ACCIDENT

Aircraft Type and Registration:	Piper PA-28R-201T, Turbo Cherokee Arrow III, G-JMTT
No & Type of Engines:	1 Continental TSIO-360-FB piston engine
Year of Manufacture:	1978
Date & Time (UTC):	9 April 2007 at approximately 1050 hrs
Location:	9 nm south of Oban (North Connel) Airport, Argyll and Butte, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - 2 (Fatal) Passengers -1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	324 hours (of which 43 were on type)[1] Last 90 days - unknown Last 28 days - 2 hours[2]
Information Source:	AAIB Field Investigation

Synopsis

The commander was planning to return to Andrewsfield Airfield, Essex, from Oban Airport after a weekend of touring with his family. The weather was poor and the commander (who was not IMC or instrument rated) said to the Air/Ground operator at Oban that he would depart "to have a look at the weather" and then return to Oban if it was not suitable. The aircraft departed Oban at 1035 hrs and the Air/Ground operator lost sight of it shortly thereafter due to the poor visibility as it headed west at approximately 1,000 ft amsl. The commander subsequently transmitted to Oban that he was changing to the en-route ATC frequency. Nothing was subsequently heard from the aircraft by any other ATC agency. The wreckage of the aircraft was discovered by a farmer the following day in the hills, 9 nm south of Oban Airfield. No technical fault with the aircraft was found apart from evidence of a pre-impact failure of the vacuum pump which would have caused the Attitude Indicator to become unreliable. The characteristics of the final flight path, particularly the high airspeed, the rapid descent and the rate of turn, were consistent with a loss of control following spatial disorientation in IMC. The vacuum

Footnote

[1] Hours on 13 September 2006 (last entry in the commander's logbook) plus 7 hours logged in the co-pilot's logbook which refer to him as the commander. This does not include his previous microlight flying or twin engine training, as noted, by him, at the beginning of his logbook.

[2] From aircraft log sheet.

pump failure, the commander's lack of instrument flying training and his apparent high blood alcohol level, all contributed to the spatial disorientation. This report contains four Safety Recommendations relating to the maintenance of vacuum pumps.

Background information

G-JMTT departed Andrewsfield Airfield, Essex, where it was based, for Oban (North Connel) Airport, Argyll and Butte, at 1155 hrs on Friday 6 April 2007, for a weekend of touring. On board were three occupants; a married couple and their daughter. The aircraft was owned by a syndicate of five people which included the father and daughter, both of whom were pilots. The father went away most Easter weekends in the aircraft and had reserved it, in the syndicates planning diary, several months in advance. Due to the father's greater flying experience and due to the fact that he was seated in the left seat, he was assumed, for the purposes of this investigation, to be the commander, and the daughter, in the right seat, to be either a passenger or acting to assist the commander. However, it had become the practice of these two pilots always to occupy the same seats, with the daughter sometimes being pilot-in-command whilst still occupying the right-hand seat. It is therefore not possible to state with certainty which of the two was in command, but throughout this report, for simplicity, the father will be referred to as the commander and the daughter the co-pilot. The mother occupied a seat in the rear of the aircraft. The occupants sat in these seats on all subsequent flights. The aircraft landed en-route at Blackpool Airport, Lancashire, at 1344 hrs for a refuelling stop and departed at 1451 hrs; it landed at Oban at 1630 hrs.

On 7 and 8 April 2007, G-JMTT and its three occupants flew out of and returned to Oban once per day. After landing on 8 April 2007, the aircraft was refuelled to full by the Air/Ground Operator (AGO), in preparation for its return journey the following day. That evening all three occupants went to dinner at a local hotel, where they were seen to consume alcohol.

History of the flight

On the following day, 9 April, the three occupants arrived at Oban at around 1000 hrs and were witnessed by the AGO to go straight to G-JMTT and load their luggage. They then went to the airfield's office where the AGO had obtained Met Forms 214[3] and 215[4] and the southern UK TAFs from Met Fax[5]. On reading the weather information, the commander noted that it was clearer in England and said in conversation with the AGO he was not instrument rated. The AGO did not ask if he had an IMC rating. He then said to the AGO that he would get airborne "to have a look at the weather" and if it was not suitable he would return to Oban. The AGO said that this would not be a problem and if they did so they would not incur any additional landing charges.

The Airport Manager and the AGO saw G-JMTT, start up, taxi out and observed an engine check being carried out before it took off at 1035 hrs. After takeoff, they saw it fly due west before losing sight of it in the poor visibility, at approximately 1,000 ft amsl. After approximately five minutes, the AGO received a transmission from the commander saying that they were at 1,500 ft amsl and were changing to the en-route frequency. The AGO gave them the

Footnote

[3] Met Form 214 is a spot wind chart showing wind speed and direction and temperature for standard levels up to FL240. It is updated four times a day.

[4] Met Form 215 is a low level weather chart and text showing a graphical display of areas of different weather up to FL100. It is updated four times a day.

[5] Met Fax is a service provided by the Met Office that allows the user to receive a copy of the latest aviation weather information direct to a fax machine.

appropriate Scottish ATC frequency and informed them that they were unlikely to receive a reply until they were further south; this was due to the high terrain. The commander acknowledged this but did not read back the frequency. Due to the AGO's concerns about the weather he phoned Scottish ATC, at approximately 1155 hrs, to enquire whether G-JMTT had made contact with them; it had not.

The commander had not filed a flight plan for the return flight to Andrewsfield, nor was he required to do so. The AGO believed that he was planning to stop at Blackpool for fuel, as he did on the outbound journey, but he had not booked to land at Blackpool, although this was required. The next day, 10 April 2007, at 1340 hrs, a farmer who was out in the hills above his farm came across the wreckage of an aircraft. He returned home and contacted the police who arrived at the scene at 1524 hrs. The wreckage was later confirmed to be that of G-JMTT.

Aircraft description

G-JMTT was an all-metal low-wing Piper PA-28R-201T aircraft (See Figure 1), powered by a single turbocharged Continental TSIO-360-FB piston engine and a two-bladed variable-pitch Hartzell propeller. It had retractable landing gear and was configured with four seats and dual flying controls in the front. It had a maximum takeoff weight of 2,900 lb and a published cruise speed of 147 kt at 6,000 feet with a power setting of 75%.

Figure 1

Piper PA-28R-201T, G-JMTT

G-JMTT was equipped with three gyroscopic instruments to assist with instrument flight: a vacuum-driven Attitude Indicator (AI), an electric Horizontal Situation Indicator (HSI), and an electric Turn Coordinator (all shown in Figure 2). The vacuum pressure to the AI was supplied by an engine-driven Parker Airborne 211CC vacuum pump. The level of suction supplied by the pump was indicated on a suction gauge located on the right side of the instrument panel (No 8 in Figure 2). A warning light on the upper left side of the instrument panel (No 7 in Figure 2) illuminated if the suction dropped below a level sufficient to operate the AI. An optional backup/auxiliary vacuum pump was not fitted to G-JMTT.

The aircraft was also fitted with a Century III autopilot which used the vacuum-driven AI as its attitude reference source. The autopilot (AP) had four modes: Roll, Heading, Altitude and Pitch. Altitude mode was a pitch mode that used the pressure from the altimeter to command the AP to maintain the pressure altitude at the time the mode was engaged. If the AI instrument failed and supplied erroneous attitude information to the AP, then the AP would not function correctly and would not be able to hold a heading or an altitude.

Aircraft operating weight

The basic weight of G-JMTT was 1,849 lb and the Maximum Takeoff Weight (MTOW) was 2,900 lb. The total useable fuel capacity was 72 US gallons which equates to 432 lb. The combined weight of the three occupants was approximately 672 lb. The personal belongings recovered by the police from the crash site weighed 128 lb. The aircraft departed Oban with full fuel so it therefore had an estimated takeoff weight of 3,081 lb which was 181 lb above the MTOW.

Figure 2

G-JMTT cockpit instrument panel before the accident

Instrument desciptions: (1) Airspeed Indicator; (2) AI; (3) Altimeter; (4) Turn Co-ordinator; (5) HSI; (6) Vertical Speed Indicator; (7) Vacuum pump pressure warning light; (8) Suction gauge

Maintenance history

The aircraft was maintained in accordance with the Light Aircraft Maintenance Schedule (LAMS). The aircraft's last maintenance was an annual inspection which was completed on 27 February 2007 when the aircraft had logged 3,474 hours. At the time of the accident the aircraft had logged approximately 3,490 hours and the engine 1,391 hours. The vacuum pump was installed on the engine on 2 June 1995 when the engine had logged 397 hours, so the pump had been in service for 11 years 10 months and had accumulated approximately 994 hours at the time of the accident.

Weather information

Aftercast

An aftercast was obtained from the Met Office. It stated that the synoptic situation at 1200 hrs on 9 April 2007 showed a warm front orientated north to south over western Scotland and into northern England. A generally fresh, westerly flow prevailed over the area. The front reached Oban at 1130 hrs and although weak was associated with outbreaks of slight rain and drizzle, from what was an extensive layer of cloud with a base that was variable but low. Rain and drizzle were, the report indicated, most likely over the mountains of Scotland, especially on windward (west facing) slopes. Below the cloud base, visibility would be reduced in precipitation and areas of mist. Hill fog would have been extensive in the region, especially on west facing slopes. In summary, the report stated that between 1000 hrs and 1200 hrs Oban would have experienced varying visibility in the range 4,000 metres to 10 km and greater. Hill fog would have been extensive over the surrounding hills, with visibility less than 200 metres. The cloud was likely to be scattered or broken stratus with a base varying from 400 ft to 1,500 ft, and a top of 2,000 ft with broken or overcast stratocumulus with a base varying from 2,000 ft to 3,000 ft, and top varying 5,000 ft to 7,000 ft, scattered or broken layers of altocumulus between 7,000 ft and 9,000 ft and little or no altocumulus in thin, well-separated layers between 9,000 ft and 20,000 ft. The mean sea level pressure was 1014 mb rising to 1015 mb during the period 1000 hrs to 1200 hrs in the Oban area. The 0º C isotherm was likely to have been at 5,900 ft. It is likely that airframe icing conditions existed in the height range 5,900 ft to 9,000 ft and possibly in the range 5,500 ft to 9,000 ft.

At 1000 hrs and 1100 hrs there were automatic reports from a station some three miles north-east of Oban. These reports indicated a light west-south-westerly flow, with temperature of 10º or 11º C, and dew point of 10º C. The temperature and dew point data are indicative of low cloud and/or mist conditions.

Oban (North Connel) Met information

There were no TAFs or METARs available for Oban. However, an observation was taken at 0930 hrs on 9 April 2006, by the AGO. This indicated that the surface wind was from 230º at 12 kt, the visibility was 7 km, there was no significant weather, although there had been recent rain and drizzle. There was scattered cloud at 500 ft aal and broken cloud at 1,000 ft aal. The temperature was 11º C and the mean sea level pressure (QNH) was 1015 mb.

Airfield information

Blackpool Airport

Blackpool Airport was operating as a 'Prior Permission Required' (PPR) airfield from 6 to 9 April 2007 due to forecast congestion over the Bank Holiday weekend and as such NOTAM number C1565/07 was issued. When the commander of G-JMTT requested permission to land at Blackpool on 6 April 2006, ATC asked him for his PPR number; he did not have one. ATC subsequently obtained one from the handling company and G-JMTT was given clearance to land. A PPR number for G-JMTT's return journey was not issued prior to it departing Oban.

Oban (North Connel) Airport

Oban was also a PPR airfield, and aircraft landing at Oban were required to give at least three hours notice. When G-JMTT landed at Oban on 6 April 2006, without such permission, the AGO raised the matter with the commander, who expressed surprise.

Visual Flight Rules

The rules for VFR flight in the UK are published in the UK Aeronautical Information Package, section ENR 1-2-1. It states:

'1 VFR Flight

VFR flights shall be conducted so that the aircraft is flown in conditions of visibility and distance from clouds equal to or greater than those specified in Table 1 below:

Table 1

Airspace Class	*F or G [uncontrolled airspace]*
Height	*Below FL 100*
Distance from cloud	*1500 m Horizontally and 1000 ft Vertically*
Flight visibility	*5 km (3)*

Notes:

(1) ***Or*** *if at 3000 ft or below and flying at 140 kt or less: Clear of Cloud and in Sight of the Surface.*

(3) ***Or*** *if at 3000 ft or below:*

either: *any aircraft flying at more than 140 kt: Clear of Cloud and in Sight of the Surface in a Flight Visibility of 5 km.*

> ***or:*** *any aircraft flying at 140 kt or less: Clear of Cloud and in Sight of the Surface in a Flight Visibility of 1500 m.'*

However, Part A, section 1, sub-section 1 to Schedule 8 of the Air Navigation Order states the following:

> *'Privileges:*
>
> *(1) Subject to paragraph (2), the holder of a Private Pilot's Licence (Aeroplanes) shall be entitled to fly as pilot in command or co-pilot of an aeroplane of any of the types or classes specified or otherwise falling within an aircraft rating included in the licence.*
>
> *(2) He shall not:*
>
> *(c) unless his licence includes an instrument rating (aeroplane) or an instrument meteorological conditions rating (aeroplanes), fly as pilot in command of such an aeroplane:*
>
> *(i) on a flight outside controlled airspace when the flight visibility is less than 3 km;*
>
> *(ii) on a special VFR flight in a control zone in a flight visibility of less than 10 km except on a route or in an aerodrome traffic zone notified for the purpose of this sub-paragraph; or*
>
> *(iii) out of sight of the surface;'*

Pilots' licences

Part of the Private Pilot's Licence (PPL) syllabus included an appreciation of instrument flying. During this element of the syllabus the student pilot has his external vision artificially restricted so as to simulate flying in IMC. During the PPL skills test, the pilot is required to demonstrate a rate 1 turn (3°/sec) through 180° using an appropriate angle of bank under simulated IMC, in order to show that he can safely regain Visual Meteorological Conditions (VMC) if he inadvertently encounters IMC.

Commander's licence

The commander gained his UK (PPL) on 10 March 1980 and it was valid for life. This permitted him to fly in VMC only. He had been observed flying in cloud, on occasions, by witnesses at Andrewsfield and with members of the syndicate.

The last entry in his logbook was 13 September 2006. However, after this date there were seven entries in the co-pilot's logbook that state the commander of these flights was the commander of the accident flight.

Co-pilot's licence

The co-pilot gained her JAR PPL on 4 October 2000; but, it was not renewed and expired on 3 October 2005. She renewed her Single Engine Piston (Land) rating on 23 July 2005 and this rating was then valid until 8 September 2007.

Prior to 2000 the CAA issued a UK PPL which was valid for life. In 2000 the CAA started issuing JAR PPLs which only had a five year validity. The CAA did not send out renewal reminders in 2005 to pilots who had obtained their JAR PPL in 2000. As a result, numerous pilots were later found to be flying on expired licences. In late 2006 the CAA started sending out renewal reminders to remedy this problem.

Medical information

Commander

The commander had held a JAA Class II medical certificate since March 1997. This carried a limitation requiring him to wear corrective lenses.

In December 2002, as a result of a heart condition, the commander was required to have an annual exercise Electrocardiogram (ECG). His last exercise ECG was in August 2005 and his Class II medical certificate was renewed on 1 November 2005. This expired on 1 November 2006. As he had not submitted a new exercise ECG he was declared medically unfit by the CAA on 15 January 2007. This was an administrative procedure that would highlight the fact that he had not done a recent exercise ECG if he applied for a new medical.

Co-pilot

The co-pilot held a valid JAA Class II medical certificate which was due to expire on 13 September 2010. This carried a limitation requiring her to wear corrective lenses.

Medical examination

Post-mortems were carried out on all three occupants by two Crown Office pathologists. They concluded that the cause of death was as a result of multiple injuries and the crash was not survivable.

Conclusive examinations for disease were not possible, but there were no obvious visible signs of disease affecting the occupants. Screening for drugs was negative in all three occupants: but both the commander and the co-pilot had positive readings for alcohol. The commander had a muscle alcohol concentration of 104 mg/100ml. The toxicologist regarded this as being equivalent to a blood alcohol concentration of 99 mg/100 ml. The co-pilot had a muscle alcohol concentration of 50 mg/100ml. The toxicologist regarded this as being equivalent to a blood alcohol concentration of 48 mg/100 ml. The pathologists and toxicologist could not entirely exclude the possibility that some of this alcohol may have been produced post-mortem as part of normal decomposition, although it was thought that this was unlikely to be a significant amount. The third occupant's muscle sample tested negative for alcohol.

Part 5 of the Railways and Transport Safety Act 2003, '*Aviation: Alcohol and Drugs*,' states the following in paragraph 93:

> *'Prescribed limit:*
>
> *(1) A person commits an offence if—*
>
> *(a) he performs an aviation function at a time when the proportion of alcohol in his breath, blood or urine exceeds the prescribed limit.'*

The prescribed blood alcohol limit is 20 mg/100 ml.

Alcohol and flying

Flying an aircraft is a highly demanding cognitive and psychomotor task that takes place in an inhospitable environment where pilots are exposed to various sources of stress. The majority of the adverse effects produced by alcohol relate to the brain, the eyes, and the inner ear, three crucial organs to a pilot.

It is advised to have a minimum gap of eight hours between consuming even a moderate amount of alcohol and flying. It is difficult to define a 'moderate' amount as individuals metabolise alcohol at different rates. However, it has been said that the average person metabolises one unit of alcohol every one to two hours, which suggests that any more than, for example, two pints of medium strength beer, ie four units, would perhaps require eight hours to metabolise out of the average person's system. Some people may be slower to metabolise the alcohol. This eight hours gap does not mean that a pilot would be in the best physical condition to fly, or that his blood alcohol concentration would necessarily be below the legal limits. A more conservative approach is to wait 24 hours from the last use of alcohol before flying and this is especially true if intoxication occurred. Folk-law cures such as cold showers, drinking black coffee or breathing 100% oxygen cannot speed up the elimination of alcohol from the body.

According to some studies, the number of serious errors committed by pilots dramatically increases at or above concentrations of 40 mg/100 ml blood alcohol. This is not to say that problems do not occur below this value. Some studies have shown decrements in pilot performance with blood alcohol concentrations as low as 25 mg/100 ml.[6]

Recorded data

The aircraft was not equipped with any crash protected recording devices, nor was it required to be so equipped. However, examination of installed equipment that has been damaged during an accident can yield some recorded information. The aircraft was fitted with a Garmin GNS 430 panel-mounted GPS unit. This unit has a moving-map display and a built-in communication and navigation radio. On examination, it was found that the internal battery that maintained the unit's memory had become detached during the accident, erasing the aircraft's last recorded position and last selected communication and navigation frequencies.

The aircraft was also tracked by the Lowther and Tiree radar installations.

There are two types of radar, primary and secondary. Primary radar detects the position of an aircraft by rapidly sending out pulses of radio waves through its rotating radar 'head' and processing the returned signals that have bounced back off aircraft. This gives distance and bearing of the aircraft from the radar installation, but no altitude information. Secondary radar works in a similar fashion but in this case the pulses of radio waves are actually communication messages that are being sent to equipment on the aircraft. The aircraft system responds to these messages by transmitting an assigned identity code and pressure altitude (if selected) in hundreds of feet back to the radar installation. Secondary radar provides distance and bearing information as well as aircraft identity and altitude but is reliant on the aircraft systems being operational. Secondary radar tracking can be lost if the aircraft suffers an electrical power failure, or the aircraft system is switched off, or if the aircraft attitude is such that there is no direct path between the radar head and the antenna on the underside of the aircraft.

Both Lowther and Tiree have primary and secondary radar heads. Due to the distance between the aircraft and these radar installations, combined with the terrain in between, the radar tracks do not cover the accident flight from beginning to end. Figure 3 shows the departure airfield, the radar tracks recorded by the Tiree and Lowther radar installations and the location of the accident site. It is worthy of note that the two tracks do not exactly coincide. This is an illustration of the magnitude of the random errors that are involved with radar returns when used at this very small scale, and shows why a detailed description of the manoeuvring of the aircraft from point to point would not be valid. Similarly, speed calculations derived from these points are prone to large errors. The strength of the radar data, when used at this very small scale, is in the motion trends.

Footnote

[6] Medical Facts for Pilots, FAA Publication AM-400-94/2 by Guillermo Salazar, M.D. and Melchor Antuñano, M.D.

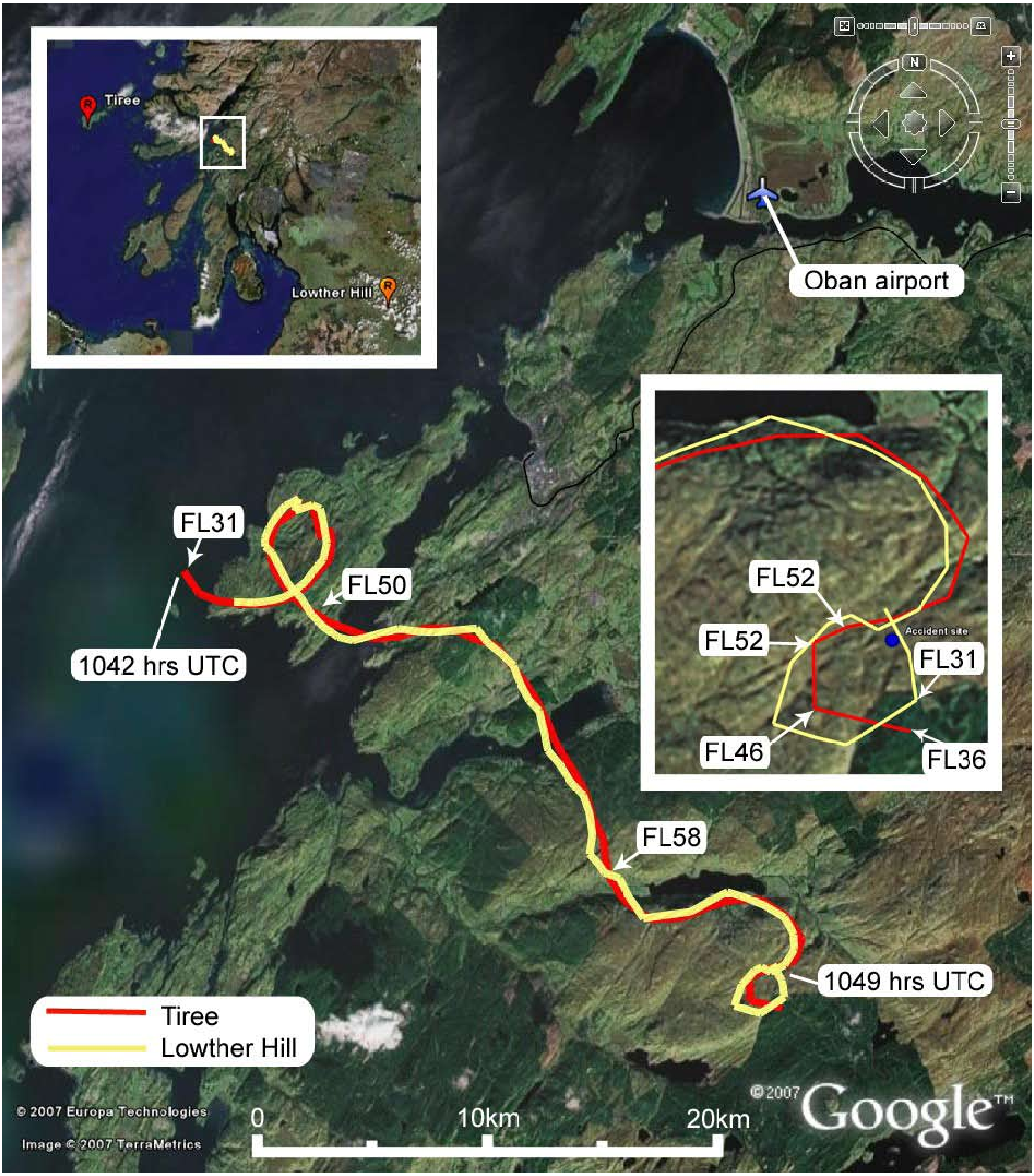

Figure 3

Overview of recorded radar tracks

Figure 4 shows the altitude data from secondary radar returns and the speed calculations derived from the positional information. All times quoted are in UTC, one hour behind the local time. All altitudes quoted are corrected for the air pressure at sea level of 1015 mb at the time but are only approximate due to the limited 100 ft resolution of radar altitude data. This gives altitude above the mean sea level (amsl) and not height above ground level.

The radar returns started at 1042 hrs with the aircraft approximately 7.5 nm south-west of Oban Airport. Terrain would have obscured any aircraft in the area between this first contact and Oban Airport below roughly 2,200 ft, with patchy coverage above this. The radar tracks showed the aircraft in a climbing left hand turn, passing through 3,300 ft. The aircraft did a complete circle over the Isle of Kerrera, 8 nm south-west of Oban, and then took a wandering path

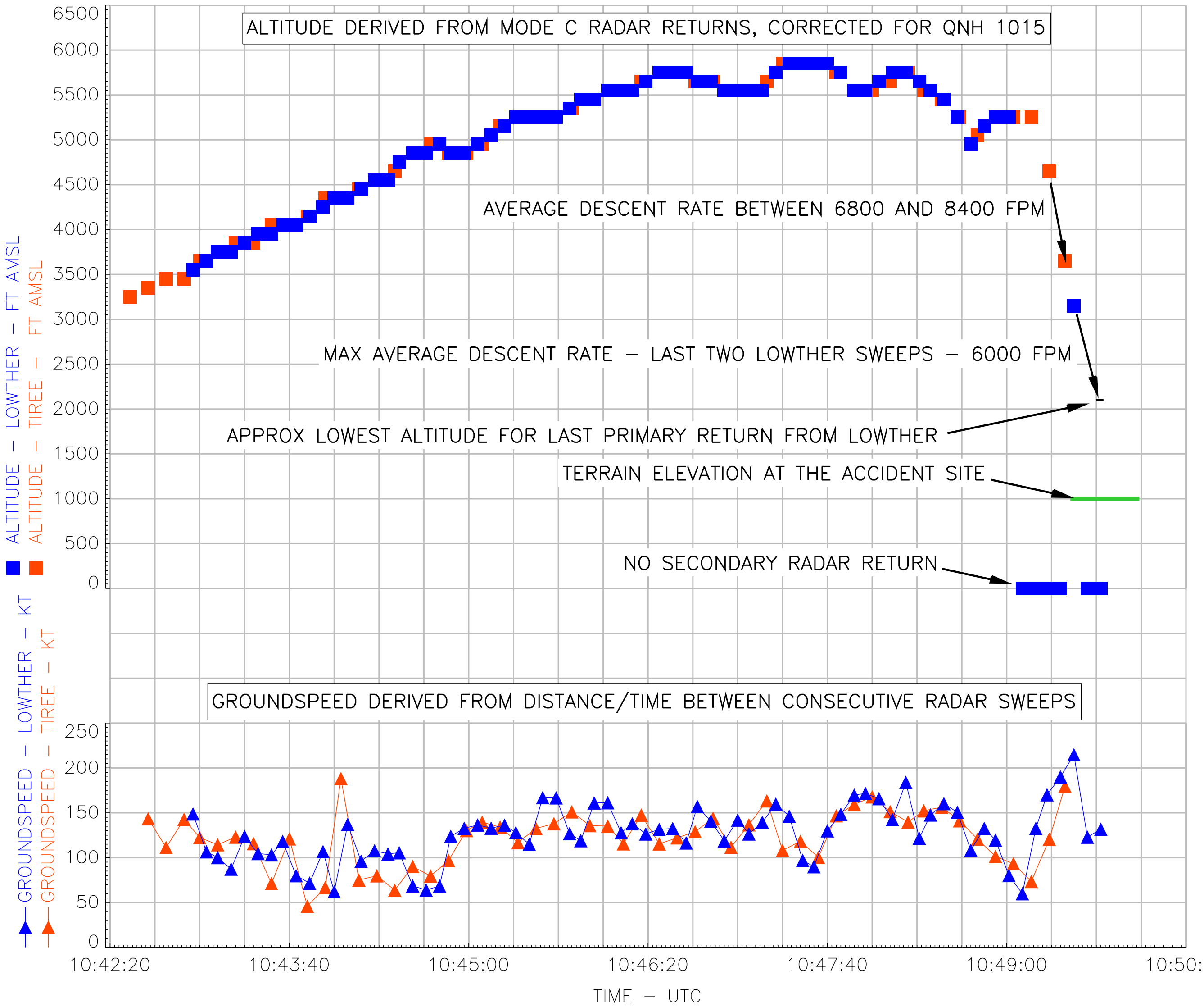

Figure 4

Altitude and time information for the Lowther and Tiree radar tracks centred on a south-easterly track, carrying on the climb to approximately 5,800 ft and then varying in altitude between 5,600 ft and 5,900 ft. At 1048 hrs the aircraft altitude reduced to 5,300 ft. The radii of the turns during the roughly south-easterly track had been reducing during the flight. Approximately 30 seconds after levelling at 5,300 ft the aircraft entered a left turn with a radius of approximately a quarter of a nautical mile. Tiree radar recorded that the altitude during this turn dropped from 5,300 ft to 4,700 ft and then to 3,700 ft in under 16 seconds, indicating an initial descent rate of between 3,800 and 5,300 feet per minute (ft/min), accelerating to between 6,800 and 8,400 ft/min. This altitude loss was during a period when Lowther had lost secondary radar tracking of the aircraft for over 23 seconds. Lowther secondary radar then picked up a final secondary return at approximately 3,200 ft, further round in the turn. This was followed by two primary returns, showing the aircraft tracking north before dropping off radar entirely at 1049 hrs. It is calculated that Lowther primary radar can detect aircraft down to approximately 2,100 ft at the last radar return point. This limits the altitude loss between the last secondary return and the last primary return, 11.6 seconds later, giving a maximum descent rate of 6000 ft/min. This shows a reduction in the descent rate just before the track was lost.

Again using the calculated 2,100 ft line of sight limit of Lowther Hill radar at the point when the track was lost, the aircraft had 1,100 ft or more further to descend before reaching the terrain. Also of note is that analysis of the accident site indicated a southerly track on impact. This would indicate that in the last 1,100 ft or so of flight the aircraft manoeuvred so as to carry out at least half a complete turn, possibly additional complete rotations, and end up 150 metres to 350 metres in the reverse direction of its last recorded track.

The availability of altitude information shows that there was electrical power available on the aircraft throughout at least the first half of the final turn and rapid descent manoeuvre. The combination of a good primary radar return but no secondary return from the same radar head, as was the case with the end of the Lowther Hill track, shows that the line of sight between the radar head and the aircraft was good and that there must be another explanation for the loss of the secondary radar return. The loss of secondary radar returns from one radar head when it is present from another radar head, as was the case just prior to the last valid secondary radar return recorded by Lowther Hill, shows that the loss is not associated with a problem with the aircraft transponder. This combination of good line of sight between radar and aircraft and an operational transponder on the aircraft, may indicate that the attitude of the aircraft hid the aircraft secondary radar transponder antenna from the Lowther Hill radar installations. This can be accomplished by presenting more than usual of the top of the aircraft to the radar. This is indicative of a pitch and roll attitude that is normally only encountered during high speed turns or unusually high pitch attitudes climbing away from the radar or large nose-down attitudes in descent towards the radar.

In summary, the radar data shows the aircraft climbing to, and holding, a relatively stable cruise altitude but with no set direction. Turns were initiated, culminating in a relatively tight turn associated with a large descent rate and unusual aircraft attitudes. Electrical power was available at least until nearly the end of the last recorded turn, well after the tight descending turn was initiated. Given the location of the end of the radar track relative to the accident site location and disparity between the direction of the last recorded track and the estimated impact direction at the accident site, the aircraft carried out at least one further half turn between loss of the radar track and impact. It is also possible that it carried out further complete turns or other manoeuvres below radar coverage. The time between the loss of radar track information and impact is not known.

Accident site and wreckage examination

The aircraft crashed on a hillside near Bragleenmore Farm, approximately 9 nm south of Oban Airport. The accident site elevation was 963 feet on undulating terrain with a nearby hill with a peak of 1,433 feet. The initial impact crater was consistent with the aircraft having made a high speed nose-down impact with a slight right bank. The fuselage had suffered severe disruption at initial impact and remnants of the cockpit and the engine travelled a further 32 metres before coming to rest. The wreckage field extended for a maximum distance of 95 metres with the lighter objects having travelled furthest, angled eastwards in the direction of the surface wind at the time. The aircraft's direction of travel at impact, as estimated from the line of travel of the major wreckage, was 178°(M). The features of the wreckage site were consistent with an aircraft impact speed of between 140 and 200 kt with a descent rate significantly more than a normal approach rate of descent for landing.

Both wings had sheared off at the fuselage and the wing fuel tanks were completely disrupted resulting in a loss of all remaining fuel. The engine had separated from its mounts and the propeller had also separated from its crankshaft flange. All major aircraft components were accounted for and there was no evidence of any pre-impact separation.

Following the on-site examination, the aircraft wreckage was recovered from the hillside and transported to the AAIB's facility at Farnborough for a more detailed examination.

Detailed wreckage examination

Flight controls

The roll controls on this aircraft type consist of two control wheels that are connected to each other and control the aileron positions through a series of torque tubes, sprockets, chains, control cables, pulleys and bell cranks. Pitch control is via an all-moving stabilator connected to the control columns through a series of cables, pulleys and push-pull rods. There were numerous separations within both of these control systems but all were attributable to overload failures which were consistent with the airframe break-up. There was no evidence of a pre-impact disconnection. The rudder is controlled by two cables connected directly to the rudder pedals. Both cables and their attachment points were intact. The stabilator trim barrel was found in a position corresponding to 0.6° of nosedown trim. The rudder trim assembly was found in a position corresponding to 1.5° of right rudder trim. Disruption to the mechanical flap control system precluded a determination of the flap position at impact.

Instruments

The flight instruments were all severely damaged and most of the instrument faces had separated from their casings. The main altimeter subscale indicated a pressure setting of between 1013 and 1014 mb. The standby altimeter subscale indicated a pressure setting of approximately 1017 mb. Both of these settings were close to the reported aftercast pressure settings of between 1014 and 1015 mb for the time of the accident. The instrument faces were examined for witness marks that might indicate any pre-impact readings but no reliable witness marks were found. The AI had broken up and dislodged the gyroscopic rotor from its housing. The rotor did not exhibit any evidence of rotational scoring, but the rotor housing had a helical score around its inner circumference that could have been caused by the rotor during the instrument break-up while the rotor was still spinning. The warning lights, including the vacuum pressure warning light, were examined but all the bulbs had broken and there were no remaining tungsten filaments, so a determination of pre-impact illumination could not be made.

Other component examinations

The throttle, propeller and mixture control levers were all bent and in the near forward position, but the disruption and damage to the throttle quadrant made these unreliable as indications of their pre-impact positions. The magneto switch was set to BOTH and the key had broken off. The autopilot control panel and computer were too severely damaged to enable testing to be carried out. The electrical wiring was examined and there was no evidence of any significant non-impact related short-circuits. The pitot tube hole was clear and the pitot heat wires were securely connected to the tube. The pitot heat switch was damaged preventing its position from being determined. The static port was clear, but the pitot-static plumbing system was too severely disrupted to enable any further examination. The plumbing for the fuel system was also severely disrupted; the fuel lines had broken into multiple pieces. The fuel tanks had also broken into several pieces. The fuel drains were in the closed position and the fuel filler cap seals were in a satisfactory condition. The throttle body fuel control unit had shattered into multiple pieces so no fuel samples were recovered.

Powerplant examination

The engine was taken to an approved overhaul facility for a strip examination. It had suffered significant impact damage, including partial separation of the oil sump and separation of the No 6 cylinder head from the cylinder barrel. The engine accessories also had varying degrees of impact damage and had all separated from the engine accessory gearbox. The propeller governor and turbocharger had also separated from the engine. The engine could be rotated freely by hand once a fractured part of the engine crankcase was pulled away from the internal counterweight. The engine was sufficiently lubricated and there was no evidence of any pre-impact mechanical failure or evidence of overheating. The spark plugs were in satisfactory condition. One magneto was too severely damaged to be tested, but the other one was rig-tested and operated normally. The turbocharger driveshaft rotated freely. The only anomalies uncovered during the engine examination were the damaged and twisted base packing seals from the No 3 and No 5 cylinders. However, the worst case effect of this would have been minor oil leaks, but none had been reported.

The propeller assembly and the crankshaft propeller flange had separated from the engine. Both propeller blades were free to rotate within the hub due to impact failure of the pitch control links. As a result, both blades had rotated approximately 180 degrees within the hub. Propeller blade No 1 was bent aft near the shank and bent forward approximately 8 inches from the tip. Blade No 2 was bent aft from the shank to the tip. It also had deep leading edge gouges, whereas blade No 1 did not. Blade No 2 had some chordwise scratches between the mid-section and the tip, although it also exhibited roughly similar lengthwise and multidirectional scratches. The propeller hub was disassembled and compression damage on one side of each blade's preload plate was observed; this was very pronounced on the No 2 blade. The preload plates were sent to the propeller manufacturer for examination. The propeller manufacturer reported that no reliable pre-impact blade angle could be determined from the numerous witness marks on the preload plates.

The crankshaft and separated crankshaft flange exhibited evidence of tensile failure over approximately half the circumference and compression failure over the other half of the circumference. There were also cracks in the nitrided layer on the tensile side of the base of the flange. These were predominantly parallel, occasionally somewhat spiral in nature, and extended well into the flange itself.

Vacuum pump examination

The Parker Airborne 211CC vacuum pump fitted to G-JMTT was examined by the AAIB and then separately by the component manufacturer. A component diagram of the pump is shown in Figure 5. The pump is driven directly by the engine's accessory gearbox which, through a drive coupling, turns a carbon rotor with carbon vanes that slide in and out by centrifugal force. A photograph of the rotor and vane assembly is shown in Figure 6. The rotor and vane assembly of the pump from G-JMTT had shattered into multiple pieces (see Figure 6). It was important to determine if the rotor had broken while the aircraft was in the air or as a result of ground impact. The rotor is driven by a metal shaft assembly which connects to a plastic coupling which is connected to a

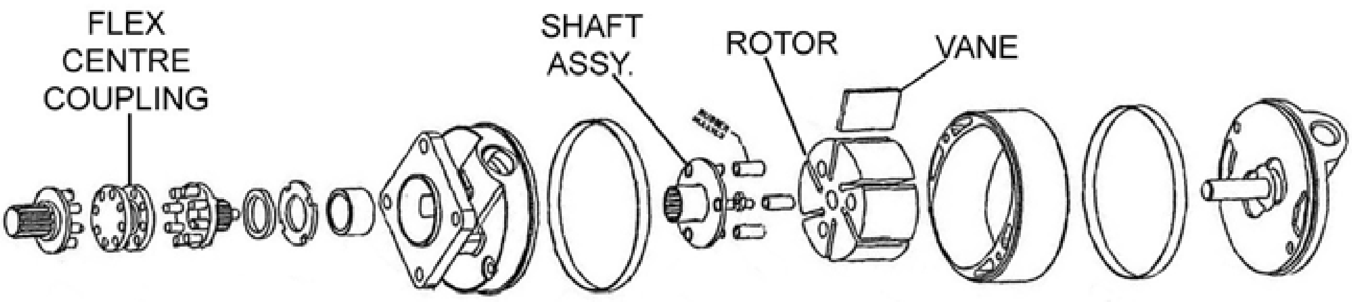

Figure 5

Parker Airborne 211CC Vacuum pump component layout

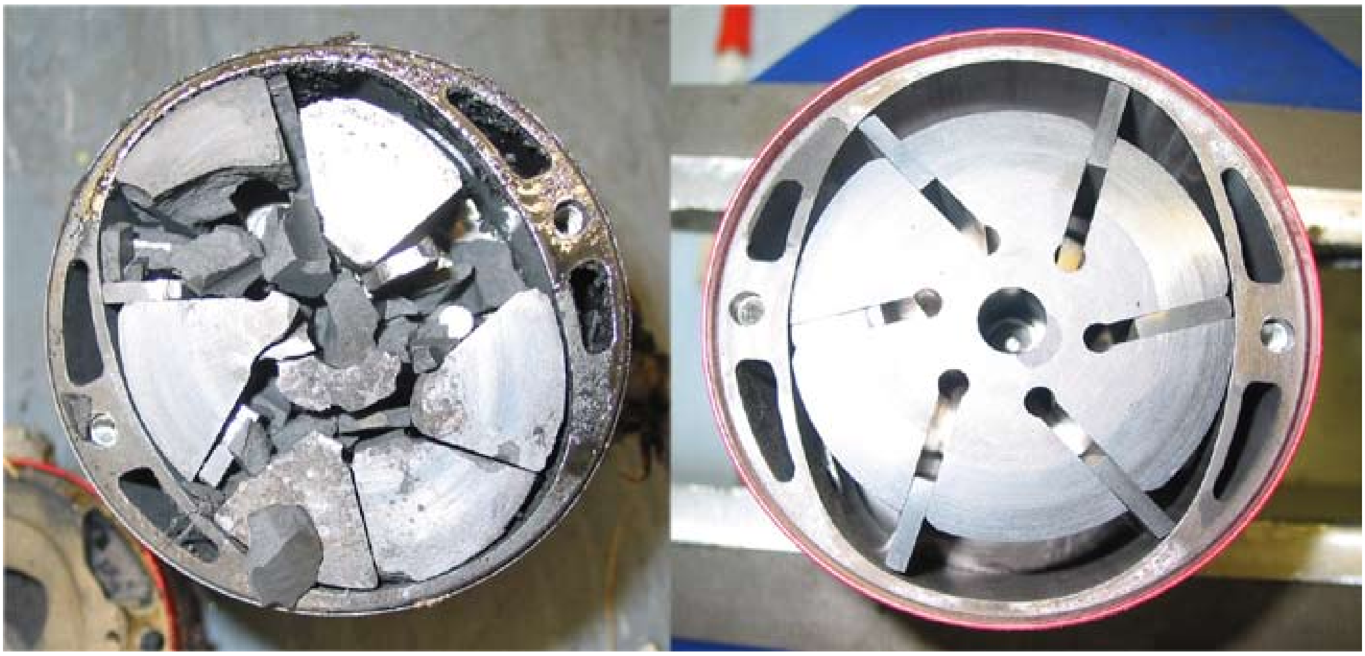

Figure 6

Damaged vacuum pump rotor and vanes from G-JMTT on left; intact version on right plastic flex centre coupling. This flex centre coupling serves two purposes: first, it absorbs torsional vibrations from the accessory gearbox drive and second, it contains a necked-down centre diameter which works as a shear point to prevent engine damage in the case of a pump failure. The flex centre coupling in G-JMTT's vacuum pump had fractured at the midpoint of its shear section due to torsional overload (see Figure 7). This can occur as a result of impact; however, both fracture faces had rub marks which indicated continued rotation of the engine-driven end after the coupling fractured (see Figure 8). The component manufacturer concluded that this rotational rubbing of the fracture surface indicated that the coupling fractured some time prior to impact, possibly even before the accident flight.

Figure 7

Fractured flex centre coupling from G-JMTT's vacuum pump

Figure 8

Rub mark on one of the fracture faces of the flex centre coupling

The vacuum pump examination also revealed that there was significant carbon/fluid streaking emanating from the shaft assembly. The carbon bearing, rotor and vanes generate carbon dust particles as they wear. The component manufacturer reported that when liquids such as engine oil or engine cleaning liquids mix with the carbon dust, they create a thick slurry which increases friction leading to premature failure of the air pump. Some causes of liquid contamination are a leaking accessory drive pad seal or engine cleaning liquid being sprayed onto an unprotected air pump.

Only part of the pump's serial number was still visible, revealing the letters '10AK'. '10' represents the month of manufacture, October, and 'AK' represents the year of manufacture, 1994. The flex centre coupling was also date-stamped '1994'. The maintenance records revealed that a vacuum pump with serial number 10AK4837 was fitted to G-JMTT's engine on 2 June 1995, so, this is probably the same vacuum pump and it had logged approximately 994 hours at the time of the accident.

Effect of vacuum pump failure

On G-JMTT the vacuum pump was used solely to supply vacuum pressure to operate the AI. Insufficient vacuum or no vacuum will result in the gyro rotor within the AI slowing down. As the gyro slows it will lose its gyroscopic rigidity and start to topple. As this happens the attitude indication, as shown by the picture of the artificial horizon on the instrument face, will start to give false indications of pitch and roll. If the autopilot was engaged it would follow these false readings. A sudden vacuum pump failure will result in an immediate loss of vacuum pressure but minutes could pass before the AI gyro has slowed sufficiently to start giving erroneous indications. The loss of vacuum pressure should, however, be apparent to the pilot by a zero reading on the suction gauge and illumination of the vacuum pressure failure light.

Previous accidents involving vacuum system failures

A search of the AAIB's database did not reveal any accident reports relating to vacuum system failures. However, a search of the NTSB[7]'s database revealed 62 accident/incidents between 1982 and June 2007 in which the vacuum system was listed among the causal factors. Of these 62 accidents/incidents, 40 were listed as severity 'Fatal'. In many of these accidents, the pilot reported loss of vacuum pressure over the radio before losing control in IMC conditions.

Maintenance requirements for vacuum pumps

Aircraft and equipment manufacturers sometimes identify items of service information, such as a Service Bulletin or a Service Letter, as either 'Optional' or 'Mandatory'. This judgement, by the manufacturer, is not necessarily agreed or endorsed by the National Airworthiness Authority where the aircraft is registered. The UK CAA has stated that there are some circumstances when such service information is deemed mandatory by association. This is the case when an Airworthiness Directive (AD) makes reference to such a Service Bulletin or Service Letter as being the means of compliance with the AD. The CAA takes the view that, even bearing in mind any other statements or comments, only service information supported by an AD is mandatory.

The aircraft was maintained in accordance with the LAMS which states in item 7 of section 3:

> *'Overhaul, additional inspections and test periods shall be those recommended by the organisation responsible for the type design.'*[8]

Footnote

7 NTSB is the National Transportation Safety Board of the U.S.A.

8 Light Aircraft Maintenance Schedule (LAMS) – Aeroplanes, CAP 411, Issue 2.

The aircraft manufacturer was responsible for the type design and its service manual for the Arrow III lists under the 1,000 hour Inspection period[9]:

> *'Replace engine or electrically driven vacuum pump(s) (Read Note(s) 5 and 25).'*

Note 5 differs slightly from this in that it states:

> *'Replace as required or at engine overhaul'.*

Note 25 refers to a 500 hour replacement time for the auxiliary electric backup vacuum system, but this was not relevant to G-JMTT as no backup system was fitted. The Arrow III service manual also contains a statement in Note 28:

> *'When servicing or inspecting vendor equipment installed in Piper aircraft, it is the user's responsibility to refer to the applicable vendor service publications.'*

The vacuum pump is considered to be vendor equipment.

The vacuum pump manufacturer published Service Letter (SL) 58 on 31 May 2002 (now superseded by SL 58A dated 23 March 2006) which listed 'mandatory' replacement times for Airborne air pumps[10]. The Service Letter, under the heading *'Background'*, stated that:

> *'in the absence of air pump mandatory replacement times provided by Airframe Manufacturers, Airborne is providing these mandatory replacement times'. This could be interpreted to mean that the Service Letter was only applicable if the airframe manufacturer had not provided replacement requirements, which was not the case. However, under the heading 'Compliance' it then stated 'Airborne air pumps must not be operated beyond the Airframe Manufacturer's specification for mandatory inspection intervals or mandatory replacement times or Airborne's mandatory inspection intervals or mandatory replacement times, whichever comes first.' Thus the intention of the Service Letter was that when the airframe manufacturer provides replacement times, the most restrictive requirement should apply. The 'mandatory' replacement for the air pump model 211CC was listed in the Airborne Service Letter as '500 aircraft hours or 6 years from date of manufacture, whichever comes first.' The underlining is as contained in the Service Letter.'*

The CAA did not make this Service Letter mandatory by issuing an AD, but required aircraft owners to assess, and where appropriate, comply with the maintenance instructions from the type design holder. The CAA stated to the AAIB that on the basis of Note 28 in the Arrow III service manual it is the responsibility of the aircraft's owner to be aware of publications relating to components and therefore to be aware of and comply with the vacuum pump manufacturer's Service Letter 58A. Therefore, the vacuum pump on the Arrow III should be tracked in the '*Time limited task and component change record*' document (CAP 543). However, this was not done by the owners or by any of

Footnote

9 Piper Service Manual for PA-28R-201/201T (part No 761 639), publication date 27 February 2004.

10 There are no significant differences between Service Letter 58 and Service Letter 58A. An electronic copy of Service Letter 58A can be obtained at http://www.parker.com/literature/Literature%20Files/ag/NAD/pdf/Service%20Letters/SL-58A.pdf

the maintenance organisations[11] of G-JMTT. The AAIB ascertained that other maintenance organisations were also unaware of Service Letter 58A. Further, some vacuum pump suppliers, who would normally supply such information to their customers, were also unaware of the Service Letter.

The maintenance manual for a '*New Piper Aircraft*' PA-28R-201 Arrow[12] (aircraft with serial numbers 2844001 and up) lists a Special Inspection for aircraft fitted with Airborne Dry Air Pumps to have the engine-driven vacuum pump replaced after 500 hours. This instruction is in line with the 500 hour requirement in Service Letter 58A.

The FAA issued a Special Airworthiness Information Bulletin (SAIB, CE-05-15) on 10 November 2004 advising registered owners of single or multi-engine piston aircraft of the need to maintain pneumatic system components that power air-driven gyro instruments properly. In this SAIB the FAA highly recommends that:

> *'if Parker Hannifin-Airborne Division air pumps and other components used in pneumatic systems that power air-driven gyro instruments are installed in your airplane, then you should follow the applicable Airborne maintenance, inspection, and replacement instructions.'*

The CAA stated to the AAIB that they concur with this recommendation.

Footnote

11 The aircraft had been maintained by the current maintenance organisation since 2006; there had been three other maintenance organisations involved since 2002. The vacuum pump life limits had been introduced in 2002 and should have been tracked in the aircraft records from that time.

12 Piper Airplane Maintenance Manual for PA-28R-201 (Part No 761-895), publication date 21 December 2005.

Search and rescue

On the morning of 10 April 2006, one of the syndicate members became concerned as he was unable to contact the commander on his mobile phone. Having got the takeoff time for G-JMTT from the Airport Manger at Oban he telephoned the commander's office to see if he had left any message. They informed him that they had not heard from him but they were expecting him in for a meeting at 0900 hrs. The syndicate member then telephoned Andrewsfield to see if they had heard from G-JMTT; they had heard nothing. He then telephoned the Distress and Diversion (D and D) cell at West Drayton, Middlesex and informed them that G-JMTT was overdue and they informed Scottish D and D at Prestwick; who instigated full overdue action at 1408 hrs.

At 1450 hrs D and D received a telephone call saying that wreckage had been found 9 nm south of Oban. As a result the search was called off.

Analysis

Conduct of the flight

The commander had been declared medically unfit by the CAA prior to the accident, and therefore was not entitled to exercise the privileges of his licence. The co-pilot's licence had expired, but as she had renewed her skills test it is likely that this was an oversight on her part. This was an oversight which was made by a number of other pilots at about that time, in part due to the change from CAA to JAA licences in the year 2000. The pilots flew in weather that was outside the privileges of their licences and no prior permission was obtained for either the landing at Blackpool or at Oban. Furthermore, the aircraft appears to have taken off from Oban 181 lb in excess of its MTOW.

The weather at takeoff and the forecast for the first part of the flight over south-western Scotland was not suitable for the intended Visual Flight Rules (VFR) flight. It is possible that the aircraft climbed in a hole in the cloud over the Isle of Kerrera. Once the aircraft had climbed to height the pilots would not have been able to keep in sight of the surface, as the privileges of their licences required them to do.

It is unlikely that the aircraft was unduly affected by airframe icing as it was above the forecast icing level of 5,500 feet for less than 2 minutes and 30 seconds.

It is not possible to determine whether the autopilot was engaged during the flight; however, whether it was or not, the inaccurate attitude information provided by the AI would have adversely affected the ability of the pilot, or the autopilot, to control the aircraft. G-JMTT appears to be under reasonably precise control until the last left turn, which is relatively rapid and where the aircraft starts to descend. The loss of secondary radar returns, during the final moments of the flight, could have been as a result of the aircraft being in an unusual attitude. This also suggests that control of the aircraft had been lost.

Accident site and wreckage examination

The accident site and wreckage spread were consistent with a high-speed nose-down impact. It was not characteristic of an attempted landing. There was some evidence, from the estimated impact attitude and impact flight path angle, that the pilot may have been trying to regain level flight shortly before impact occurred.

There was no evidence of a pre-impact structural failure or a pre-impact problem with the flight controls. It is likely that there was adequate fuel on board, and the engine examination did not reveal any anomalies that would have affected its operation. There was evidence that the propeller had detached from the engine due to a bending load applied to the crankshaft in the initial impact. The propeller exhibited insufficient evidence of rotational energy for the investigation to eliminate engine failure, but an engine failure would not have directly resulted in a loss of control. From an altitude of 5,000 ft the aircraft could have glided a distance of approximately 6 nm down to 1,000 ft, at a moderate descent rate of 1,000 ft/min. Thus the only evidence found during the wreckage examination that could have directly contributed to the loss of control was the evidence from the failed vacuum pump.

Vacuum pump failure

The vacuum pump manufacturer determined that the rub marks on the fracture faces of the flex centre coupling indicated that the fracture had occurred prior to impact while the engine was still turning. The failure could have been triggered by a worn vane that broke or as a result of excessive friction build-up from the liquid contamination, or a combination of both. The source of the liquid contamination could not be determined, but the vacuum pump had been in use for more than 11 years and for approximately 994 hours, well in excess of the 6 year and 500 hour time limits mandated by the pump manufacturer in their Service Letter 58A.

The aircraft owners and several aircraft maintenance organisations were not aware of Service Letter 58A, which was not mandated by an Airworthiness Directive. The instructions for vacuum pump replacement in the Arrow III service manual were open to interpretation and not consistent with SL 58A. One interpretation of the text in the manual was that the engine-driven vacuum pump should be replaced at the 1,000 hour inspection period. However, Note 5 states that it can be replaced as required or at engine overhaul. The Parker Airborne 211CC vacuum pump cannot be inspected for wear without disassembling it and this is not permitted in the field. An external visual inspection of the pump would not reveal that a pump was close to failing. Therefore, the only safe solution, particularly if the aircraft is to be operated in IMC and there is no backup system, is to comply with the limits specified in SL 58A. The AAIB therefore recommends that:

Safety Recommendation 2007-002

The Civil Aviation Authority should publicise the vacuum pump replacement requirements in Parker Airborne Service Letter 58A and recommend that operators and maintainers of such aircraft which will be operated under Instrument Flight Rules, comply with the limits specified therein.

The CAA has advised that the existing requirements contained in the Light Aircraft Maintenance Programme and in the Light Aircraft Maintenance Schedule will be publicised in a Letter to Owners/Operators and by an article in an issue of the General Aviation Safety Information Leaflet (GASIL).

The aircraft manufacturer has published a 500 hr limit for Airborne vacuum pumps in its *New Piper Aircraft* Arrow Service Manual. It has not retrospectively applied this limit to older Arrow aircraft. However, the same type of Airborne vacuum pump could be fitted to both. The vacuum pumps should be treated the same, regardless of which aircraft type they are fitted to. The AAIB therefore recommends that:

Safety Recommendation 2007-003

The New Piper Aircraft Company should revise their maintenance manuals to ensure that the maintenance requirements for vacuum pumps are consistent across their product range.

The problem of inconsistent or inadequate maintenance requirements for vacuum pumps could apply to other aircraft manufacturers. The AI is the primary instrument for safe flight in IMC. When the AI is vacuum-driven the vacuum pump becomes an important component for safe flight in IMC. Therefore, all aircraft manufacturers should evaluate the maintenance and replacement instructions recommended by vacuum pump manufacturers, and then incorporate these requirements in the aircraft's maintenance manual. The AAIB therefore makes the following Safety Recommendations to EASA and the US FAA:

Safety Recommendation 2007-004

The European Aviation Safety Agency (EASA) should mandate compliance with vacuum pump maintenance and replacement requirements, to ensure that aircraft fitted with vacuum-driven Attitude Indicators can be safely operated in Instrument Meteorological Conditions when such aircraft are certified to do so.

Safety Recommendation 2007-005

The US Federal Aviation Administration (FAA) should mandate compliance with vacuum pump maintenance and replacement requirements, to ensure that aircraft fitted with vacuum-driven Attitude Indicators can be safely operated in Instrument Meteorological Conditions when such aircraft are certified to do so.

Spatial disorientation

From the aftercast it is possible that the pilots were flying between layers of cloud. If they were flying in cloud it would have been necessary for them to fly by sole reference to the flight instruments. Although the pilots had received basic instrument flying familiarisation training, their experience level made it unlikely that they would have been able to control the aircraft accurately in IMC for any length of time.

With the absence of outside visual references, physical sensations can produce compelling perceptions of the aircraft's attitude and manoeuvres that differ markedly from those indicated by the flight instruments and spatial disorientation can occur. This tends to be more likely when recent and/or total instrument flying experience is low and in a high stress situation, or with alcohol in the pilot's blood.

One type of vestibular illusion, commonly known as the 'leans', is where the pilot may have a conscious knowledge of his genuine orientation from his instruments or the outside world, yet retains a very compelling false feeling of leaning for a considerable time. If there are no instruments to give the pilot any visual input, the aircraft could easily enter a turn that develops into a spiral dive and accelerates, as seen in the final moments of the radar returns.

Alcohol was measured in the pilots' muscle at a level which would be significantly in excess of the equivalent blood levels stipulated in the Railways and Transport Safety Act 2003. Whilst the toxicologist and pathologists accepted that some of the alcohol detected may have been produced post-mortem, they believed it was unlikely to be a significant amount, especially as the third occupant exhibited no evidence of alcohol. If these levels genuinely reflect the amount of alcohol present in the blood at the time of the accident, it is possible that they may have produced some decrement in performance which may have been prejudicial to the safe conduct of the flight.

While it is not known when the vacuum pump failed, the effects of the failure probably started to manifest themselves with erroneous AI indications just before the aircraft entered the left turn, approximately 24 seconds before the radar track was lost.

The circumstances of the accident to G-JMTT could alternatively be explained by some form of brief and temporary incapacitation of the pilot, brought on by a medical or toxicological symptom, without this necessarily leaving any evidence. Due to the disruptive nature of the impact it was not possible to tell if there was any medical reason, in the form of disease, for the accident. The commander had a medical history of a heart condition which may have caused some form of incapacitation.

The flying conditions, added to the probable failure of the AI, are likely to have led to an increase in stress to all the occupants. This could have led the commander to become distracted and/or incapacitated due to the stress of the situation.

Search and rescue

The pilots had not filed a flight plan or booked into Blackpool for the return journey. As a result no ATC agencies were formally aware of the flight. Had the pilots filed a flight plan, overdue action should have been initiated one hour after G-JMTT's ETA at Blackpool.

Conclusion

The aircraft crashed after control was lost while in IMC. The characteristics of the final flight path, particularly the high airspeed, the rapid descent and the rate of turn, were consistent with the effects of spatial disorientation. The pilots were not IMC or Instrument Rated, and alcohol was present in both pilots. It is likely that the accident resulted from loss of control as a result of the pilots following unreliable indications from the AI, whilst in IMC. The AAIB has made four Safety Recommendations relating to the maintenance of vacuum pumps.

The pilots were not IMC or Instrument rated. Had they been flying under VFR conditions, in sight of the surface, they would probably have been able to maintain control of the aircraft.