Fokker F27-500 Friendship, G-BVOB
No & Type of Engines:	2 Rolls-Royce Dart 532-7 turbo prop engines
Category:	1.1
Year of Manufacture:	1968
Date & Time (UTC):	22 March 2005 at 1140 hrs
Location:	Runway 27, Guernsey Airport, Channel Islands
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to left landing gear, wheels and brakes
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	10,611 hours (of which 8,231 were on type) Last 90 days - 32 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional AAIB enquiries

Circumstances

Following an uneventful landing on Runway 27 at Guernsey, the aircraft executed a 180º turn to the left in order to back-track the runway, with the intention of vacating at the threshold. Having completed the turn the commander applied sufficient power for taxiing and immediately felt a violent shimmy/vibration from the left landing gear. Thinking that a tyre had burst, he slowed the aircraft and found that the problem disappeared. However, after covering a short distance ATC advised that they could see that the tyres were intact, but that the complete wheel assembly was moving back and forth. The aircraft was stopped, the Airfield Fire Service was called and the aircraft was shut down.

Subsequently, personnel from another operator's engineering organisation inspected the aircraft and found that the torque link centre bolt had failed, thus allowing the torque links to separate. This in turn had allowed the wheel assembly to castor about a vertical axis, resulting in damage to the tyres, wheel rims and brake components caused by the unsecured torque links. It had been the oscillatory castoring action that caused the vibration felt by the crew.

The head and shank of the failed torque link bolt was found on the runway, together with a castellated nut and debris from the wheels. The separated, threaded tail of the bolt, onto which the nut had attached, was not found.

Following essential repairs, which included the replacement of the wheel and brake assembly, the aircraft was cleared by the aircraft manufacturer for a ferry flight to the operator's base, where the left landing gear was removed for a thorough inspection. The recovered portion of the torque link bolt, together with the castellated nut, was sent to the AAIB for a metallurgical examination.

Examination of the torque link bolt

An illustration of the main landing gear torque link assembly is shown at Figure 1, where it can be seen that the centre torque link bolt is retained by the castellated nut together with a headed locking pin and a split pin. The last two items were also not recovered, and it was considered likely that, assuming they had been present at the time of the incident, they had remained with the missing portion of the bolt.

The bolt had failed at the run-out of the threaded section, and examination under a scanning electron microscope revealed the presence of ductile dimples, which are a characteristic of ductile overload, across the entire fracture surface. There was no evidence of progressive crack growth, such as fatigue, and there was no evidence of bending. It was concluded that the observed features were consistent with the failure occurring as a result of an axial tensile overload.

It was considered that one means of developing an excessive tensile overload could be if the nut had been turning relative to the bolt as a result of frictional forces (between the bearing surfaces of the individual components within the assembly, ie the nut, washers and torque links) each time the torque links compressed on landing. However, rotation of the nut could only be possible after shearing the locking pin. The lack of damage on the sides of the castellations suggested that such an event had not occurred, although of course it was not possible to confirm that the pin had been present prior to the this incident. Furthermore, the bearing face of the nut exhibited no evidence of witness marks that would indicate it had been turning relative to the face of the adjacent washer, (which was also not recovered). Whilst the washer could have turned relative to its bearing surface on the torque link, there was no such evidence on photographs of this item.

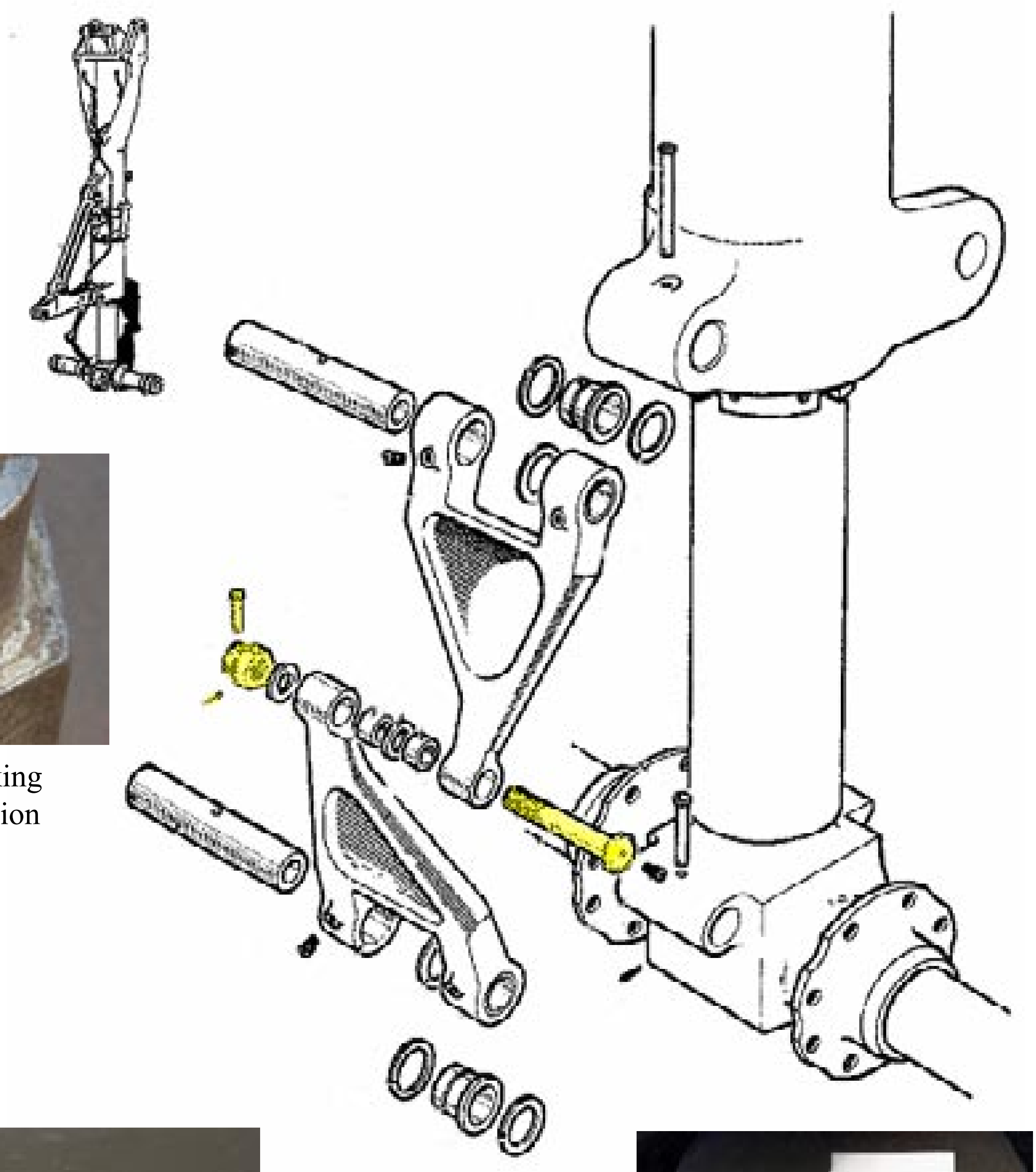
Inside the nut, the threads had been severely damaged, consistent with an axial load having been applied in a direction away from the head of the bolt. The metallurgical examination observed that although the crests of the threads had been flattened, they did not appear to have been stripped.

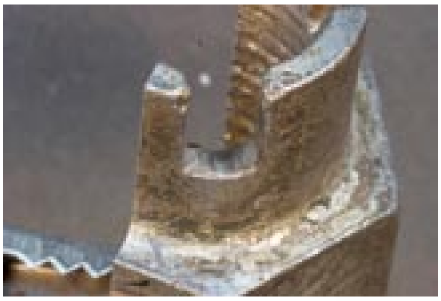
It was noted that the bottom of two opposite castellations showed evidence of witness marks that indicated that the locking pin had been present at least at some stage during the life of the nut.

It was not possible to conclude from the examination of the components the exact sequence of events that led to the failure of the bolt. It was particularly difficult to account for the absence of the detached bolt tail, as it would be expected to have remained in the nut, together with the locking pin. Assuming the latter had been intact at the time of the tensile failure, the bolt tail could only have exited via the top of the nut; it could not move in the opposite direction unless the locking pin had sheared. Either way, the threads in the nut must have been damaged to the extent that they were unable to retain the bolt.

Maintenance requirements

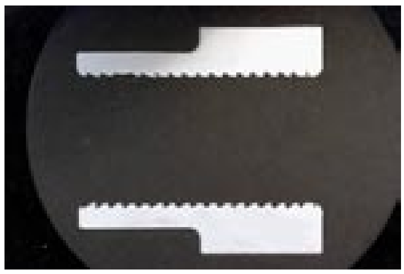
The operator's aircraft maintenance programme requires a periodic inspection of the main landing gear centre torque link bolt for correct torque loading. This occurs





Indentation of the locking pin in base of castellation

Nut and bolt portion, as found



Cross section of nut, showing thread damage

Figure 1

Main landing gear layout, showing details of torque link components

(Photos: QinetiQ)

every 'C' check, which is the earlier of 550 flight hours or eight months. The detailed instructions in the aircraft maintenance manual (AMM) calls for the removal of the split pin and shackle (locking) pin and the nut to be loosened. The nut should then be torque tightened to 60 lbf in, with a washer of appropriate thickness being used to obtain the correct locking position. A note states that: "An end float of the hinge pin is not allowed". The final instruction is to fit the locking pin and split pin.

The operator stated that the above check was last conducted on this aircraft on 8 August 2004.

Previous occurrences

The aircraft manufacturer was aware of one previous similar event, occurring in 1991, in which the torque links separated during taxiing for takeoff. It was found that the nut, which was not recovered, had stripped the threads off the bolt and sheared the locking pin, part of which was retained in the drilling in the bolt. The latter was otherwise intact and the investigation concluded that the cadmium plating on the bolt had deteriorated to the extent that corrosion had occurred in the threads, with consequent weakening.

Subsequent to the 1991 occurrence, the aircraft manufacturer recommended that those aircraft operated in high-humidity environments should periodically have the torque link centre bolts replaced, such as at each landing gear overhaul or landing gear shop visit. This advice was published in a 'Service Experience Digest'.

Discussions with the landing gear manufacturer following the incident involving G-BVOB suggested that any end float of the torque link bolt could result in a 'hammering' action on the threads as a result of the torque loads transmitted via the wheel assembly in service. It was considered that this may have been a feature of the 1991 incident, in which the threads were progressively weakened.

Other information

In considering the factors that could result in what was, to all intents and purposes, a simple overload failure of the bolt, it was decided to request an examination of the brake units from the left landing gear, since any defect that could cause them to snatch might cause such a failure. An examination was conducted by an overhaul agent, with no defects being found.

Discussion

The investigation was hampered by the fact that the detached portion of the bolt was not recovered; it was thus not possible to confirm that the locking pin was in position, or the extent of any damage. Despite the observation that the threads within the nut did not appear to be stripped, the very fact that the bolt was missing suggested that they were damaged to the extent they were no longer effective.

Despite the extensive service experience of this type of aircraft around the world, the only similar occurrence the aircraft manufacturer was aware of involved a corrosion process; this had not happened in this case. Examination of the available part of the bolt indicated a simple overload failure, such as might occur if a wheel struck a kerb or some other obstruction. An overload failure is essentially an unstable process, which implies that it occurred as a single event, as opposed to a series of 'partial' failures. This additionally implies that the failure occurred at the end of the landing roll, possibly as the aircraft was performing a 180º turn to the left, thus imposing maximum stress on the bolt. Although it seems unlikely that the failure occurred at an earlier time, this could not entirely be ruled out.

INCIDENT

Aircraft Type and Registration:	Aerospatiale AS355F1, G-FFRI
No & Type of Engines:	2 Allison 250-C20F turboshaft engines
Category:	2.2
Year of Manufacture:	1982
Date & Time (UTC):	19 July 2004 at 0945 hrs
Location:	Near Lasham Airfield, Hampshire
Type of Flight:	Public Transport
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to right engine drivetrain and coupling housing tube
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	7,200 hours (of which 1,800 were on type) Last 90 days - 60 hours Last 28 days - 18 hours
Information Source:	AAIB Field Investigation

History of the flight

The pilot had flown passengers from Lasham to the Farnborough Airshow and was returning to Lasham empty. Whilst approaching Lasham in the cruise at 1,500 ft amsl and 120 kt IAS, a thump was heard from an indeterminate source. On checking the engine instruments, the pilot noticed that the No 2 engine was indicating ground idle rpm. He shut down the engine and performed an uneventful single engine landing at Lasham. The pilot recalled that whilst on the ground at Farnborough he had felt an unusual high frequency vibration that he could not trace.

Background

This incident was reported to AAIB by the operator who initially believed that it may have been related to Eurocopter Alert Telex 63 00 21 that addressed problems with combining gearboxes delivered new, or newly overhauled and fitted with freewheel rollers finished with an incorrect surface coating applied. The combining gearbox fitted to G-FFRI did not fall into the category of combining gearboxes affected by the Alert Telex (and corresponding EASA Airworthiness Directive) and, as described later, there appears to be no connection between the incident and freewheel problems.

Examination of the aircraft

G-FFRI was examined in the owner's hangar at Lasham. Externally it appeared completely undamaged but upon lifting the cowling of No 2 engine it was clear that the flexible coupling (often referred to as a 'Thomas' coupling) between the engine drive shaft and the combining gearbox had disintegrated and the coupling housing tube in which the shaft runs had been shattered as a result.

The coupling housing tube is a structural part of the engine accessory gearbox (see Figure 1) and is attached to the combining gearbox via a universal, or gimbal, joint. This is because the coupling housing tube is a fundamental part of the engine mounting structure. The engine itself is mounted on a single elastomeric point and the housing tube-to-combining gearbox attachment forms the second element to locate the engine. In the absence of the latter, the engine is free to rock laterally and longitudinally around the single bolt in the elastomeric mount. The No 2 engine of G-FFRI was in this condition since the universal joint had been destroyed by the flailing Thomas coupling/drive shaft. The coupling itself had broken into scores of pieces and was distributed around the Main Rotor Gearbox (MRGB) compartment.

Because of a high workload the operator was unable to progress removal of the affected transmission and engine components for some weeks and it was agreed that these would be forwarded to Eurocopter, together with the fragments of Thomas coupling, for examination.

Previous cases of coupling failure

The Thomas coupling is widely used in helicopters for any application in which torque is transmitted by a shaft which is subject to small variations in alignment. Such misalignments (maximum 1° 30') are absorbed by, in this case, a 14-element 'sandwich' of thin stainless steel leaves (flector leaves). Continued operation of the coupling with misalignments greater than this can lead to fatigue fractures of individual elements and, if not detected, this in turn can lead to failure of the entire assembly.

Misalignment of the engine/transmission can occur due to deterioration of either the transmission or engine mounts. In the AS355F1 model helicopter, torsional loads on the MRGB are reacted by four elastomeric pads attached to the upper fuselage deck. As described above, one element of the engine mount also uses elastomeric suspension and thus any significant deterioration of the elastomers can lead to relative movement of either the MRGB or engine.

On 8 December 1992, another AS355F1 helicopter, registration G-OHMS, suffered a similar failure of the Thomas coupling of the No 2 engine. An uneventful single-engine landing was also achieved without damage to the helicopter. The AAIB report on this incident (AAIB Bulletin 1/94), noted that there had been four previous cases of coupling failure known to the manufacturer, one of which had been the subject of an earlier AAIB field investigation (AAIB Bulletin 12/91, registration G-WMPA). The other three were, according to the manufacturer, considered to be due to deterioration of the MRGB elastomeric mounts.

No significant deterioration of the MRGB mounts was found on G-WMPA but, in the case of G-OHMS, a number of the elastomeric laminated pads were found to have deteriorated to the extent that, in the manufacturer's opinion, MRGB location could have been compromised. It was concluded that this was probably responsible for the Thomas coupling failure.

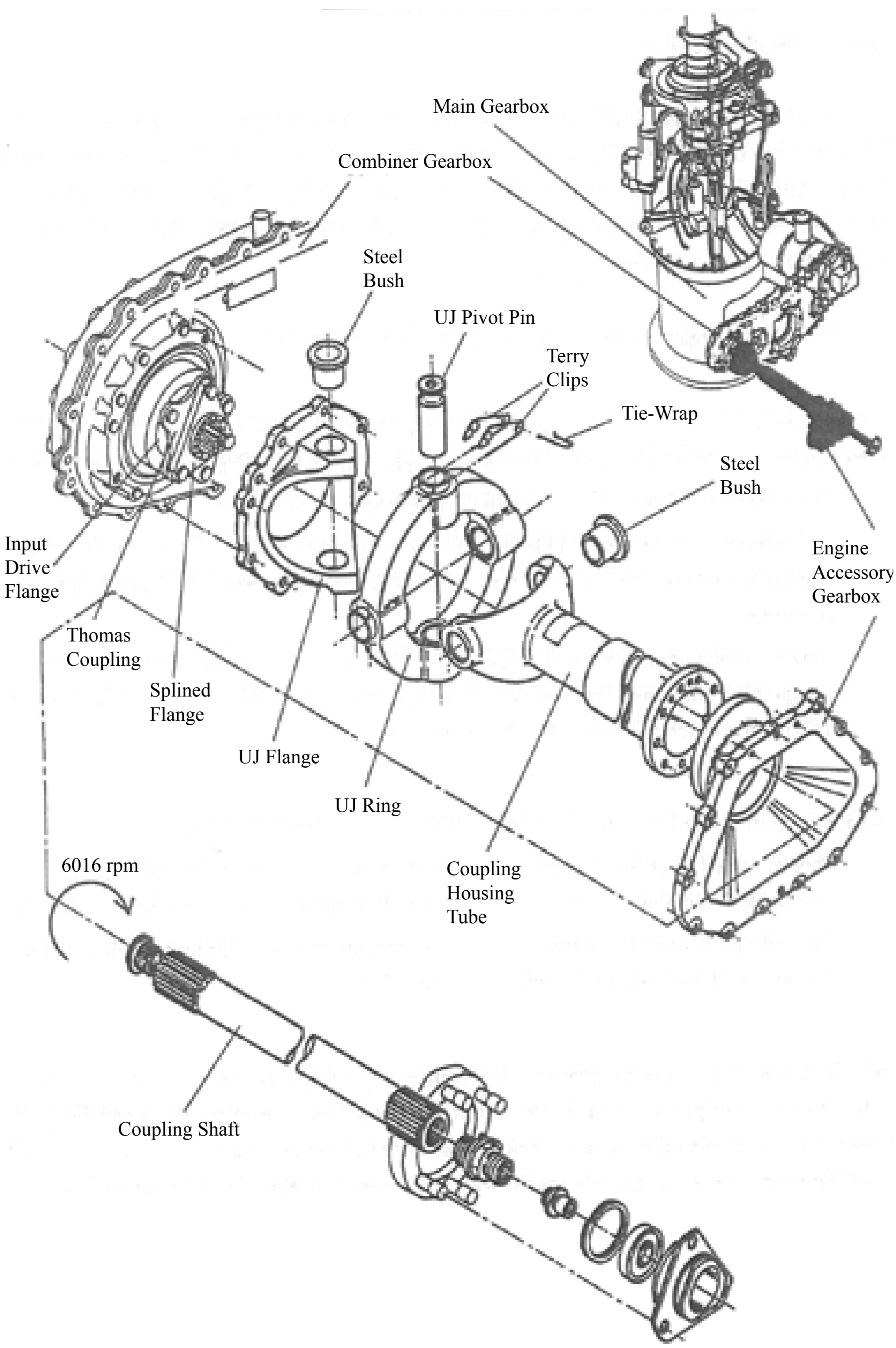


Figure 1

Engine to Main Gearbox Drive Train - exploded view

Interrogation of the CAA's Mandatory Occurrence Report database suggest that no additional complete Thomas coupling failures had occurred in the UK between the G-OHMS and G-FFRI incidents but it was noted that some 11 cases of discovery of cracked or even broken leaves are recorded, including one in August 2004.

Subsequent examination of G-FFRI

The MRGB and combining gearbox were despatched, via Eurocopter's UK agent but not under AAIB supervision, to the factory at Marignane. Inspection showed no evidence of freewheel slippage or other problems but it appears that the fragments of Thomas coupling, including the coupling flange bolts, and the coupling housing tube, which the operator insists were packed with the MRGB, were missing and have not been recovered.

Inspection of the MRGB elastomeric suspension did not reveal any significant deterioration. The engine mounting was submitted for laboratory examination by the AAIB to determine whether visible damage to the elastomer was indicative of deterioration. The examination found that there were no significant material property differences between the mount from G-FFRI and a new, unused, item.

The former was found to be some 3.7 mm shorter than the latter, apparently due to settling of the elastomer under the weight of the engine in-service. This is not considered significant in terms of the degree of misalignment at the Thomas coupling.

Discussion

The reports into the G-OHMS and G-WMPA incidents describe the various factors which could be instrumental in failure of Thomas couplings, namely:

1 Degraded MRGB bilateral suspension
2 Relaxed torque on the Thomas coupling flange bolts
3 Disconnection of the gimbal joint on the coupling housing tube due to loss of a quick-release 'Terry' clip

It is evident that degradation of the engine elastomeric mount should be added to this list, since it appears to have the same potential as a degraded MRGB suspension to provoke misalignment leading to fatigue cracking of the flector leaves.

No evidence was found that either item No 1 or item No 3 above were responsible for the failure of the Thomas coupling of G-FFRI. It is regrettable that any evidence regarding the condition of the coupling flange bolts seems lost, particularly in the light of a discovery made by the same maintenance company in January 2005 and brought to the attention of the AAIB. During routine maintenance on an AS355F2 helicopter (not G-FFRI), it was necessary to dismantle the engine drive Thomas couplings. Four of the six nuts and bolts seemed quite normal but two showed signs of severe frettage of both the nut and the bolt, apparently caused by a loose-fitting split pin (Figure 2). The pins themselves were intact but, as can be seen from Figure 2, the loss of material from the nut is considerable. Informal contact with another maintenance company suggested that they, too, had experience of this phenomenon as did an AAIB consultant metallurgist who had observed it in applications other than helicopters. The helicopter had flown a total of 5,597 hours since new and the combining gearbox had a total of 1,072 hours since overhaul (overhauled gearboxes are supplied with new Thomas couplings and hence bolts).

The remedy for this potentially hazardous condition would appear to be fairly simple, therefore whilst there is no evidence that the failure of the coupling from G-FFRI was related to the issue of split-pin frettage, the following Safety Recommendation is made:

Safety Recommendation 2005-081

It is recommended that Eurocopter review the design, or maintenance procedures adopted for the installation, of 'flector' couplings to ensure that the potential for fretting of the split-pin/nut/bolt assembly is eliminated.

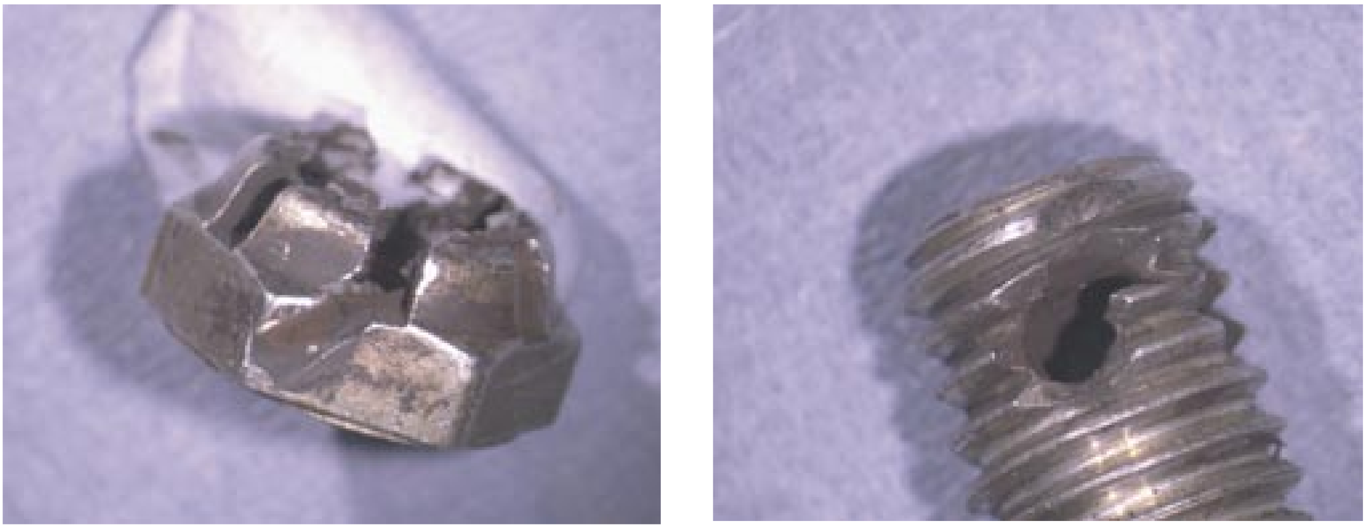


Figure 2

A coupling flange nut and bolt removed from a Thomas coupling fitted to an AS355 helicopter showing severe fretting caused by a loose-fitting split-pin

ACCIDENT

Aircraft Type and Registration:	Avid Speedwing Mk4, G-BUFV
No & Type of Engines:	1 BMW R100 piston engine
Category:	1.3
Year of Manufacture:	1992
Date & Time (UTC):	10 June 2005 at 2000 hrs
Location:	Lough Neagh, Northern Ireland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Ditched
Commander's Licence:	FAA Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	135 hours (all on type) Last 90 days - 21 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and engine examination by AAIB

After landing from an earlier uneventful 45 minute flight from Toomebridge, the pilot decided to carry out another flight and took off again without having shut down the engine. Shortly after takeoff, at around 300 ft, he noticed a change in engine note and a 'metal ringing' sound. At the same time he noted a loss of engine power, and although the engine still responded to throttle movement with a change in rpm, the aircraft was unable to maintain altitude. The pilot switched both ignition switches off and then on again, and similarly both fuel pumps; he also checked that the fuel was selected on.

The pilot adjusted the pitch attitude to achieve a speed of 65 mph, and selected a field in which to carry out a forced landing. As he approached his selected field he realised that it was crossed by electricity cables and that there might not be sufficient distance in which to land the aircraft. He then decided that to continue to approach into the field would result in impact with trees and, having enough airspeed to avoid the trees, he accepted that the only alternative was to ditch the aircraft into nearby Lough Neagh.

The aircraft struck the water approximately 150-200 m from the shore above a sandbank with a water depth of around 4 ft. The pilot and passenger were uninjured and able to exit the aircraft through the perspex roof. They stayed with the aircraft and were rescued by the emergency services who had been alerted by a group of people on-shore who had witnessed the accident.

Description and history

The Avid Speedwing is a high wing kit-built aircraft, with a maximum take-off weight of 463 kg. It has a two seat, side-by-side configuration. Fitted to this aircraft was a R100 BMW air cooled, two cylinder four-stroke, horizontally opposed motorcycle engine. For installation in an aircraft a Rotax gear box is fitted to the crankshaft at the rear of the engine and a tractor propeller attached. The engine is then installed in the reverse orientation to that of the motorcycle installation and so to ensure adequate cooling by the airflow the orientation of the cylinder baffles is reversed.

The aircraft had been operated by this owner since 2001. The engine had completed around 104 hours since its last top overhaul which was when the engine was converted and installed in this aircraft. In April 2005 the engine was removed following alternator problems and at this time the engine mounts were changed. The engine was taken to a BMW service agent to rectify oil seepage around the alternator, located at the rear of the installed engine, and a gasket was changed.

Engine Examination

The engine was stripped in the presence of the PFA and representatives from a maintenance organisation specialising in the conversion of BMW motorcycle engines for aircraft installation. The left cylinder rocker cover was removed and the cylinder head nuts that tighten onto the cylinder through studs were removed. The torque values on the cylinder head nuts were noted to be less than that required in the manual (26-29 lb_f ft). The cylinder head was then removed and a hole observed around one of the two cylinder head studs where hot gasses had burned through the head gasket and the outer cylinder casing (see figure 1 and 2). The right cylinder head nuts were also found to be tightened to less than the correct torque setting. The engine was otherwise mechanically sound and free to rotate.

Figure 1

Left cylinder head showing burn through of the casing around one cylinder head stud

Figure 2

Left cylinder head gasket

The engine would have been re-built when it was converted to the aircraft installation by a previous owner. Although there is no specific advice in the overhaul manual, it is normal good engineering practice to check the torque tightening of cylinder head nuts after an initial run-in period of 5-10 hours, as loosening of the nuts can occur during operation.

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-IRAN
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	3 July 2005 at 1510 hrs
Location:	Pleshey, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage to nose leg, engine frame, propeller, fin, left tailplane
Commander's Licence:	Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	331 hours (of which 91 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

History of flight

The pilot was on a local flight from Andrewsfield Airfield, Essex. About 30 minutes into the flight the pilot reported that, whilst returning to Andrewsfield and shortly after descending from 2,500 ft to 1,500 ft, the engine abruptly lost power. The pilot selected the carburettor heat ON, checked the mixture was rich and that the magnetos were selected to BOTH. He then attempted to restart the engine but to no avail.

The pilot, realising that he was now at a low height, concentrated on flying the aircraft for a forced landing into a field. The field contained standing wheat which was about two feet high. Before touchdown the pilot held the aircraft just above the crops in an attempt to land at the correct speed and to reduce the subsequent ground run. However, the main wheels became entangled in the crops, the nose wheel dropped and dug into the ground. The aircraft then flipped over and came to rest inverted, suffering extensive damage to the nose leg, engine frame, propeller, fin and left tail plane. The pilot vacated the aircraft through one of the doors having suffered no injuries. The local emergency services were quickly on the scene and offered their assistance.

The pilot reported that he had used the carburettor heat at least once on this flight prior to the engine stopping and believed that the most likely cause of the engine stopping was an ignition problem.

Weather

The Meteorological Office provided an aftercast for the area at the time of the accident. It indicated that a slack, moist, west-south-westerly airflow covered the area with a cold front becoming slow moving over south-east England. Specific conditions were as shown in Table 1.

The visibility was expected to be 15 to 30 km, with mainly broken strato-cumulus clouds at 2,500 to 3,000 ft.

The pilot reported that the weather, he had obtained from Andrewsfield, indicated the surface wind as 280°/5 kt, visibility 24 km, broken cloud at 2,800 ft, temperature 17.6°C and humidity 78%.

Engine examination

The aircraft and its engine were inspected at the crash site by the maintenance organisation that usually serviced the aircraft. At the time of the inspection the carburettor heat control was fully in thus providing no heating to the carburettor, the throttle was at idle and the mixture was fully rich. The engine showed no signs of any leakage, the oil level was within limits and there were no signs of damage to any ignition components or control cables.

The engine was subsequently sent to an independent maintenance organisation for further tests. It was reported that the engine started without difficulty, had no defects and the engine produced power to within 5% of maximum, which are within the limits set by the testing organisation.

Icing

The aftercast temperature and dew point, for the time of the accident, were plotted on the Carb Icing Chart in Safety Sense 14, found in LASORS and AIC 145/1997. They fall, at best, in the *Moderate icing - cruise power/ Serious icing - descent power* area, and at worst, in the *Serious icing - any power* area.

An extract of LASORS Safety Sense 14, *Piston Engine Icing* is shown below:

Carb icing is not restricted to cold weather, and will occur on warm days if the humidity is high, especially at low power settings. Flight tests have produced serious icing at descent power with the ambient (not surface) temperature over 25°C, even with relative humidity as low as 30%. At cruise

Height (agl)	Wind velocity	Temperature	Dew Point	Relative Humidity
Surface	250°/5 kt	+ 17·3°C	+ 14·9°C	86%.
1,000 feet	250°/5 to 10 kt	+ 14.4°C	+ 10.4°C	77%
2,000 feet	250°/10 to 15 kt	+ 11.2°C	+ 8.9°C	86%.

Table 1

Specific weather conditions

power, icing occurred at 20°C when the humidity was 60% or more. (Cold, clear winter days are less of a hazard than humid summer days because cold air holds less moisture than warm air.) In the United Kingdom and Europe where high humidity is common, pilots must be constantly on the alert for the possibility of carb icing and take corrective action before an irretrievable situation arises.

Conclusion

The ambient meteorological conditions and the flight profile preceding the engine failure, together with the absence of any defect with the engine, suggest that carburettor icing was the most likely cause of the engine failure.

ACCIDENT

Aircraft Type and Registration:	Cessna 180K Skywagon, G-BETG
No & Type of Engines:	1 Continental Motors O-470-U piston engine
Category:	1.3
Year of Manufacture:	1977
Date & Time (UTC):	15 May 2005 at 1350 hrs
Location:	Dunkeswell, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, minor damage to cowling, engine shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	339 hours (of which 27 were on type) Last 90 days - 6 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft carried out an overhead join and circuit to land on the asphalt Runway 05 at Dunkeswell, following a short private flight from Franklyn's Field Airstrip near Wells. The surface wind was light and variable. The aircraft bounced on touchdown and, despite the pilot's attempts to control it, bounced again. After the second bounce the propeller struck the runway and the aircraft pitched forward onto its nose, shock loading the engine and damaging its cowling. The pilot was uninjured.

The Skywagon is a four seat, high wing monoplane with tail wheel landing gear. The main landing gear struts are constructed from spring steel, which is considered by some operators to result in livelier handling on the ground than other Cessna types. The addition of large, low pressure 'tundra' tyres on the accident aircraft may have exacerbated this characteristic. This aircraft was also fitted with an aftermarket wing tip modification, intended to reduce stalling speed, but this is not reported to have a detrimental effect on ground handling. The pilot considers that the accident was the result of a poorly judged landing, and could have been avoided had he executed a go around after the first bounce.

ACCIDENT

Aircraft Type and Registration:	DA40D Diamond Star, G-HASO
No & Type of Engines:	1 Thielert TAE 125-01 Diesel piston engine
Category:	1.3
Year of Manufacture:	2003
Date & Time (UTC):	29 June 2004 at 1345 hrs
Location:	Field near Old Stratford, Northamptonshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose gear collapsed, broken propeller blade and right winglet damaged
Commander's Licence:	Student Pilot
Commander's Age:	23 years
Commander's Flying Experience:	77 hours (all on type) Last 90 days - 49 hours Last 28 days - 26 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus component examination and further enquiries by the AAIB

Synopsis

The aircraft's engine failed in flight when most of the oil was lost overboard. From an altitude of 2,000 ft the pilot carried out a successful forced landing into a field. The engine's turbocharger compressor had been damaged resulting in an imbalance that caused vibration. This vibration induced a fatigue failure of a bearing and a piece of this bearing passed into the oil scavenge pump, causing it to seize. With the pump seized, the oil separator overfilled causing the engine oil to escape via the breather vent line. This caused a loss of oil that resulted in the engine overheating and then seizing. Two safety recommendations were made to reduce the probability of a recurrence.

History of the flight

The pilot was returning to Cranfield Airport following a solo navigation exercise when the engine caution light illuminated on the annunciator panel. He then noticed that the oil pressure had decreased to the amber low pressure region of the digital oil pressure gauge. The engine then suffered from a sudden loss of power with the digital power reading reducing from 89% (cruise setting) to 65%. The pilot transmitted an urgency call to Cranfield Approach and then pressed the reset button on the annunciator panel. Moments later the oil pressure reduced into the red range, the engine failed and the propeller stopped. The pilot reported the engine failure and set his transponder to the '7700' emergency code. He then initiated the engine restart procedure while the aircraft was at an altitude of approximately 2,000 ft. The engine was successfully restarted and ran for approximately 20 seconds before stopping again.

The pilot committed himself to a forced landing, carried out his forced landing checks and then flew a constant aspect approach to a field. After touchdown in the field the aircraft rolled for approximately 20 m through crops and then slewed 45º to the left before coming to a rest. The nose gear collapsed during the landing roll but the pilot was able to vacate the aircraft normally via the front canopy door.

Engine instrumentation

The aircraft was equipped with an engine data logger which recorded the accident flight. The data showed that at a power lever setting of 94% the manifold pressure started to decrease followed by the oil pressure decreasing. The oil pressure decreased continuously for a period of 74 seconds before the engine stopped turning. The data showed that the engine was restarted 13 seconds later but the oil pressure began to reduce again immediately and the engine stopped after 23 seconds.

Aircraft examination

The aircraft was recovered and examined by the maintenance organisation. Apart from the collapsed nose gear and a broken propeller blade, the aircraft had sustained minor damage. The length of the aircraft's belly was coated in oil and the oil dipstick revealed that almost no oil remained in the engine's sump. Further examination revealed that most of the oil had escaped via the breather vent line of the oil separator (which exits under the belly) and a small quantity via the engine's exhaust. The engine was transported to its manufacturer for a more detailed inspection and teardown. The only other item of note from the aircraft examination was that an incorrect type of air intake hose had been fitted. The air intake hose fitted to G-HASO was a SCAT-10 hose without an inner lining. The approved hoses fitted at manufacture are SCEET-10 hoses with inner linings.

Engine description

The TAE 125-01 engine, also known as the Centurion 1.7, is a 4-cylinder turbocharged Diesel engine based on an automotive engine. The engine is liquid cooled and has a wet sump oil system. The constant speed propeller is driven by an integrated reduction gearbox and an electronic FADEC (Full Authority Digital Engine Control) system monitors and controls engine and propeller operation. The turbocharger boosts engine power output by compressing ambient air, which is then cooled by an intercooler, before the compressed air passes into the cylinders. The turbocharger is driven by the engine's exhaust gases as depicted in Figure 1.

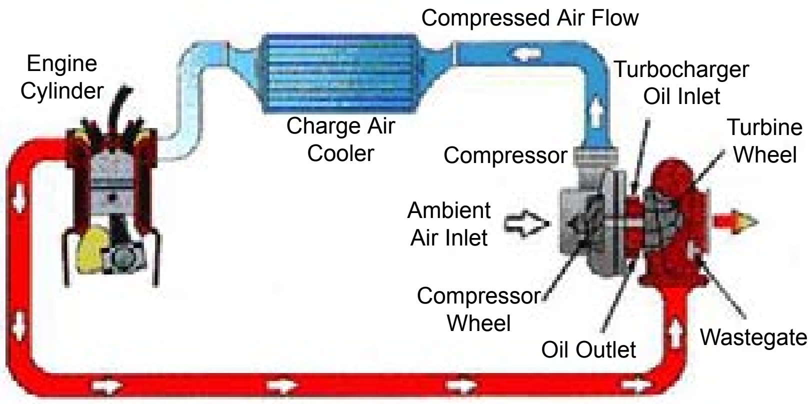


Figure 1
Schematic of turbocharger on TAE 125-01 engine

Turbocharger description

The TAE-125 turbocharger consists of a radial compressor and a centripetal turbine which are connected with a common shaft. The compressor is made up of a 12 bladed compressor wheel and a spiral compressor housing, both of which are made of aluminium. The turbine consists of an 11 bladed turbine wheel made of high-temperature-resistant nickel-ferrous alloy and a turbine housing made of grey cast iron alloy. The compressor wheel and a steel 'radial and axial' bearing are secured to the common shaft as shown in Figure 2. The radial and axial bearing is a plain bearing that supports the shaft and restricts its axial movement. Oil from the engine is fed to the turbocharger for bearing lubrication and then passes into a 'catchtank' beneath the turbocharger.

Engine oil system description

The engine has a wet sump oil lubrication system that is driven by an internal pump inside the engine and an external scavenge pump mounted on the gearbox. A schematic of the oil system is depicted in Figure 3. Oil passes from the engine to the turbocharger and then drops into the catchtank beneath the turbocharger. Oil also passes from the engine into an oil separator that is vented to atmosphere through a breather vent line. The oil separator separates the air from the oil and the recovered oil passes into the turbocharger catchtank. An engine driven scavenge pump then sucks the oil from the lowest point of the catchtank and pumps it back into the engine's sump. This scavenge pump has two stages; one stage pumps engine oil back to the sump and the other stage pumps gearbox oil to the propeller governor (not shown).

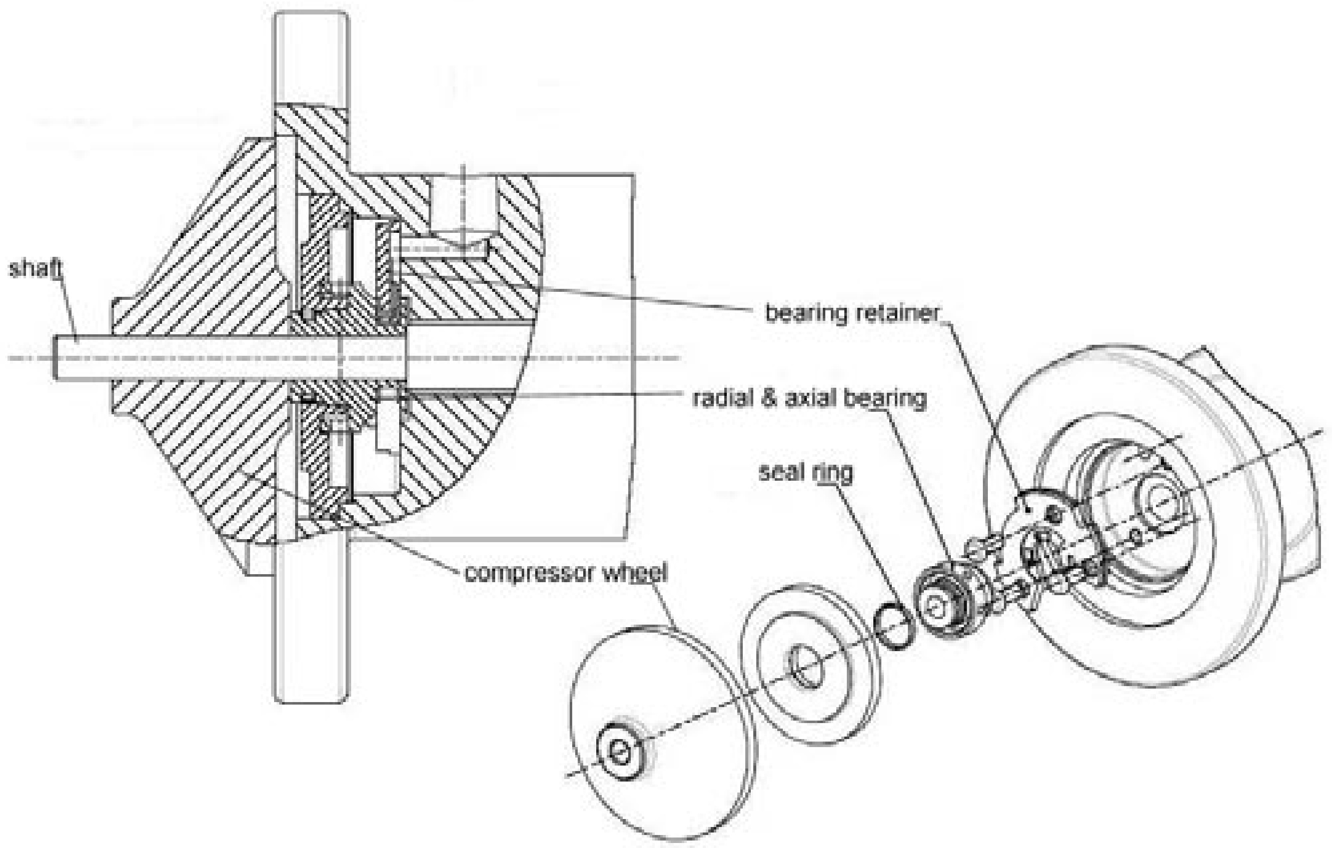


Figure 2

Layout of turbocharger compressor section

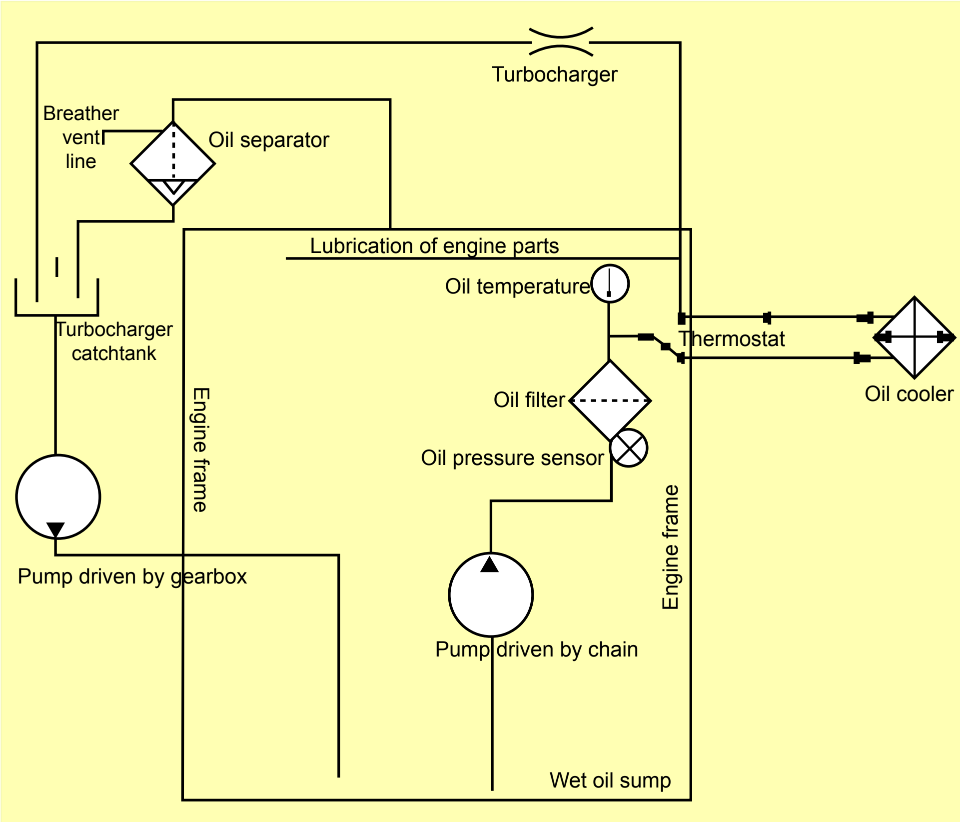


Figure 3

Oil system schematic diagram

Maintenance history

At the time of the accident the aircraft had accumulated 246 flight hours, the engine had accumulated 193 hours and the propeller 246 hours. The last maintenance carried out on the aircraft was a 200 hour inspection on 11 June 2004. During this maintenance check the air intake hose between the air filter and turbocharger was examined for leaks, damage and secure attachment but, reportedly, it was not removed. The air filter, oil filter and engine oil were changed. The maintenance work previous to this was an engine change carried out on 4 June 2004. The engine was changed due to a suspected cracked cylinder head. During the engine change the air intake hose would have been removed but not necessarily replaced.

Engine examination

The engine was stripped and examined by the aircraft manufacturer but it was also inspected by an air accident investigator from the German BFU (Federal Bureau of Aircraft Accidents Investigation). An examination of the combustion chamber revealed severe overheating damage as a result of loss of lubrication. The oil scavenge pump was found seized and its driveshaft had sheared. Disassembly of the scavenge pump revealed a piece of metal debris wedged between the gears (see Figure 4). The metal debris was identified as a part from the turbocharger radial and axial bearing.

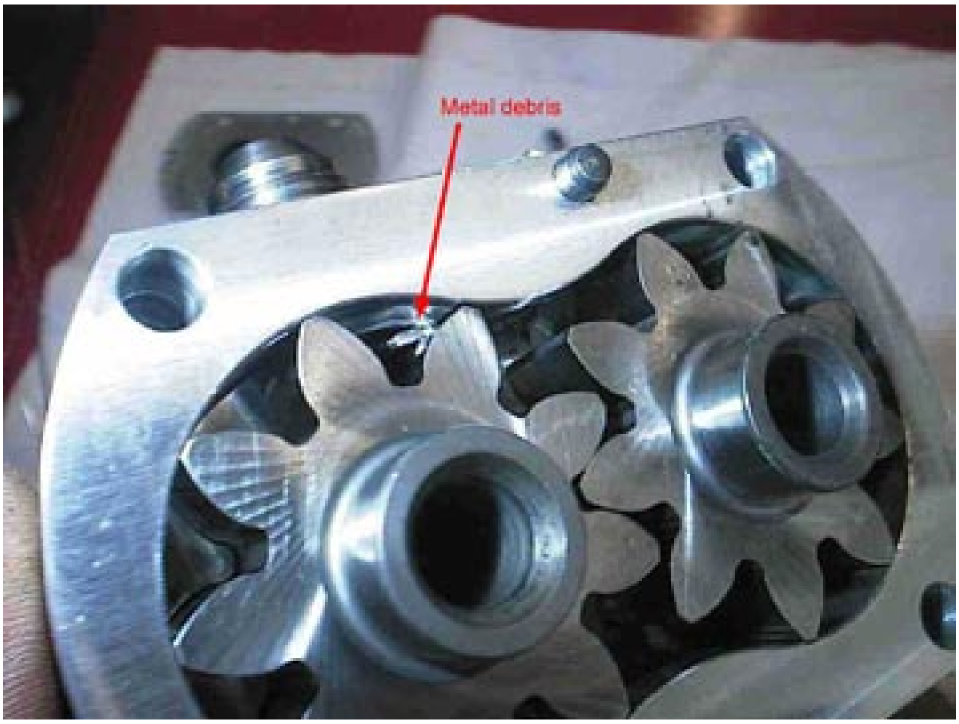


Figure 4

Metal debris wedged between gears of oil scavenge pump

Turbocharger examination

The turbocharger examination revealed that the radial and axial bearing had failed in three pieces. The thrust collar of the bearing had broken off and separated into two pieces (see Figures 5 and 6), one of which was found wedged inside the scavenge pump and the other was located inside the turbocharger catchtank. The bearing was examined by an independent metallurgist whose microscopic examinations revealed that the bearing had failed due to fatigue. The bearing was also examined by another engine manufacturer who concluded that the fatigue failure of the bearing was caused by increased vibrational loads.

The compressor wheel had suffered leading edge damage to many of its blades. To establish the cause of this damage the compressor wheel and its casing were sent to an independent engine manufacturer for examination. The compressor blade tips had evidence of tip rub. Four of the compressor blades had sharp nicks on their leading edges, as indicated with white arrows in Figure 7. Compressor blade No 5 had suffered the most damage with a 4 mm section of its leading edge torn away against the direction of rotation. Blade No 5 also exhibited small shallow impact marks on its concave side (hidden side in Figure 7) close to the leading edge damage. These impact marks were darker and therefore older than all the other shinier impact marks. The compressor casing exhibited rotational scoring marks where the compressor blade tips had rubbed against it, and a small (1.4 mm long) piece of debris was found in the gap between the casing and the inlet cone. This debris was analysed using energy dispersive x-ray which revealed that it consisted primarily of aluminium with small amounts of nickel and iron. Some of the damaged areas of the compressor were also analysed which revealed small amounts of iron at concentration levels exceeding those

Figure 5

New radial & axial bearing on the left and failed radial & axial bearing on the right (note the missing thrust collar)

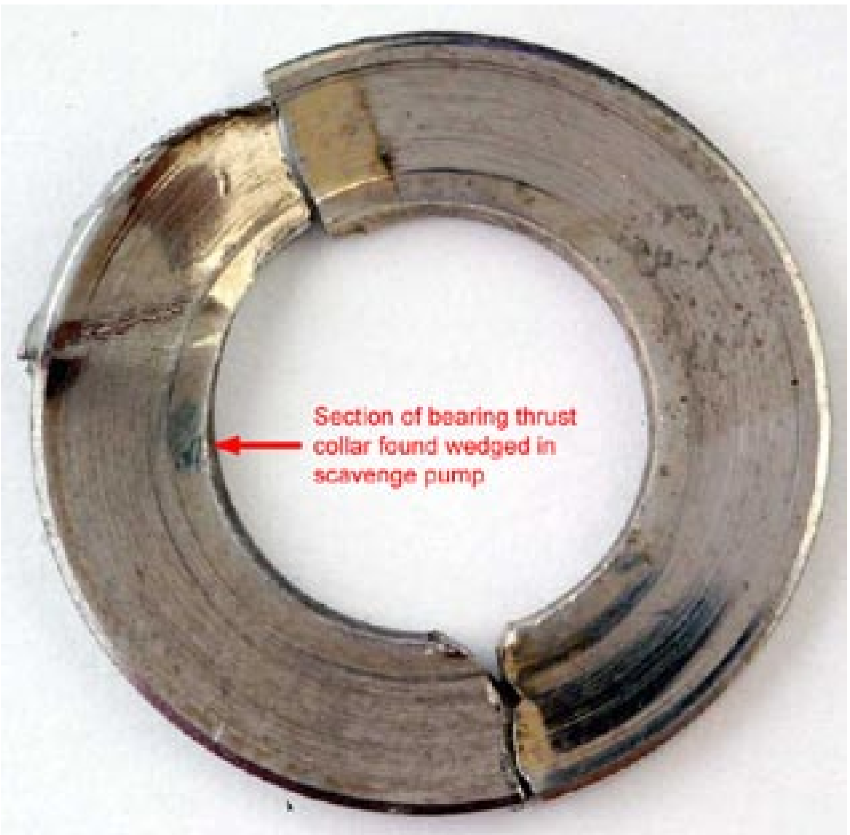


Figure 6

Failed thrust collar from radial & axial bearing (left section found inside scavenge pump; right section found inside turbocharger catchtank) in the compressor's base material. Although iron is an element within the material of the compressor, the nickel found on the debris was a foreign element - no part of the compressor section contains nickel. The examining engineer concluded from this evidence that some foreign object containing nickel had entered the compressor section and then either impacted a blade directly or become wedged between the blades and the compressor casing, causing casing rub and chipping of the blades. This would have led to an imbalance which would have caused vibration and rotational forces that could explain the bearing failure. Once the bearing had failed the compressor wheel would have moved forward causing additional damage and blade deformation (possibly causing the torn leading edge on blade No 5).

Air intake examination

An air filter filters all intake air before it passes to the turbocharger inlet via a hose, normally a SCEET-10 hose, but in G-HASO's case it was a SCAT-10 hose. The air filter exhibited no defects or signs of impact damage. The aircraft also has an alternate air system which, when selected by the pilot, allows air to bypass the air filter, and instead pass through a coarser metal mesh. However, this system is only used in an emergency when the air filter becomes blocked. The metal mesh also did not exhibit any impact damage. The last time the air intake hose had been removed was during the aircraft's engine change on 4 June 2004. The engine change was carried out by an engineer from the engine manufacturer whilst

Figure 7

Turbocharger compressor wheel
(note: green area is green dye applied at manufacture)

being overseen by the aircraft operator's maintenance engineer. Both engineers believed that it was the other engineer and not themselves who re-installed the air intake hose. It could not be established how (or if) any debris was introduced into the air intake system during maintenance. Also, it could not be established when or how the incorrect type of air intake hose was installed on the aircraft. However, the intake hose appeared undamaged and the metal used to reinforce the hose was examined and analysed. It did not contain any nickel.

Analysis

The engine failure was caused directly by a loss of lubricating oil which resulted in the engine overheating and its eventual seizure. The oil was lost overboard because the scavenge pump seized, resulting in the turbocharger catchtank and subsequently the oil separator over-filling. Once the oil separator overfilled, all the oil vented through the breather vent line which exits under the aircraft's belly. The scavenge pump seized because a piece of the failed radial and axial bearing dropped into the turbocharger's catchtank and was then sucked into the scavenge pump (there was no filtering element between the catchtank and the scavenge pump).

When it was first discovered that the radial and axial bearing had failed due to fatigue, two possible scenarios were considered: (a) the bearing had failed first resulting in a compressor imbalance which caused all the damage on the compressor wheel, or (b) the compressor was damaged first causing an imbalance which resulted in fatigue failure of the bearing. The engine manufacturer believed that (b) had occurred and that the compressor was damaged by ingestion of a foreign object, because they had never encountered a failure of the bearing before. The compressor was therefore examined by an engineer from an independent engine manufacturer. This engineer discovered some debris between the compressor casing and inlet cone that contained nickel. The existence of nickel in the compressor could not be explained as no compressor component contained nickel. Although none of the impact marks on the compressor could be directly linked to an impact from an object containing nickel, the possibility of such an impact could not be ruled out. It was also possible that an object had not caused a direct impact with the compressor but had become lodged between the compressor blade tips and the compressor casing, causing the imbalance and subsequent compressor damage.

If a foreign object had caused the compressor failure it is likely that it was introduced into the air intake system during maintenance, because there was no evidence of a foreign object having been ingested through the air intake filter. The last known time the air intake hose was removed was during the aircraft's engine change. The fact that a SCAT-10 hose was installed instead of a SCEET-10 hose was an anomaly, although it did not appear to be a contributory factor to the engine failure or a source of a foreign object.

Regardless of the mechanism of the compressor failure it remained clear that the failure of the engine itself was directly caused by seizure of the oil scavenge pump. Had the section of bearing not been sucked into the scavenge pump, the engine would have continued to operate, albeit at a lower power setting due to the reduced manifold pressure from the failed turbocharger. It would be desirable to have a system whereby a failure of the turbocharger for any reason would not lead to pieces from the turbocharger causing seizure of the scavenge pump. The possibility of installing a coarse mesh filter between the scavenge pump and the turbocharger catchtank was discussed with the engine manufacturer, but this idea was rejected by the manufacturer because it could introduce additional failure mechanisms such as mesh blockage and leakage due to faulty maintenance. Alternatively, the design of the turbocharger catchtank and oil exit point could be modified to reduce the likelihood of large pieces of debris passing from the catchtank into the scavenge pump.

Conclusions

The engine failure was probably caused by the following sequence of events:

1. The turbocharger compressor was damaged by ingestion of a foreign object containing nickel.
2. It is likely that the foreign object was introduced during maintenance.
3. The compressor damage resulted in an imbalance that caused vibration.
4. The vibration induced a fatigue failure of the axial and radial bearing's thrust collar.
5. A section of the failed thrust collar dropped into the turbocharger catchtank and was then sucked into the oil scavenge pump.
6. The oil scavenge pump promptly seized, shearing its driveshaft.
7. The turbocharger catchtank and subsequently the oil separator started to overfill with oil.
8. The engine oil pressure started to reduce.
9. Once the oil separator was full, the oil began to exit via its breather vent line under the aircraft's belly.
10. The loss of engine oil circulation resulted in the engine overheating and its eventual seizure.

Safety Recommendations

To help prevent a similar accident from occurring again the AAIB issued the following safety recommendations:

Safety Recommendation 2005-047

Thielert Aircraft Engines should modify the TAE-125-01 diesel engine's oil system to reduce the likelihood of sections from a failed turbocharger causing seizure of the oil scavenge pump.

Safety Recommendation 2005-048

The European Aviation Safety Agency (EASA) should consider requiring Thielert Aircraft Engines to modify its TAE-125 diesel engine's oil system to reduce the likelihood of sections from a failed turbocharger causing seizure of the oil scavenge pump.

Safety action taken

As a result of this accident the engine manufacturer has revised the TAE-125 engine maintenance manual to include a note which states: "When replacing the air filter check carefully that no loose parts are in it." The AAIB does not believe that this change is sufficient to prevent similar accidents from occurring again. A foreign object ingestion or a failure of the turbocharger for any reason should not lead directly to engine seizure.

Response to Safety Recommendations

The EASA delegated national aviation authority for oversight of Thielert Aircraft Engines is the LBA (Luftfahrt-Bundesamt) which is the German equivalent of the UK Civil Aviation Authority. The LBA responded to Safety Recommendation 2005-048 as follows:

> *'It is not appropriate to design the engine such that it will not fail in such a case of FOD'* (ie as a result of a foreign object being introduced into the air intake system during maintenance).

They stated furthermore that:

> *'It is also not appropriate to design the engine so that a failure of the turbocharger for any reason does not lead directly to an engine seizure. A failure of the turbocharger can cause a drastic power reduction or an IFSD (in-flight shutdown) for several reasons (reduction of air supply, releasing parts can seize intake valves of the combustion chamber and can destroy the valve train immediately). But all these failure cases are not probable and are considered in the failure analyses and safety assessments during engine certification. Never have considerations been taken to protect the intake pipe after the turbocharger and the combustion chamber from releasing parts of the turbocharger.*
>
> *We agree with the objection of the manufacturer that a coarse mesh filter between the scavenge pump and the catchtank can introduce additional failure mechanisms. Experience from turbine engines has shown that strainers on the suction sides of oil pumps can cause problems in the oil system, especially when it is not possible or difficult to maintain them. For that reason the former JAR-E paragraph 570 (a) (3) "The suction side of each pressure and scavenge pump shall be fitted with a strainer of adequate capacity to protect the pump and to ensure that the pump entry is not restricted under any starting or operating procedures." was deleted (NPA-E 23).*
>
> *A design change of the catchtank might be useful. But from our point of view there is no need for an immediate design change. Operation of the engine outside the certified limits and/or subsequent faulty maintenance may damage the engine at any time.'*

The response from Thielert Aircraft Engines to the Safety Recommendations expressed agreement with this response from the LBA.

The purpose of the AAIB is to improve aviation safety by determining the causes of air accidents and serious incidents and making safety recommendations intended to prevent recurrence. The AAIB therefore stands by Safety Recommendations 2005-047 and 2005-048 because they are formulated to prevent recurrence.

ACCIDENT

Aircraft Type and Registration:	Druine D.31A Turbulent, G-ARLZ
No & Type of Engines:	1 4C02 MK.X (Modified) Piston Engine
Category:	1.3
Year of Manufacture:	1961
Date & Time (UTC):	17 July 2005 at 1120 hrs
Location:	Taw Mill, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage to landing gear, propeller and wing spar
Commander's Licence:	Private Pilot's License
Commander's Age:	62 years
Commander's Flying Experience:	581 hours (of which 2 were on type) Last 90 days - 19 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was being flown from Exeter to Taw Mill to attend a PFA fly-in. On arrival at the airfield, the pilot carried out a left base join for grass Runway 17 which has a total length of 500 m. Although the pilot had not previously landed at Taw Mill, he was aware of the advice issued by the 'Devon Strut' internet site which states:

> *'There is a 100 ft upslope from the threshold of r/w 17. It is common practise to land uphill with a tailwind but this depends on aircraft type and pilot experience. If not sure, make a low level pass to assess conditions.'*

As he approached the airfield, he estimated from ground smoke that the wind was light and from the north-west giving a tailwind component to Runway 17. The final approach appeared normal but as the pilot flared the aircraft, the airspeed decayed rapidly and the aircraft landed heavily. Both main landing gear assemblies broke off and the aircraft came to a halt rapidly. The propeller blades both shattered as it slid along the ground. The pilot was able to escape uninjured from the open cockpit. The pilot considered that maintaining a slightly higher groundspeed during the latter stages of the approach might have prevented critical energy loss during the flare.

ACCIDENT

Aircraft Type and Registration:	Grob G115 D2, G-BVHF
No & Type of Engines:	1 Lycoming AEIO-320-D1B piston engine
Category:	1.3
Year of Manufacture:	1994
Date & Time (UTC):	6 June 2005 at 0844 hrs
Location:	Dundee Airport, Fife
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Right landing gear embedded in fence, nosewheel sheared off, right wing, nose and propeller severely damaged
Commander's Licence:	Commercial Pilot's Licence with Instructor rating
Commander's Age:	32 years
Commander's Flying Experience:	815 hours (of which 8 were on type) Last 90 days - 129 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the instructor plus flight testing by the flying school

History of the flight

The aircraft was being used for initial flying instruction of an Air Cadet student in the sponsored Air Cadet Pilot Scheme. It was the second flight in which the student was given full control of the aircraft, both in the circuit and for the landing, and the accident happened at the end of the second circuit. The aircraft was operating from Runway 28 and the weather was fine with good visibility and a reported wind of 300º at 3 kt.

The instructor reported that the earlier parts of the flight had gone well, with good pre-flight preparation and no apparent aircraft problems. Given the student's level of experience, the first circuit had been flown satisfactorily and he had demonstrated what he had been taught in the previous day's lesson by another instructor. The early part of the final approach was slightly high and the landing was 'firm'.

The instructor reports that the second circuit was flown in a similar way to the first, with more confidence. Again, the early part of the final approach to landing was flown slightly high but the student corrected this by reducing power and lowering the nose. The approach was flown at a constant 65 kt and appeared stable. Permission for a 'touch and go' was received from ATC in good time.

Approaching the runway threshold, the student began to align the aircraft with the runway, as instructed, and smoothly to reduce the power for landing. At this point the instructor considered that he had no reason to take control and was 'following through' the student's control inputs. The aircraft then seemed to start a sudden roll to the left and the instructor immediately took control, stating "I have control". The student acknowledged this, although the instructor recalled that the student momentarily resisted his application of full power. The instructor applied control to stop the aircraft veering further left, raised the nose to an attitude slightly above the horizon and initiated flap retraction from the '60º' setting to the 'Takeoff' setting. However, the aircraft did not respond to his control inputs and the only viable option appeared to be a forced landing on the grass to the left of the runway. The instructor was later uncertain about the operation of the stall warning horn but commented that he believed it had sounded twice on the base leg but not during the approach nor during the go-around. He was also uncertain of the actual airspeed at the time.

The aircraft touched down some 10 m from the boundary fence, after an initial contact of the left wingtip with the ground. The aircraft ran into the fence at an angle of about 45º and, after an initial impact between the left wingtip and one of the fence posts, it slid to the right. The nose leg collapsed and there was extensive damage to the nose, which was embedded into the fence, and to the right wing, which was nearly severed by another fence post during the slide to the right. There was, however, no fire and the instructor and student were able to leave the aircraft without assistance and without injury.

Further information

After the accident the student prepared a written statement and this was consistent with the instructor's recollection. The student considered that he began to experience control difficulties at a height of about 100 ft and this worsened close to the ground. He concurred that, with full power applied and flaps returned to the 'Takeoff' setting, the aircraft did not appear to respond to the instructor's control inputs, and the left side of the aircraft seemed to drop.

Examination of the aircraft after the event did not show any mechanical deficiencies which would have preceded the event. The stall warning system, which operates off a vane on the left wing, was functional and there was no evidence of disruption or restriction in the flying control system. The position of the flaps, which are electrically actuated, indicated that they were travelling to the 'Takeoff' position, as selected by the instructor.

An ATC witness from the control tower, approximately 170 m to the right of Runway 28 and nearly abeam the touchdown area, had a good view of the event. It appeared to this witness that the "aircraft stalled at about 50 ft, on a go-around" and that the left wing dropped, followed by the nose. Before the aircraft struck the ground to the south of the runway, it appeared that the nose had been raised so that the initial impacts were on the left wingtip and the left main landing gear.

The flying school, which had recently acquired a total of four Grob G115 D2 aircraft, took a strong interest in the possible causes of this accident and discussed it with the AAIB. A senior instructor and the instructor involved in the accident attempted to replicate the accident conditions, at altitude, but without success. Further work by another instructor indicated that the conditions could be replicated if go-around power was applied without sufficient compensating right rudder. The resulting left 'wing drop' would then be exacerbated if right aileron were applied alone, rather than 'picking up' the left wing with right rudder. The chief flying instructor concurred, adding that the instructor appeared to have been slow in taking control from the student on the final approach and that a contributory factor may have been the slight delay when the student momentarily resisted the instructor's application of full power.

The aircraft commander later took the opportunity to comment on this AAIB account of the accident. He emphasised, in particular, his recollection that the aircraft had not stalled and that he had not used any significant amount of aileron during the attempted go-around. He had followed through the student's control inputs and there was no delay in his taking control of the aircraft. He considered that a lack of aircraft performance had been a major factor in the event.

ACCIDENT

Aircraft Type and Registration:	Maule M6 Super Rocket, N6130X
No & Type of Engines:	1 Lycoming 10-540-W1A5D piston engine
Category:	1.3
Year of Manufacture:	1989
Date & Time (UTC):	6 August 2005 at 1226 hrs
Location:	Old Winchester Mill Lane, West Meon, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Minor, to propeller and left wingtip
Commander's Licence:	Private Pilot's Licence
Commander's Age:	73 years
Commander's Flying Experience:	4,704 hours (of which 650 were on type) Last 90 days - 40 hours Last 28 days - 16 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was returning from Thruxton to the grass airstrip at which it was based, 20 nm to the southeast. The wind reported at Thruxton was from 280° at 5 kt, and the pilot estimated that the wind at the airstrip was approximately 10 kt from the same direction. He elected to land on Runway 24, which has a total length of 350 m and is slightly down hill in the landing direction. After a normal approach and touchdown the pilot found that the brakes were ineffective, and he was unable to stop the aircraft before it overran the airstrip boundary. The aircraft sustained minor damage to the propeller and left wingtip as it passed through a hedge onto a lane whose metalled surface was approximately three feet below the level of the runway. The pilot was uninjured.

The Maule M6 is designed to operate from short, unprepared strips. The pilot stated that he had carried out many successful landings in this aircraft at this airstrip. He attributed the accident to loss of braking on the damp runway, caused by a light fall of drizzle on the grass surface earlier in the day. There was no evidence of mechanical brake failure.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140, G-BTVR
No & Type of Engines:	1 Lycoming O-320-E3D piston engine
Category:	1.3
Year of Manufacture:	1976
Date & Time (UTC):	11 June 2005 at 1209 hrs
Location:	Full Sutton, Yorkshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Aircraft beyond economical repair
Commander's Licence:	Student Pilot
Commander's Age:	45 years
Commander's Flying Experience:	10 hours (all on type) Last 90 days - Unknown hours Last 28 days - Unknown hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The student pilot was completing a period of solo consolidation and his landing was to be on Runway 04 at Full Sutton Airfield. The wind at the time was reported as 060º at 8 kt. Whilst on final approach for a touch-and-go, the pilot allowed the airspeed to drop, causing the aircraft to land heavily and bounce several times. An attempt was made to recover the situation, and in doing so, the pilot believes that he may have inadvertently pushed the left rudder pedal causing the aircraft to turn rapidly to the left. As the aircraft departed the grass runway, the pilot opened the throttle in an attempt to climb clear of a line of trees, but this was to no avail. The aircraft struck a tree, rolled inverted and finally came to rest in a field of crops. There was no fire and the pilot was able to exit the aircraft having only suffered minor injuries.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181, G-MERI
No & Type of Engines:	1 Lycoming O-360-A4M
Category:	1.3
Year of Manufacture:	1980
Date & Time (UTC):	10 July 2005 at 1426 hrs
Location:	Carlisle Airport, Cumbria
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	492 hours (of which 6 were on type) Last 90 days - 49 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

After completing normal power checks, the aircraft was cleared to backtrack and subsequently takeoff from asphalt Runway 25 which has a TORA of 1,714 m. Engine power and acceleration appeared normal during the take-off roll and the aircraft climbed away at 75 kt. At approximately 100 ft above the airfield, the engine suffered a rapid loss of power and the pilot prepared to land on the runway remaining. The engine then recovered to full power and the aircraft began to climb again. At this point, the pilot decided to execute a low level circuit and land back on Runway 25 due to his concerns regarding the engine performance. Whilst climbing straight ahead through 300 ft, the engine suffered a second loss of power which persisted; the engine remaining at approximately idle power. The pilot considered that there was not enough runway remaining and selected a field to his right for a forced landing. During the descent it became apparent that the aircraft did not have sufficient gliding range to reach the selected field and that a collision with hedges in the field's undershoot was inevitable. The pilot slowed the aircraft to reduce the effect of the impact and hit the top of a hedge at right angles. The aircraft continued across a minor road and came to rest in the hedge on the opposite side with both wings and the landing gear becoming detached. All occupants were able to evacuate the aircraft through the main cockpit door.

The engine, which was approximately 10 hours away from its next 50 hour check, had no history of power problems. At the time of takeoff, the OAT was 27ºC the dew point 17ºC. In these conditions the carburettor would be susceptible to icing with descent power set. Since, in this accident, the power loss occurred at take-off power, the presence of severe carburettor icing is considered very unlikely. A magneto check, carried out during the pre take-off power checks, would indicate that partial ignition failure was also unlikely.

The aircraft had last been flown the previous day and had been refuelled to full tanks at the end of that day. The aircraft had been parked overnight inside a hanger and the pilot had checked the fuel system for water contamination prior to the accident flight. Engine power loss shortly after an aircraft has changed attitude, such as on rotation, can sometimes be attributed to water entering the fuel feed to the carburettor.

From the evidence available, however, the cause of the engine power loss could not be positively determined.

ACCIDENT

Aircraft Type and Registration:	Piper PA-32R-300, G-BSYC
No & Type of Engines:	1 Lycoming IO-540-K1G5D Piston Engine
Category:	1.3
Year of Manufacture:	1977
Date & Time (UTC):	25 June 2005 at 1640 hrs
Location:	Wolverhampton Airport, West Midlands
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller and underside of aircraft damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	340 hours (of which 126 were on type) Last 90 days - 33 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot, who owned the aircraft, had been conducting a local flight from Wolverhampton Airport where Runway 04 was the runway in use. Weather conditions were fine, with a surface wind from 050º (M) at 11 kt. After flying for nearly one hour the pilot re-joined the circuit at Wolverhampton via left base but had to request an orbit in order to gain separation from an aircraft ahead. The pilot carried out a normal approach but, as the aircraft was in the landing flare, the gear warning horn sounded. The pilot was aware that the aircraft seemed to be settling lower than normal and considered a go-around, but by this time the aircraft had touched down with the landing gear retracted. The aircraft came to a stop on the runway and the uninjured pilot was able to vacate without difficulty. The airfield fire service attended the scene, followed by the local emergency services. In an honest report, the pilot stated that he had forgotten to lower the undercarriage. He had just returned from a two week visit to the USA where he had flown some 40 hours in fixed-undercarriage PA-28s. The pilot considered that this recent flying had contributed to his error. The late, unplanned orbit to gain separation from the other aircraft would have been an additional distraction.

INCIDENT

Aircraft Type and Registration:	Pitts S-1E, G-LITZ
No & Type of Engines:	1 Lycoming IO-360-B1B piston engine
Category:	1.3
Year of Manufacture:	1994
Date & Time (UTC):	8 July 2005 at 1600 hrs
Location:	Buckland Newton Airstrip, Dorset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Upper and lower wings, engine, propeller, main and tail wheels damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	13,650 hours (of which 130 were on type) Last 90 days - 220 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst landing at a grass airstrip, the 'spade' fitted beneath the right aileron caught up in longer grass at the edge of the strip, causing the aircraft to ground loop.

History of flight

The pilot had visited the 700 m unlicensed grass airfield, five days prior to the accident and assessed it as suitable for operation of the aircraft. He landed on a heading of 247º, with reported wind conditions of 10 kt at 315º. The landing initially appeared normal but the pilot felt the aircraft 'dragging' to the right into the longer grass at the edge of the runway. It then ground looped, resulting in the propeller striking the ground together with both right wing tips. The pilot reported that he did not feel or hear any impact immediately prior to the aircraft pulling to the right or any unusual feedback through the control column. It came to a halt upright at approximately 180º to the landing direction, ten feet off the right edge of the runway. The pilot was uninjured and the aircraft suffered damage to the upper and lower wings, undercarriage, engine and propeller.

Analysis

The aircraft had been modified by the addition of 'spades' on the ailerons on the lower wing. These devices extend between approximately six and ten inches below the lower surface of the wings, dependant on aileron position. These 'spades' provide aerodynamic assistance to the pilot's aileron control inputs. The right aileron spade had broken from the aileron and was found approximately 50 m behind the aircraft's final resting place on the right edge of the runway.

Operation on a surface such as a grass results in irregular compressive undercarriage loads, and the possibility that the aircraft's wheels could run into depressions or over tussocks. This would result in a reduction in the wing and 'spade' ground clearances. Aileron deflection and/or any roll input to counteract crosswind effects would further decrease these clearances.

It is likely that, given the nature of the operating surface, and from the information contained in the pilots report, at some point during the landing roll the right aileron spade ran through a section of longer grass, dragging the aircraft to the right and leading to the subsequent ground loop.

ACCIDENT

Aircraft Type and Registration:	Staaken Z-21 Flitzer, G-ERIW
No & Type of Engines:	1 Volkswagen 2180 piston engine
Category:	1.3
Year of Manufacture:	2004
Date & Time (UTC):	16 July 2005 at 1230 hrs
Location:	Popham Airfield, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Top wing and engine bearing damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	32 years
Commander's Flying Experience:	147 hours (of which 33 were on type) Last 90 days - 52 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot made a normal approach to grass Runway 03 at Popham. During the flare prior to landing, the hand grip of the control column slid off the column allowing the nose to pitch down. Before the pilot could regain control, the nose hit the ground and the aircraft pitched over onto its back. The pilot, who was wearing a 4 point harness, was able to vacate the aircraft's open cockpit without injury.

The hand grip was made from turned wood and held onto the control column using a friction fit. During recent hot weather, the wooden grip had cracked, allowing it to move freely on the steel shaft of the control column. A new grip is currently being manufactured from aluminium which will be secured onto the control column by a retaining bolt.

ACCIDENT

Aircraft Type and Registration:	Agusta Bell 206A JetRanger, G-OJEF
No & Type of Engines:	1 Allison 250-C18B turboshaft engine
Category:	2.3
Year of Manufacture:	1969
Date & Time (UTC):	27 May 2005 at 1600 hrs
Location:	Haverfordwest Airfield, Dyfed
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Main rotor head and blades detached, fuselage severely damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	161 hours (of which 18 were on type) Last 90 days - 18 hours Last 28 days - 18 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus eyewitness accounts

History of the flight

The pilot and his wife had completed an uneventful flight from a private site near Southampton to Haverfordwest Airfield. The weather was good with a south-westerly wind at about 20 kt, visibility in excess of 10 km and broken cloud at about 2,000 ft. The helicopter was positioned on the downwind leg for a left hand circuit to Runway 21. A normal approach was made to Runway 21 with the surface wind from 220°/10-15 kt. The helicopter was hover taxied along the runway and turned right along the taxiway/parking area, towards the refuelling point. As the helicopter neared the hangars it turned sharply which the pilot tried to correct with some effect. He could not recall in which direction the helicopter turned but decided to try to turn it into wind and takeoff. On raising the collective lever, the helicopter did not respond and suspecting there may be a technical problem, the pilot elected to perform an immediate landing. The landing gear contacted the ground and the helicopter bounced rolling to the left. The main rotor blades contacted the grass surface to the east of the taxiway which sheared the main rotor mast. The main rotor head and blades detached and the fuselage came to rest on its left side. There was no fire and the pilot carried out the emergency shut down drills. Both occupants were uninjured and vacated the helicopter through the pilot's door on the right side of the aircraft. The airfield Rescue and Fire Fighting Service promptly attended the scene.

Eyewitnesses

An instructor pilot in a Cessna 150 had been in radio contact with the pilot of the Bell 206 and had just landed when the helicopter accident occurred. Although at some distance, he described the helicopter as in a hover taxi when it became unstable, pitching up and down and rising and descending. Although he could not be certain he believed that the helicopter yawed rapidly to the left before impacting the grass.

A second witness was a private pilot who also flew a Bell 206. He saw the helicopter hover taxiing along the taxiway and described the same unstable pitching and rolling motion. He saw the helicopter descend rapidly from a high hover taxi and the right skid touch before the helicopter bounced some five feet back into the air before descending onto its left side, the main rotor blades striking the ground. During these manoeuvres, the helicopter rotated through approximately 180° to the right.

Analysis

No definite cause for the accident could be identified but when turning right off the runway the helicopter hover taxied in a northerly direction along the taxiway. The surface wind was then from the left rear quarter direction. The weather-cocking effect induced a yawing motion which, when combined with the airflow under the horizontal stabiliser pitching the helicopter nose down, created difficult flying conditions for the pilot.

In attempting to maintain control, the pilot was probably making large control movements associated with the pitching and rolling reaction of the aircraft described by the witnesses. His attempt to take off by raising the collective pitch control did not produce any significant climb or acceleration from the helicopter. This was probably due to using a high power setting in the downwind condition which did not produce the normal take-off reaction. The bounce occurred due to a positive lowering of the collective pitch control in order to land immediately. This produced a high rate of descent and the excessive left roll angle permitted the main rotor blades to strike the ground.

ACCIDENT

Aircraft Type and Registration:	Enstrom 280FX, G-MHCK
No & Type of Engines:	1 Lycoming HIO-360-F1AD piston engine
Category:	2.3
Year of Manufacture:	1985
Date & Time (UTC):	21 May 2005 at 1015 hrs
Location:	Barton Airfield, Manchester
Type of Flight:	Trial Lesson
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fire damage to aircraft skin and engine area
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	67 years
Commander's Flying Experience:	20,000 hours (of which 12,000 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and metallurgical examination of exhaust system component

Following a normal start-up, the pilot had lifted the helicopter into a hover when he noticed a burning smell and saw smoke coming from the area around the engine. He reported that the helicopter then lost power and he landed back on the helipad. The pilot was informed by ATC that the aircraft was on fire and he shut off the fuel and electrics. Both the pilot and passenger exited the aircraft without injury. The fire was extinguished by the Airport Fire Services.

After the fire had been extinguished the pilot looked inside the engine bay and found the exhaust pipe from the turbocharger had become detached. He concluded that the flames were as a result of the paint being heated by the exhaust exiting the turbocharger.

The exhaust pipe had been fitted to this helicopter for a significant period of time; it was maintained 'on-condition' and was required to be visually inspected every 50 hours in accordance with the maintenance checklist. The last such inspection was carried out one and a half hours flying prior to the accident.

Metallurgical examination of the exhaust system

The exhaust from the turbocharger outlet passed via a short pipe through an aperture in the skin to overboard.

Subsequent examination revealed that this pipe had failed, allowing exhaust gases to heat the aircraft skin, leading to the smoke and fire. The location of the detached exhaust pipe and the damage to the engine cover is shown in Figures 1 and 2. The exhaust pipe was returned to the AAIB for examination and is shown in Figure 3. The pipe had failed circumferentially around the weld attaching the flange to the main tube (see Figure 4). The material of the main tube and the flange was specified to be 321 grade stainless steel and the filler weld material was specified as AMS5680 (347 grade stainless steel).

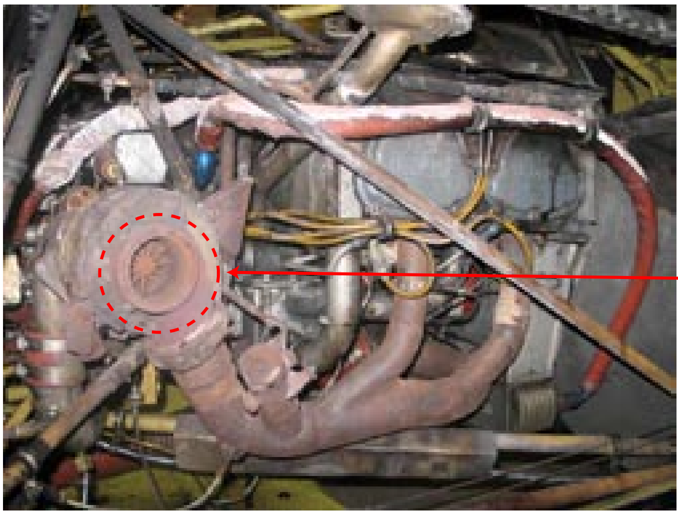


Figure 1

Figure 2

Photographs courtsey QinetiQ

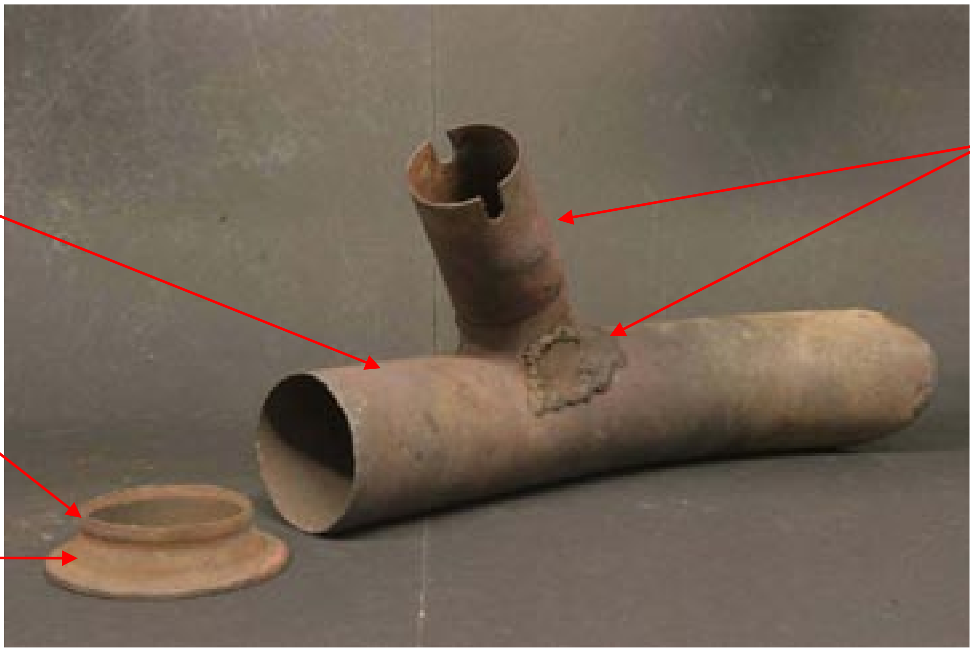


Figure 3

Exhaust pipe 'as found'

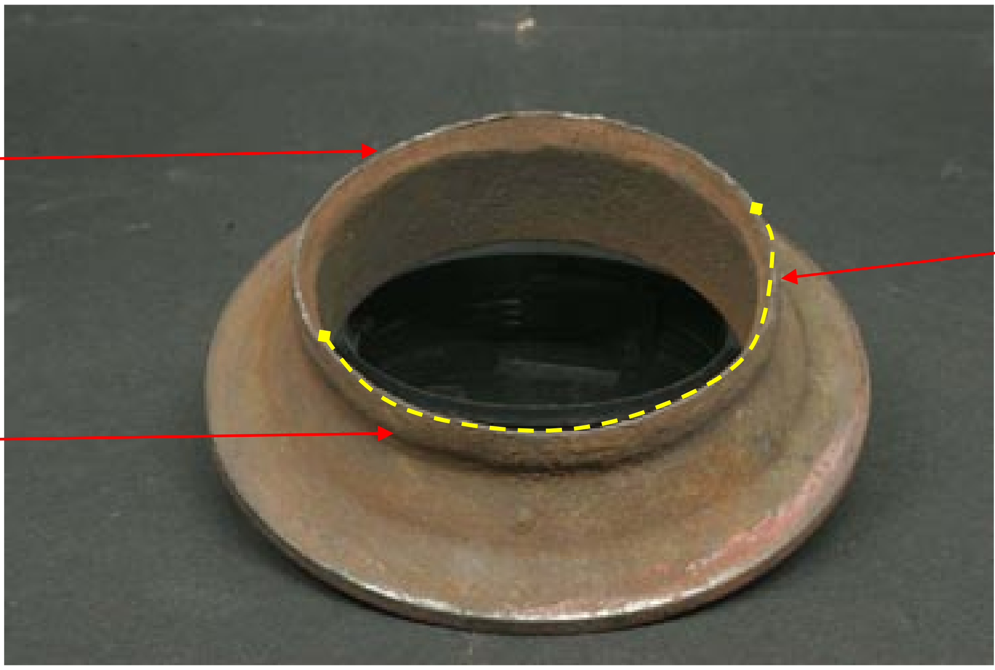


Figure 4

Exhaust pipe flange showing fracture surface and corrosion

Photographs courtsey QinetiQ

The exhaust pipe was sent for metallurgical examination. It was found that:

'Visual examination of the fracture surface revealed one half to be severely corroded and the other half exhibited blue/purple colours in the fracture surface (locations shown in figure 4); these colours may be indicative of heat tinting of the component.

Scanning Electron microscopy (SEM) of the fracture surface on the flange revealed that:

'the coloured area from the visual examination exhibited intergranular cracking on the outer edges. In the centre of the intergranular cracking were areas of fatigue. Approximately 60% of the fracture surface was severely corroded, which had removed any fine detail in that area. The extent of the corrosion would indicate that the crack had been present for some length of time.'

It was concluded that:

'The Enstrom 280FX turbo charger exhaust pipe failed due to intergranular cracking around the weld connecting the flange to the main tube. It is probable that the cause of the intergranular cracking was due to sensitisation of the austenitic 321 stainless steel during welding. Sensitisation occurs in some austenitic stainless steels in the temperature range of 500 – 850°C. The formation of chromium carbides at the grain boundaries lowers the corrosion resistance and thus is susceptible to attack in an environment the steel would usually resist. Hence, a result of sensitisation is that the component becomes more vulnerable to intergranular corrosion. The fatigue found in the fracture surface would have been a secondary failure mode initiated by cyclic loading on the reduced thickness of the tube caused by the intergranular cracking.

Previous events

A previous incident to an Enstrom 280c G-BRPO where the clamp securing the exhaust pipe failed was reported in AAIB Bulletin 1/2005. The report stated that the turbocharger exhaust pipe:

'was detached from the turbocharger, allowing the exhaust to impinge directly on the inside of the skin, resulting in the local overheating previously mentioned. The pilot had assumed that this had been dislodged in the landing, however the clamp securing it had fractured in fatigue, allowing it to become dislodged in flight. This pipe also connected to a bypass pipe from the engine exhaust system, and once dislodged this allowed exhaust from close to the cylinders to be directed at the bulkhead immediately behind the pilot. The entire engine compartment would have filled with exhaust fumes, accounting for smoke in the cockpit.'

The manufacturer's agent advised that fractures of this type of clamp are rare and there have been no reported incidents of the failure of the exhaust pipe.

INCIDENT

Aircraft Type and Registration:	Robinson R44 Clipper II, G-SHAN
No & Type of Engines:	1 Lycoming IO-540-AE1A5 piston engine
Category:	2.3
Year of Manufacture:	2005
Date & Time (UTC):	10 June 2005 at 1900 hrs
Location:	Private site 2 nm west of Chesham, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to main rotor mast fairing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	9,000 hours (of which 4,500 were on type) Last 90 days - 200 hours Last 28 days - 70 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The helicopter had taken off from a private site on a farm and five minutes later, while making a normal approach to a field in another part of the property, the pilot heard a slight noise when the aircraft was about 100 ft agl. After landing it became apparent that one of a pair of wires, which traversed the field and the valley in which it lay, had been severed by coming into contact with the helicopter's main rotor mast fairing. The damage to the aircraft was limited to the mast fairing.

This experienced pilot concluded that the accident was caused by his inability to see the wires, which spanned approximately 900 feet across the valley. He described the wires as green in colour and set against a green background of trees and grass. The telegraph poles that supported the wires at each side of the field were obscured by trees and shrubs and the wire that was broken was reported as being of corroded copper.

The weather at the time of the accident was good, with less than five knots of wind, visibility in excess of 10 km and no significant cloud. The approach to land had been made into the evening sun and the contrast between the bright sky and darker ground vegetation probably contributed to masking the presence of the wires. It is not known why one wire was struck and not the other but it may have been that one sagged further than the other as they hung across the valley.

Another report (see AAIB Bulletin No: 1/2004, registration G-BAGL) describes a wire strike in which the pilot of that helicopter did not see a pair of green wires when he was taking off from a field. Again the pilot described the green wires as difficult to see against the background, which in that case was a set of buildings. It was also reported that the telegraph poles which supported the wires were, again, hidden by trees.

ACCIDENT

Aircraft Type and Registration:	Cameron Z-250 Balloon, G-CDIN
No & Type of Engines:	3 Cameron Shadow burners
Category:	3
Year of Manufacture:	2005
Date & Time (UTC):	12 June 2005 at 0643 hrs
Location:	Dunkirk, near Faversham, Kent
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 12
Injuries:	Crew - 1 (Serious) Passengers - 3 (Serious, 8 Minor)
Nature of Damage:	Distortion of basket and frame
Commander's Licence:	Commercial Pilot's Licence (Balloons)
Commander's Age:	47 years
Commander's Flying Experience:	392 hours Last 90 days - 8 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Summary

The flight was planned as a pleasure flight of around one hour duration. At a low height, while the pilot was searching for a suitable landing site, the balloon encountered an area of sinking air on the lee side of a hill. The basket and frame contacted a concrete and brick bunker, hit the ground and then lifted off again. The pilot brought the balloon back down and it eventually came to rest against a large tree some 230 m further on. There were a number of injuries sustained amongst those on board. It was suspected that most of the injuries occurred during the initial impact.

History of flight

On the evening before the accident the pilot checked the ballooning forecast and general weather conditions on the Meteorological Office website and also discussed the conditions on the telephone with the operator's Chief Pilot. The decision was made for the pilot to meet his passengers at Leeds Castle and to fly from there providing the weather in the morning was suitable.

In the morning the pilot released a weather balloon from Leeds Castle and saw that there was too much northerly drift in the wind to allow a safe flight from there. He decided to move the balloon and the passengers to an alternative site further south at Lashenden (Headcorn)

Aerodrome. At Headcorn the pilot sent up another weather balloon; he observed that the wind was very calm with the aerodrome windsock hanging vertically down, and thereby made the decision to fly. The balloon was prepared for flight with the assistance of the chase crew and some of the passengers. The pilot gave the passengers a briefing on the flight and landing procedures.

At 0536 hrs the balloon lifted off and drifted slowly, at 0 to 4 kt, north across the aerodrome at around 20 ft agl. As the balloon ascended the direction of travel became north-easterly and at 1,000 ft the pilot reported that the wind was from the south-west at 10 to 15 kt. This was stronger than he had anticipated and was taking the flight towards the Lenham area at the foot of the North Downs[1], an area that he knew had limited landing opportunities. The pilot decided to climb to 2,000 ft and at that altitude he could see another balloon to the east of his position at a height of around 3,000 ft. He decided to climb up to see if the wind was more favourable at that level but when he reached 2,500 ft he realised it was still from the same direction but the speed had increased to between 15 and 20 kt so he stopped climbing.

Not wanting to fly over the North Downs, the pilot decided to find a suitable landing area and thought that he might be able to land at Challock Airfield. However the wind took him to the west of Challock so he looked for an alternative landing site. He made several descents to lower levels but when he did so he experienced 'curlover', sinking and turbulent air close to the ground, such that he needed to keep the burners lit to maintain level flight. The balloon was travelling across the ground at speeds varying between 12 and 20 kt while the pilot continued unsuccessfully to try to find a landing site.

Shortly after crossing the A2 trunk road and at a fairly low height, with coastal towns and the sea 5 nm ahead, the pilot felt the balloon sinking. He ensured that all the burners were on but the balloon continued to descend. The balloon basket and burner frame hit hard against a concrete and brick bunker and the passengers were thrown about. It then hit the ground and lodged momentarily against a tree before lifting off again. The pilot called out to the passengers to get into the landing position and to stay in the basket. He could see a clear area of field and playing fields ahead and pulled the ripcord to bring the balloon down. The balloon made a landing some 210 m further on, hit the ground once more and then got caught against a tree in a hedgerow, where it came to rest.

Post-landing actions

The pilot turned off the fuel supply and the burners and ensured that the balloon was secure. He then checked the condition of his passengers and asked those who were able to do so to get out of the basket and to assist the others. He used his mobile telephone to call the recovery crew and in turn asked them to call the emergency services. There was a short delay before he could give them his exact position because the batteries in his GPS had run out at the end of the flight and he had to replace them.

The pilot was himself injured having suffered a dislocated shoulder but he continued to assist the passengers until the emergency services arrived. The air ambulance and the local ambulances arrived and their crews helped the remaining passengers out of the basket with the exception of two who could not be safely lifted out. When the fire service arrived their commander realised that the passengers would need to be cut free from the basket and asked the pilot if this was in order. The pilot advised him to proceed and briefed him on the location of the fuel supply lines which he thought might contain some remaining gas.

Footnotes

[1] A ridge of elevated terrain aligned north-west to south-east which rises to over 600 feet amsl.

The pilot, a full time fire service officer, was then helped away to a nearby ambulance but he continued to watch what was happening. He saw that the fire crew were attempting to cut the basket in a place close to the fuel lines and shouted for them to stop. They stopped cutting and he re-briefed them on the areas where it was safe to cut. The remaining two passengers were then freed from the basket and taken to a local hospital.

Injuries to persons

The initial impact against the bunker was at around 16 kt forward speed and it is at this time that the most serious injuries are thought to have occurred. The majority of the passengers did not anticipate the impact, although one person was able to brace himself at the last moment and did not suffer any injury. There were three passengers detained in hospital for more than 48 hours, two of whom had suffered broken or crushed vertebrae. The other injuries were principally heavy bruising, particularly to legs, ribs and knees and a number of broken fingers. Subsequent impacts with the ground and trees caused some further injuries, in particular scratches and cuts.

Pilot experience

The pilot had been flying balloons for some 12 years, initially as a private pilot and then as a commercial pilot for the previous 5 years. He had accumulated just under 400 hours total flight time and had flown two flights on the day before the accident. He flew on a part time basis for the operator, making himself available two or three days a week. Although most flights were planned for one hour duration the pilot reported than on some occasions he had needed to land earlier because of adverse conditions. He was familiar with the Kent area having carried out many of his previous flights there but he had not previously flown across the location where the accident occurred.

For navigation the pilot used a 1 to 50,000 scale Ordnance Survey map annotated with significant features, including good and bad landing areas. He also carried a handheld GPS which he could use to determine his speed and also to relay his position to the recovery crew.

The aircraft

This Cameron Z-250 balloon had been supplied new to the operator in March 2005. The balloon had an envelope volume of 250,000 cu/ft and was equipped with three burners mounted above a twelve place double T-partition basket. The four vertical supports of the frame were each fitted with protective padding. There was space for three passengers in each partition, rope grab handles were supplied inside the basket. Passengers were briefed to face rearwards and crouch down in the basket holding the grab handles when instructed to adopt the landing position.

On the morning of the accident flight the ambient weather conditions gave a maximum lift capability of 2,093 kg. The actual mass at lift off was calculated at 1,774 kg which gave an underload of 319 kg.

Meteorological information

The Ballooning Forecast

The pilot accessed the online service from the Meteorological Office Internet website on the evening before the accident. This enabled him to check the general weather conditions and the ballooning forecast for the south-east region. The Meteorological Office Ballooning Forecast is funded by the Civil Aviation Authority and provided as a free service to pilots.

A preface page on the website contains a note on the purpose of the ballooning forecast. The note states:

These forecasts, issued daily, should be used in conjunction with AIRMET or forms F214 and F215.

Note that the forecast surface wind is an estimate of the wind speed and direction averaged over a ten-minute period, followed by the probable maxima (gusts) that may be experienced over flat, open countryside. The surface wind speed, and individual gusts, over variations in topography, trees and buildings, may be higher.

The forecast issued at 2130 hrs on the day preceding the accident contained the following information (see below):

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NOTE

THIS FORECAST IS PROVIDED AS A SUPPLEMENT TO AND NOT A SUBSTITUTE
FOR, AIRMET OR CHART FORMS 214 OR 215.

==

AREA: SOUTHEAST
PERIOD: DAWN TO MIDDAY, 12 JUNE 2005

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SURFACE WIND (DEGREES TRUE): 220/03-06KT, LOC 08KT NE, BECMG 290/10-12KT IN NW BY 09Z, 310 BY 12Z, AND GEN INCREASING 10-12KT BY 12Z.

THERMALS: NIL OR WEAK AT FIRST, BECMG MOD BY 09Z.

INVERSIONS: NIL.

SEA BREEZES: LOC DEVELOPING ALONG S COT BY 11Z.

LEE WAVES: NIL.

LOWEST PRESSURE (QNH): 1006MB E LATER.

SURFACE AIR TEMPERATURE:
0600: PS10, LOC PS12 S.
0900: PS14, LOC PS16 SW.
1200: PS15, LOC PS19 SW.'

OUTLOOK UNTIL DUSK:
MOD SEA BREEZES ALONG S COT DYING OUT BY LATE AFTERNOON. NW SURFACE WINDS GEN LIGHT, LOC MOD INLAND UNTIL EARLY EVENING, BECM N IN NE BY EVENING. OCNL RAIN OR SHOWERS IN NE DYING OUT DURING EVENING, OTHERWISE GOOD VISIBILITY AND VRB CU SC.

==

ISSUED AT 2130 UTC 11 JUN 2005

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Ballooning forecast issued at 2130 hrs 11 June 2005

Other sources of meteorological forecasts

Forms F214 and F215 referred to in the note preceding the ballooning forecast contain some graphics and take longer to download than the plain text of the ballooning forecast. Using a domestic telephone line and modem it took approximately two minutes to access the website and to download the ballooning forecast; each 214/215 form took an additional minute. To cover a typical morning flight a total of four forms would be required.

Form 215 lists the weather fronts, cloud, visibility, freezing level and precipitation for the entire UK but does not provide wind information. Form 214 is the UK Low-Level Spot Wind Charts for the UK. It was produced at 21:06 hrs the evening before the accident, valid for the period between 0000 hrs and 0600 hrs UTC. It did not illustrate a spot wind for Kent. The nearest spot winds were for 50º00'N 02º30'W (the English Channel 35 nm north of Guernsey) 50º00'N 02º30'E (in France) and 52º30'N 00º00'E (near Peterborough). Interpretation of the form's wind tables for the 1,000 ft and 2,000 ft altitudes suggested that the winds at those altitudes over Kent would be either variable in direction or west-south-westerly at speeds of 5 to 10 kt. The updated version of F214 issued at 02:57 hrs on the morning of the accident showed similar wind directions but interpolation of the tables suggested that the wind strength would be nearer 10 kt at both altitudes.

The AIRMET forecasts for the seven UK regions (including one for south-east England) were available from the same Meteorological Office website and have no graphics. Typically each can be downloaded by modem in 15 seconds immediately after the balloon forecast has been downloaded. These forecasts contain wind and temperature information for the altitudes of 1,000, 3,000 and 6,000 ft for the specific region. The pilot did not use these forecasts when considering whether or not to launch on the morning of 12 June and a copy of the specific forecast was no longer available to the AAIB when it was requested.

The operator also subscribed to a commercial meteorological service. For a morning flight the general procedure was for the Chief Pilot to telephone the forecaster the evening before to obtain a specific forecast for the proposed flight area. He would then contact any other pilot flying for the operator and discuss the weather conditions. The decision whether or not to call the passengers in for the flight would be based on these forecasts and the passengers would then be advised during the evening. In the morning the local conditions at the take-off site would be assessed by releasing one or more weather balloons and the final decision whether or not to fly would then be made.

The forecast from the commercial source on the evening before the accident was summarised on the flight paperwork as follows:

SURFACE WIND FROM 360º AT 2 TO 4 KT, WIND AT 2,000 FEET FROM 290º AT 5 TO 10 KT, VISIBILITY MORE THAN 20 KILOMETRES, NIL WEATHER, CLOUD SCATTERED OR BROKEN AT 3,000 FEET, TEMPERATURE 9ºC AND PRESSURE 1021 HPA.

The pilot commented that it had been his custom in the past to watch the BBC weather forecast on the evening news to obtain an overview of the weather situation but that he no longer did so because the synoptic picture including isobars was no longer provided.

Accuracy of the meteorological forecasts

The observed surface wind conditions at both Leeds Castle and Headcorn were described as very light or calm. The weather balloons launched at Leeds Castle and later at Headcorn both moved away in a northerly direction.

An aftercast for the period covering the time of the accident was obtained from the Meteorological Office which gave a best estimate of the likely conditions. The synoptic situation showed low pressure over Scandinavia and high pressure over France and Germany which was feeding a light west to north-west flow over south-east England. A table was provided which is reproduced below:

Height amsl	Wind direction (ºT) & speed (kt)	Temp (ºC)
Surface	210-240 / 7-10	+12.5
1,000 ft	250 / 10-15	+9.8
2,000 ft	270 / 15-20	+7.5

Table 1

Winds/Temperatures

The aftercast further provided an assessment of the accuracy of the forecast, which is summarised as follows:

> The 1,000 and 2,000 foot winds (Form 214) had been 5 to 10 kt stronger than forecast. The Low Level forecast (Form 215) had given good guidance and the morning ballooning forecast had also given good guidance with the exception that the increase in wind strength had occurred 1 to 2 hours earlier than forecast.

Recorded data

Data was recovered from the pilot's GPS which gave the time, speed and direction of flight until approximately the point of impact with the bunker, at which time the batteries appear to have run out. Altitude information was not recorded. The recorded data allowed the track of the flight to be overlaid on a map (see Figure 1).

Accident site

The accident site was in an area of agricultural fields, woodlands, abandoned buildings and structures from a second world war military installation, the former RAF Dunkirk Chain Home Radar Station. There were also two tall radio masts, the tops of which are 686 ft amsl. The nearest of these two masts was approximately 200 m to the east of the flight path taken by the balloon. The accident site, which was about 340 ft amsl, was on the northern boundary of a medium sized hay field. To the north of the hay field was a large cattle grazing field in which were a number of individual substantial trees. The boundary between these two fields consisted of a substantial hedge/small tree row with an embedded post and wire fence. To the south-south-west of the accident site the land ascends to a ridge, the top of which is, on average, 370 ft amsl and 500 m distant from the accident site. The ridge was covered with trees that were 60 to 70 ft in height. To the north-north-east of the accident site the land descends, over a distance of 4 km, to the residential area of Chestfield which is on the outskirts of the Thames Estuary coastal town of Whitstable. Large areas to the east and north-east were heavily wooded.

Impact sequence and parameters

The first impact was between the long side of the balloon's burner frame and the upper north-west corner of an abandoned bunker. The corner of the building was about 230 m to the north-north-east from the top of

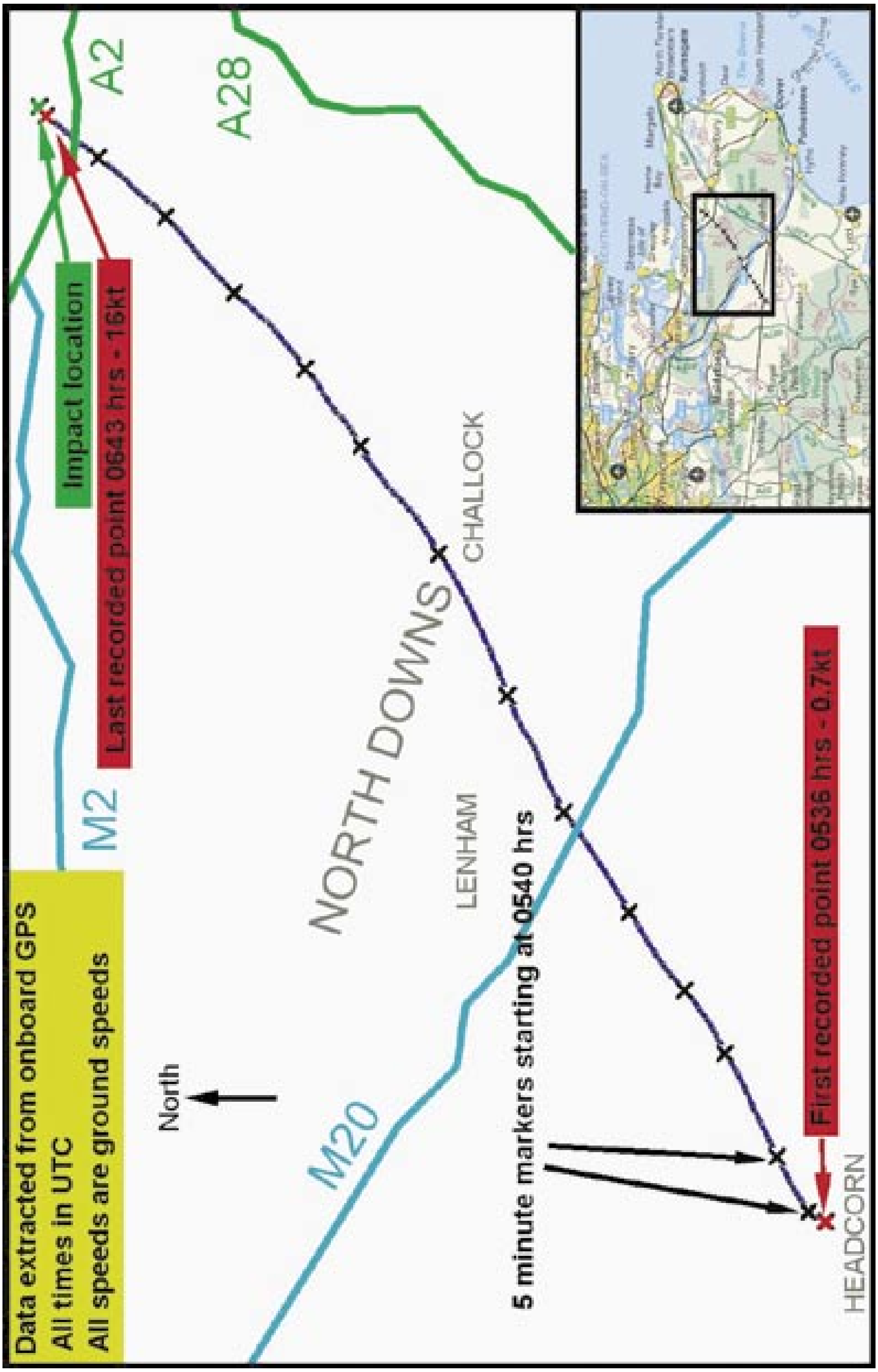


Figure 1

GPS recorded ground track.
(Accident to G-CDIN on 12 June 2005 at Dunkirk)

the ridge and 25 ft above ground level. At the time of this impact the balloon was travelling at approximately 20 mph, on a track of about 035ºM and descending at a rate in excess of 400 ft/min. Immediately following this impact a lower corner of the balloon's basket struck the top of a grass-covered solid embankment that was 2 m from and 8 ft below the corner of the bunker. After this second impact the basket slid in a north-north-easterly direction down the side of the embankment coming momentarily to rest in the side of an elderberry tree. Evidence from marks within the elderberry tree indicated that after momentarily coming to rest, the basket was pulled almost vertically upwards out of the tree's branches. After ascending from the elderberry tree the balloon continued to travel on a track of about 035ºM for approximately 210 m before the bottom of the basket impacted the ground in the hay field some 30 m south of the field's northern hedge with embedded fence boundary. The lower corners of the basket made further ground impacts within the hay field prior to it coming to rest in an upright attitude embedded in a small tree within the field's boundary hedge. The balloon's envelope draped itself over the top of the tree and into the next field to the north. The bottom of the basket came to rest about 6 to 12 inches above the ground.

Engineering examination

No disconnections or incorrect rigging of the balloon's envelope, basket or burner systems were found. A detailed inspection of the fabric of the balloon's envelope found two minor tears both of which showed good evidence of having occurred either during the impact with the elderberry tree and/or the tree in the hedge row. Sufficient fuel (gas) was found in the connected gas tanks for a further 15 to 20 minutes of flight. All three burners were tested using the gas contained within the connected tanks and found to function satisfactorily. The balloon's basket, which was of wicker construction, had suffered minimum damage during the ground impacts. The material and type of construction of the basket absorbed a large amount of the ground impact forces.

Operator information

The operator held an Air Operator's Certificate (AOC) issued by the Civil Aviation Authority. The company operated two balloons in the local area, flown from two different locations, and employed a full time Chief Pilot, who would normally pilot one balloon. If two balloons were scheduled to fly at the same time then a freelance pilot was employed. The Chief Pilot would normally be involved in pre-flight discussion and decisions on the suitability of the weather for both flights until each balloon was prepared for flight.

Analysis

The ideal conditions for balloon flights are smooth stable air with light winds. While conditions at surface level may be good, stronger winds at higher levels can give rise to steep wind gradients with associated turbulence. The direction of travel and distance covered by a balloon are also dependent upon the prevailing wind. Therefore an understanding of the winds above the surface is essential when planning a flight.

There are several difficulties when planning a balloon flight. The calmest conditions are usually found in the early morning and late evening. For a morning flight the conditions will tend to deteriorate as time passes because the air will be heated and mixed as the day progresses. Therefore, for a morning flight an early start is required but in order to be allow both passengers and crew to have a night's rest, a decision in principle regarding the flight has to be made some hours before the flight takes place. This means that the forecast also has to be obtained some hours before the flight with an associated reduction in accuracy. Thus there will be occasions when flights have to be cancelled in the morning even though all the passengers have arrived. Also, because the actual conditions may only become apparent or can change while a flight is in progress, there will be times when a pilot has to decide to land earlier than intended.

The pilot had access to a number of different sources of weather information, although it is not known precisely what information he did obtain. There were some differences between the different forecasts but the indication generally was there was a good chance of being able to fly in the morning. The decision to invite the passengers to fly was based on this information.

On the morning of the flight the surface winds were almost calm but the direction of drift was to the north, meaning that Leeds Castle, with the Downs rising nearby to the north, was not a good take-off site. The launch site was moved to Headcorn from where it was expected that a reasonable length of flight would be possible. The conditions for takeoff were good and it was only as the balloon climbed through 1,000 feet that the pilot realised that the wind direction did not favour a full one-hour flight.

The balloon's track, as shown in Figure 1, was initially about 060º and then later backed towards 040º. These tracks are not consistent with the commercial forecast issued the previous evening but they were reasonably consistent with the Met Office Ballooning forecast. They were also consistent with the observed northerly direction of travel of the weather balloons launched by the operator from Leeds Castle and Headcorn. However, the wind at 2,000 ft was stronger than any of the forecasts. The balloon was, therefore, taken more quickly than expected towards the North Downs. The pilot recognised this and hoped to land at Challock, an airfield just on the Downs. However he was not able to do so and as the balloon crossed over the 600 ft amsl ridge, the air would have become more mixed leading to the less calm conditions he experienced. Although he was searching and made several descents to a lower level, the pilot was not able to find a landing site. As the coast got nearer there would have been increasing pressure upon him to find a site and perhaps to accept a less favourable landing environment.

The accident site was close to the top of a small ridge which rises steeply to 400 ft and runs in a north-south direction. As the balloon came across the top of this ridge the pilot experienced a downdraft and although he tried to maintain his height by using all three burners, he was not able to prevent the impact with the concrete and brick bunker. By flying at a low height the balloon was particularly vulnerable to such local wind effects but balanced against that was the pilot's desire not to miss a suitable landing site. The pilot's dilemma had really arisen earlier when the balloon had crossed up and over the North Downs area.

After the impact with the bunker the pilot's main concern was to get the balloon down onto the ground as soon as he could and he used the ripcord to bring the balloon down quickly.

Safety action

Since the accident, the Operator has reviewed the suitability of its take-off sites for southerly wind conditions. The company is considering using sites further to the south in such conditions to reduce the possibility of inadvertently crossing over the North Downs.

Sources of meteorological information

The ballooning forecast includes a note which emphasises the need to consult other sources. In practice a number of different pages and charts may need to be viewed, all of which can be time consuming, particularly for those without high-speed internet access and printing facilities. It is possible that some pilots do not take enough trouble to collect the full information and rely principally on the 'ballooning forecast'. It would be helpful therefore if this forecast contained some additional information about the wind that could be expected in the lower levels.

The spot wind chart Form 214 is not optimised for ballooning but the AIRMET forecasts for the seven UK regions have regional wind information for the altitudes 1,000, 3,000 and 6,000 ft. These forecast winds could usefully be repeated in the ballooning forecasts. However, the UK CAA, which funds the forecasts, does not consider it appropriate to include only the wind information from the AIRMET forecast into the ballooning forecast. Consequently, balloon pilots may have to rely on the AIRMET forecast or on commercial sources for suitable low-altitude wind forecasts. The additional time incurred in downloading the AIRMET forecast is negligible.

ACCIDENT

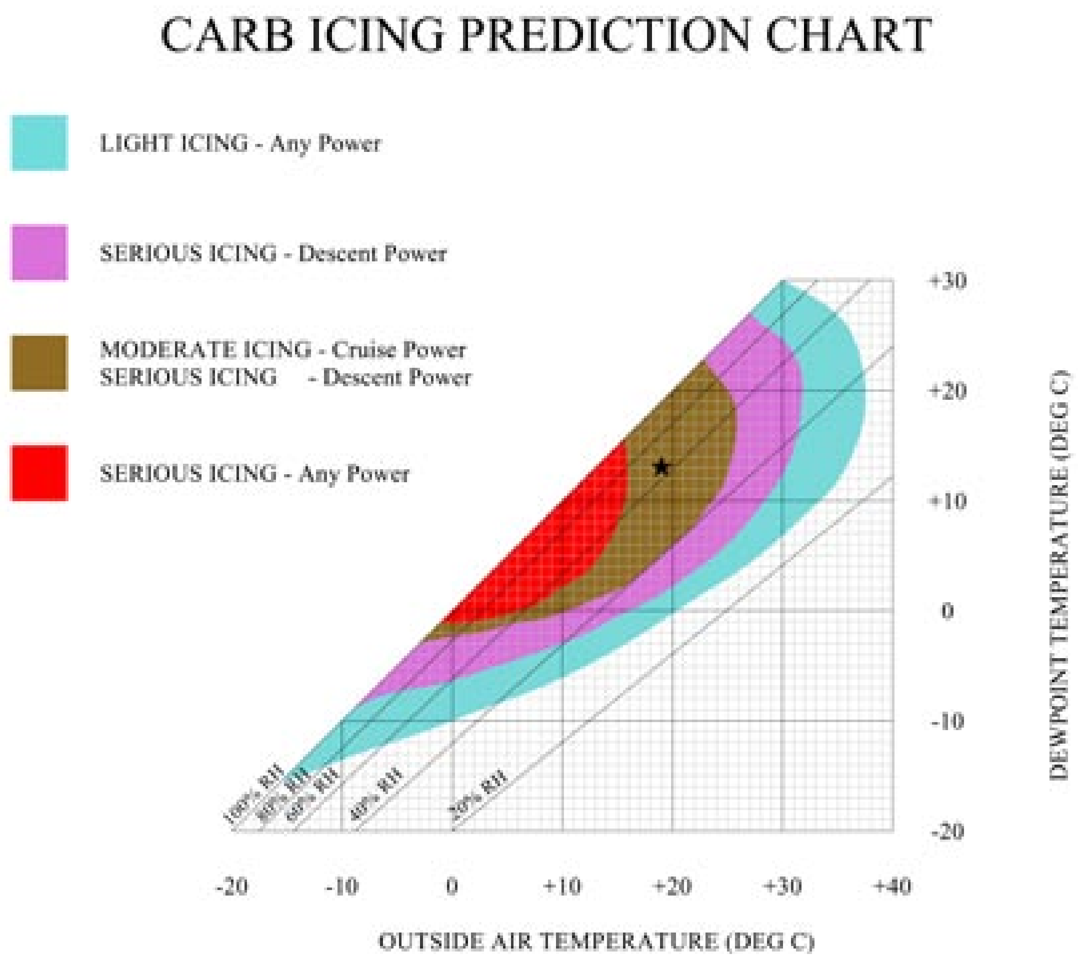
Aircraft Type and Registration:	Rans S6-ESD, G-MWTT
No & Type of Engines:	1 Rotax 503 piston engine
Category:	1.4
Year of Manufacture:	1991
Date & Time (UTC):	26 June 2005 at 1300 hrs
Location:	Insch, Aberdeenshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right wing damaged, nose landing gear collapsed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	260 hours (of which 150 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquires by AAIB

History of flight

Prior to the accident flight the aircraft had twice been flown earlier in the day with each flight lasting about one hour. The aircraft was then refuelled using three gallons of unleaded MOGAS, obtained from a local garage. Following a normal engine start the aircraft taxied out, took off and climbed away apparently normally. As it passed 300 ft, an uncommanded reduction in power occurred, coupled with a gentle turn to the right. An attempt was then made to restore engine power, but there was little response from the throttle. When it was moved back and then reapplied, the engine stopped. A forced landing was carried out in a field of long grass but, as the nose came down after the main wheels had touched, the nose gear collapsed. The pilot and his passenger, who were wearing lap strap and diagonal harnesses, exited the aircraft without injury.

Following the accident the propeller was free to turn and fuel was found in the float chamber of both carburettors. Also an inspection of the fuel filters showed them to clean.

The weather at the time of the accident was observed as being a wind of 5 kt from 135° with good visibility. The temperature was 19ºC with a dew point of 13ºC, and this placed the engine in the *'moderate icing at cruise power and serious icing at descent power'* area of the carburettor icing prediction chart.



The engine is due to be examined at a later date and, if a definitive cause of the failure becomes evident, this will be reported on in an addendum to this report in a future edition of the AAIB Bulletin.

BULLETIN CORRECTION

AAIB File:	**Ref: EW/C2004/02/06**
Aircraft Type and Registration:	Cessna F177RG Cardinal, G-TOTO
Date & Time (UTC):	9 February 2004 at 1205 hrs
Location:	Meppershall Airfield, Shefford, Bedfordshire
Information Source:	AAIB Field Investigation

AAIB Bulletin No 6/2005 page 32 refers

Figure 1, Diagram of the landing gear hydraulic and electrical system, is a very simplistic diagram and omits some very important electrical components and circuit wiring. As a result part of the second paragraph in the section headed '**The landing gear system'** is incorrect. Below is the amended paragraph with the corrected areas highlighted.

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

Following the aircraft's return to service the operator found that two identical items, one from each main landing gear, had not been fitted. These items, part number 2041030-6 are described as a shell and liner. Their purpose is to react the weight of the aircraft between the airframe and the main landing gears when the aircraft is on the ground. Without these items fitted the downlock latch pivot pin would react some of these forces for which it was not designed. It is possible that if these shells and liners were not fitted prior to the accident that the forces placed on the downlock pivot pins caused the initiation and propagation of the fatigue failures that were found.

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