Aircraft Type and Registration:	Socata TBM 700B, N30LT
No & Type of Engines:	1 Pratt & Whitney PT6A-64 turboprop engine
Year of Manufacture:	2001
Date & Time (UTC):	6 December 2003 at 1124 hrs
Location:	180 metres west of Runway 01 threshold at Oxford (Kidlington) Airport, Oxfordshire
Type of Flight:	Declared as Private (see text)
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Fatal) Passengers - 2 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	FAA Commercial Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	More than 1,573 hours (of which approximately 500 hours were on type) Last 90 days - not known (see text) Last 28 days - not known (see text)
Information Source:	AAIB Field Investigation

Synopsis

Towards the end of a flight from Brussels to Oxford (Kidlington), the pilot was cleared to land from a visual straight-in approach to Runway 01. The surface wind was reported as 030°/15 kt. As the aircraft crossed the airfield boundary, it started to roll to the left. Shortly after, it struck the ground to the west of the runway threshold. Despite an extensive investigation, no technical malfunction was identified which could have caused the apparent uncontrolled roll to the left. Although there was no other conclusive evidence which would explain the manoeuvre, it is possible that control of the aircraft was lost during application of power to adjust the flight path or in an attempted late go-around, or as a result of an unknown distraction.

Background to the flight

The passengers had previously flown in N30LT with the pilot and had agreed with him that he would fly them from Brussels International Airport to Oxford Airport on 6 December 2003 and return the next day.

On the morning of 6 December, the pilot flew N30LT from Liege Airport to Brussels, landing at 0840 hrs. Another pilot, who confirmed that the accident pilot flew the aircraft throughout the flight from the left cockpit seat, accompanied him on this flight. The aircraft appeared fully serviceable and the autopilot was used for the ILS approach to Runway 25L with an estimated cloud base of 300 feet agl. At 250 feet agl, the autopilot was disconnected and a manual landing was made at about 85 kt using full flap. The automatic fuel mode[1] was checked prior to takeoff at Liege and was used throughout the flight; on landing the fuel appeared balanced between the two fuel tanks. After landing, the aircraft was refuelled to full with 640 litres of JET-A1 fuel.

The accompanying pilot considered that the accident pilot was very well. He, the accompanying pilot, left before the passengers arrived. One witness in Brussels subsequently confirmed that the accident pilot was seated in the front left cockpit and thought that the passengers were seated in a row behind the pilot.

Flight classification

The flight was categorised by the commander as a 'Private' flight. However, during the investigation it was considered that this categorisation might not have been correct. One of the two passengers had a fractional ownership agreement with a company based in Luxembourg and he contacted the company when he required a flight from Belgium to Oxford. The company did not have an aircraft available and contracted N30LT from a Belgium company. The Belgium company was the owner but an American company registered the aircraft.

Enquiries made of the United States National Transportation Safety Board (NTSB) resulted in a view that the flight would have been more appropriately categorised as 'Commercial-on-demand' rather than 'Private'. N30LT was not certified by the Federal Aviation Administration (FAA) for 'Commercial-on-demand' and the national authorities in UK, Belgium and Luxembourg have been advised of the situation.

[1] The selector which controls the fuel has three positions: left, right and off. When the system is set to automatic an actuator, commanded by an electronic sequencer, automatically allows the engine fuel to be fed from one tank or the other, for predetermined periods, without pilot intervention.

History of the flight

The aircraft took off from Runway 25 Right (R) at Brussels on a 'Costa 4C' departure at 1017 hrs; the Air Traffic Controller noted no unusual events during the takeoff. The aircraft transited at Flight Level (FL) 240 and a descent was commenced at 1052 hrs down to FL120. This flight level was then maintained for some 10 minutes before a further descent was made at 1110 hrs. By 1120 hrs, the aircraft was level at approximately 2,000 feet amsl. The aircraft had been under the control of 'Brize Norton Radar' since 1116 hrs and the pilot had requested 'radar vectors' towards Oxford. For separation reasons, the controller turned N30LT to the left and cleared the pilot to descend to 2,000 feet on a pressure setting of 1029 mb. At 1122 hrs, the controller advised the pilot that the airfield was at a range of four miles; the pilot replied that he had visual contact and was transferred to 'Oxford Tower' on frequency 133.425 MHz.

On check-in, the pilot of N30LT reported that he had Runway 01 in sight and was at a range of three miles. The controller responded by clearing the aircraft to land with a surface wind of 030°/15 kt. No other transmissions were made from N30LT and, at 1124 hrs, another pilot in the circuit transmitted to ask ATC: "Did you see what happened there?" The 'Tower' controller had just seen the aircraft start to roll to the left as it crossed the aircraft boundary and appear to impact the ground almost inverted. ATC personnel immediately initiated their emergency procedures. The Aerodrome Fire Service (AFS) recorded the alert at 1125 hrs and were on the crash scene some three minutes later. By then, other eyewitnesses were already at the scene and were moved away due to fuel leaking from both wings. Local authority fire services arrived on the scene at 1130 hrs.

One of the first witnesses on the scene was a doctor. On his advice, the fire services removed the pilot from the aircraft to check for signs of life but, once clear, the pilot was declared as dead. There were no indications of life from the two passengers who were found in the rearmost seats of the aircraft.

Witnesses

There were numerous eyewitnesses to the accident. Most were inside buildings or vehicles and none of these were aware of any changes in engine noise. However, one witness (Figure 1: Witness A) was outside on a bicycle and stated that an increase in engine noise made him look upwards as the aircraft passed almost directly overhead. None of the witnesses saw any smoke or flames, or anything fall from the aircraft.

Another witness was a flying instructor who was airborne with a student and who had just joined the Oxford visual circuit from a practice instrument approach. He stated that there was no low cloud, the visibility was 10 km or better and that he had experienced no turbulence or icing during his flight. He heard the pilot of N30LT check in on the Tower frequency and then saw a single-engine aircraft at the same height as himself and just over a mile from the threshold of Runway 01; at the time the aircraft was at about 540 feet agl. Later, with his own aircraft established on 'finals', he saw the other aircraft directly ahead on 'short finals' pointing towards the runway with no apparent drift. As he watched the aircraft, he saw it suddenly roll quite fast to the left to about 60° angle of bank. He then saw it in plan form as if the aircraft had pitched nose up. It continued to roll to the left, but at a slower rate, until it impacted the ground about 20° off the vertical. As it impacted the ground, the witness could see most of the underside of the aircraft; he could see that the landing gear was extended but was not sure about the flap configuration.

One other witness was a flying instructor (Figure 1: Witness B) who was in his car and leaving the airport. He was stopped at traffic lights to the south of Runway 01 and facing approximately west. When he heard the sound of an aircraft over his car, he looked to the right and saw a single-engine aircraft on approach to Runway 01. His impression was that the aircraft was at about 50 feet agl and in a normal position for a landing on the threshold of the runway. As he watched, he saw the aircraft begin a gentle banked turn to the left; the rate of roll was constant and he thought that the nose of the aircraft rose as the bank was at about 60°. The aircraft continued to roll and the nose of the aircraft came down as it did so; the roll continued almost through 360° and he lost sight of the aircraft shortly before he heard the noise of the impact. He left his car to go to the scene and arrived there shortly after another witness. The aircraft was lying on its left side and slightly nose down and fuel was flowing out of a large tear in the right wing.

Witness A had been cycling in a northerly direction along the left of the main road adjacent and almost parallel with Runway 01. Approximately 150 metres south of the airport, he became aware of a light aircraft and presumed that it was on an approach to land; this witness had previously held a PPL and was familiar with Oxford Airport. A considerable increase in engine noise caused him to look up and he saw an aircraft passing almost directly overhead. It was rolling to the left and was already banked about 40° left when he first saw it. It continued to roll very quickly to more than 90° of bank before the roll direction reversed. When the aircraft was banked about 60° to 70° to the left, it then commenced a turn to the left through about 90° before rolling almost level, following which it suddenly lost height and impacted the ground in a nose low attitude and with some slight left bank. Throughout the manoeuvres, the impression of the witness was that the engine noise remained constant and that the aircraft's height remained at about 30 feet agl.

Other witnesses were driving south along the same main road. Most saw the aircraft rolling continuously to the left. Some thought that it was displaced to the left of the approach to Runway 01 and some had the impression that it was lower than normal as it approached the road. Most also thought that it was beginning to go-around just as, or just after, the aircraft started to roll.

Airport information

The airport is 270 feet amsl. Runway 01 has a Landing Distance Available of 1,200 metres, is 23 metres wide and has an asphalt surface. The threshold is displaced by 170 metres from the start of the asphalt surface. The PAPIs have a 3.5° slope, are located to the left of the runway and are 128 metres from the threshold.

Weather

The Meteorological Office at Exeter provided an aftercast covering the time of the accident. The data they supplied was as follows:

> The synoptic situation at 0000 hrs on 6 December showed a weak warm front lying from Anglesea to Norfolk, moving south-west, and a weak cold front lying from Hebrides to Firth of Forth, also moving south-west. By 1200 hrs, the cold front had cleared Oxford to lie from West Wales to the Isle of Wight. A moist north-easterly flow affected the area. Weather at Oxford was cloudy with light drizzle, which had cleared by 1100 hrs. The surface visibility was 10 to 15 km and the mean sea level pressure was 1029 mb and rising. Cloud was FEW at 1,200 feet, SCT at 1,500 feet and BKN at 2,500 feet. The freezing level was 7,000 feet with a sub zero level developing between 2,500 and 4,500 feet. The surface wind was 040°/15 kt, gusting to 25 kt. Air temperature was +08°C and dew point was +05°C.

Enquiries made with the police helicopter crew, who were called to the scene of the accident and arrived there at 1144 hrs, indicated that there was no cloud below 2,000 feet amsl. The pilot flew a normal approach to Runway 01 from 700 feet to 50 feet agl and experienced no turbulence.

The route from Brussels to Oxford lay close to the frontal zone with cloud layers of varying intensity up to 27,000 feet. The freezing level was 7,000 feet with a sub zero layer forming in and behind the frontal zone. Moderate icing (defined as conditions in which change of heading and/or altitude may be considered desirable) was possible in cloud up to 14,000 feet.

Flight Recorders

The aircraft was neither equipped with a flight data recorder (FDR) nor a cockpit voice recorder (CVR) as neither was required by regulation.

The aircraft was equipped with a SHADIN Incorporated engine trend monitor (ETM) system. The ETM system consisted of a combined display and processor unit, which was installed in the instrument panel, and a recorder (not crash protected), which was mounted below the right rear passenger seat. The primary purpose of the system was to automatically record data points for use by the Pratt and Whitney engine condition trend monitoring (ECTM) program. The system also recorded data points for engine and airframe cycles and engine temperature exceedances.

The data from the ETM recorder was successfully downloaded. A total of 664 data points were recovered, dating from 13 March 2003 to 6 December 2003. The time recorded in each of the reports was acquired from the ETM internal clock, which was manually updated through the ETM display and processor unit.

On 6 December 2003 an aborted engine start was recorded, prior to the accident flight engine start. The record was generated by the inter-turbine temperature (ITT) exceeding 250º C and the gas generator speed (NG) exceeding 13%, which then proceeded to drop below 10%.

One minute after the aborted engine start, the engine was successfully started. Seventeen minutes after this start, a takeoff was recorded when the indicated airspeed exceeded 90 kt. The airspeed at takeoff was 99 kt with the aircraft on a heading of 250°. Thirty-eight minutes after the engine start, a stable cruise report was recorded at FL240 at an indicated airspeed of 186 kt and engine torque (TQ) of 96%. The stable cruise report was generated when, for two minutes, altitude did not vary by more than 200 feet, indicated airspeed did not vary by more than 20 kt and TQ did not vary by more than 2%. This report was the last data point to be recovered for 6 December 2003.

All of the downloaded data was analysed by the engine manufacturer. No anomalies were found and the engine parameters were found to be within the PT6A-64 engine operating limits. The ETM processor non-volatile memory (NVM) was also downloaded but, due to impact damage, no additional data could be recovered.

Radar information

National Air Traffic Services Limited provided secondary radar information on N30LT from two radar sources at Heathrow. Some of this information has been included in the history of flight. The final radar contact was at 1122:29 hrs, at a height between 1,420 and 1,520 feet agl with the aircraft approximately 2.6 nm from the threshold of Runway 01. The accident occurred at 1124:10 hrs. Therefore the time from the last radar contact to the runway was 1 minute and 41 seconds, giving an average ground speed of about 93 kt and an average descent rate of approximately 870 feet per minute. Figure 2 details the radar track for the last part of the flight.

Operational information

The pilot had completed his conversion to the TBM 700 on 21 July 1999 at an approved training centre. Since then, his flying logbook indicated that he had flown regularly throughout Europe and the USA. His last recorded flight in his logbook was 25 September 2003 in a single engine piston aircraft. His previous recorded flight in a TBM 700 was in N30LT on 14 September 2003. Information from one of his colleagues indicated that he had been involved at his normal work (0800 hrs to 1600 hrs each day), non-flying, during the week prior to his accident. For the month prior to that, he had been in Florida, where he owned a light piston engine aircraft; he had reportedly flown a number of flights during this period. The pilot had previously flown into Oxford with a colleague about a year before the fatal accident.

On the evening prior to the accident, the pilot had contacted a pilot colleague to ask if he would accompany him on the flight to Oxford. There was no requirement to operate with two pilots but this was a preferred option, particularly if the forecast weather was poor. The colleague was unable to do so but agreed to accompany him on the flight from Liege to Brussels. The pilot went to bed about 2200 hrs. The next morning, he left home about 0610 hrs to drive to the home of his colleague. By 0730 hrs, they had arrived at Liege. Takeoff from Liege was recorded at 0820 hrs.

At the time of the accident, there were two other aircraft in the circuit positioned behind N30LT. The previous movement had been an EC 135 helicopter, which had crossed Runway 01 at 1122 hrs from east to west at 50 feet agl about 100 metres upwind of the threshold. Once clear of the circuit, the helicopter had turned to the south-west. Subsequent to the accident, the helicopter manufacturer was asked to evaluate the possibility of turbulence from the EC 135 being a factor in the accident. Experience with the helicopter indicated that the turbulence generated was not a hazard to other light aircraft. Additionally, based on the time interval and surface wind, any turbulence would have been well clear of the location where N30LT started to bank to the left.

A weight and balance calculation, based on declared occupant weights and estimated baggage weights indicated that the aircraft was approximately 131 kg over the Maximum Take-off Weight (MTOW) of 2,984 kg with a CG position of 32.2% at the time of takeoff from Brussels. At the time of the accident, the estimated weight of N30LT was 2,942 kg and the CG position was within Flight Manual limits (19.5 % to 36 %) at 32.5%.

The Pilot's Operating Handbook (POH) recommended that a minimum of 10% TQ be maintained on final approach until the landing was assured. This was to ensure positive and rapid engine response to throttle movement. Normal approach speed with full flap is 80 kt. At the accident weight and configuration, the POH showed the stall speed at idle power with 0° bank as 61 kt.

Other TBM 700 accidents

Of the 256 TBM 700 aircraft built up to January 2004, seven (including N30LT) have been involved in fatal accidents and a further eight have been destroyed but without loss of life. These accidents covered the period between 1992 and 2003. These accident reports, plus an additional 17 reports dealing with other TBM 700 accidents, were reviewed to look for similarities with the accident involving N30LT. Of the fatal accidents, none were considered as having common features with N30LT. However, four other accidents involved the aircraft rolling to the left when engine power was increased. Two of these occurred in the UK and both were investigated by the AAIB.

The first of these occurred on 10 December 1992 to F-GLBD; it was reported in AAIB Bulletin 2/93. The flight involved a sales demonstration flight and the accident occurred during landing. The pilot in the right seat was handling and was instructed by the commander in the left seat to increase power. With no apparent reaction from the handling pilot, the commander applied some hand pressure to the power lever. As he did so, the handling pilot released his hold on the power lever and put both hands on the control wheel. The power lever moved to the fully open position and the handling pilot could not stop the aircraft rolling rapidly to the left and the left wing tip striking the ground.

The second non-fatal accident occurred on 24 October 2003 to N700VA and was reported in AAIB Bulletin 2/2004. The aircraft bounced on landing and then yawed and rolled left. The pilot applied power to go-around but was unable to prevent the left wingtip from striking the ground.

The third of these accidents occurred on 13 May 2002 to N700AR and was investigated by the Bureau D'Enquetes et D'Analyses pour la Securite de L'Aviation Civile (BEA). The pilot was on approach at low power and, just before the flare, applied power to correct his flight path. The aircraft banked to the left and the wing tip touched the runway. The BEA considered that the probable cause of the accident to N700AR was a '*Late correction of flightpath on short finals'*.

The fourth accident occurred on 15 December 2000 to N45PM and was investigated by the US National Transportation Safety Board (NTSB). The pilot was on his third attempt at a GPS approach in poor weather. When he became visual with the runway, he realised that his aircraft was low on the approach and he increased engine power. He considered that there was a slow engine response but when power increased, the left wing dropped and contacted the ground. The NTSB considered the probable cause of the accident was that '*the pilot did not attain the proper glidepath on the instrument approach*'. The pilot's decision not to fly to an alternate airport and his decision to continue the approach in weather conditions below the published minimums were contributing factors.

Fuel imbalance

On 6 January 2004, following a request by the AAIB, the manufacturer undertook a flight test to evaluate fuel imbalance. During the test flight, the fuel imbalance varied between 73 and 55 US gallons. It was found that increasing corrective aileron deflection was required with reducing speed and that full corrective aileron deflection was required at 70 KIAS to maintain wings level with a fuel imbalance of 69 US gallons. However, the company test pilot involved considered that an average pilot would have been technically able to complete a landing or go-around. The maximum allowable fuel imbalance detailed in the POH is 25 US gallons.

Flight tests

On 14 and 15 January 2004, the AAIB investigators, accompanied by investigators from the BEA, visited the manufacturer at Tarbes Airport to discuss the circumstances of the accident. During the visit, the AAIB investigators took part in a flight test in a similar aircraft to N30LT to evaluate certain possibilities. At the time, preliminary investigation had indicated that the aileron trim of N30LT at impact was at full left travel and the rudder trim at 85% left travel. Subsequent examination confirmed that the aileron and rudder trims were both close to the neutral position. A summary of the flight test, which was flown between FL100 and FL150, was as follows:

1. In a clean configuration and zero TQ, the aircraft stalled between 70 and 75 KIAS. At the stall, the aircraft always rolled to the left. The left roll could be corrected by the use of aileron. Some stalls were performed with full left aileron trim and 85% left rudder trim but this appeared to make no appreciable difference in roll.

2. With the landing gear down and 10° flap, the aircraft stalled between 67 and 68 KIAS. Stalls were performed with zero engine TQ and some were performed with full left aileron trim and 85% left rudder trim. At the stall, the aircraft always rolled to the left.

3. With landing gear down and 34° flap (normal landing configuration), the aircraft stalled between 55 and 60 KIAS. Stalls were performed with both zero and 20% TQ and some were performed with full left aileron trim and 85% left rudder trim. At the stall, which occurred at pitch attitudes of up to 11°, the aircraft always rolled to the left and rudder was required to counter the roll.

4. In all cases, the stall was preceded by the stall warning, which activated approximately 10 kt above the stall. Additionally, in the various configurations, a go-around was performed from engine settings of zero and 20% TQ and from various airpeeds down to 70 kt. These resulted in rolls to the left, which were easily controlled. However, it was

noted that the slower the initial airspeed, the more pronounced was the roll. It was also noted that there was no natural buffet prior to the stall.

5. A normal landing was achieved both with the yaw damper on and off. No difficulties were experienced in either configuration.

Subsequently, on 1 September 2004, AAIB investigators flew in another TBM 700 from Luton Airport to Oxford (Kidlington) to replicate the last recorded radar position of N30LT and review the subsequent approach. Although there was no information available on the configuration of N30LT at that point, it was possible to achieve an accurate threshold speed from that position even with a moderate tailwind. However, it did require an engine TQ close to zero.

The aircraft manufacturer performed another flight test in a TBM 700 on 28 October 2004 to evaluate the engine acceleration time from 0% TQ to 100% TQ. Their results showed that with the inertial separator turned off, the acceleration time was 3.0 sec at 85 kt and 3.1 sec at 75 kt , and with it turned on, which is the normal situation for landing, the acceleration time was increased to 3.4 sec at 85 kt and 3.9 sec at 75 kt. These times were based on the instrumented engine data and did not take into account the small time delay between throttle movement and first torque increase. The aircraft manufacturer also stated that the throttle was not moved excessively rapidly in order to protect the engine (as it was a prototype aircraft not fitted with a torque limiter).

Medical aspects

As a result of the post mortems, the pathologist concluded that the accident was not survivable and that the three occupants had died of multiple injuries. He considered that, in each case death would have been virtually instantaneous. Additionally, there was no evidence of any pre-existing disease which may have caused or contributed to the accident. Finally, there was no evidence of any alcohol, drugs or any toxic substance which may have caused or contributed to the accident in any of the occupants.

Aircraft description

The Socata TBM 700B is an all-metal, single engine turboprop, pressurised aircraft with a six or seven seat cabin configuration (including the pilot's seat). It has a maximum take-off weight of 2,984 kg and a maximum cruise speed of 300 KTAS at FL260. Its PT6A-64 free turbine engine powers a four-bladed Hartzell constant speed propeller. The aircraft is certified for single pilot operations.

The aircraft has a reversible mechanical flying control system and the wings have large span flaps which reduce the maximum stall speed to the required 61 KCAS for this class of aircraft. The flaps have three positions: up, takeoff (10°) and land (34°). A monitoring device interrupts movement if asymmetry between the left and right flap surfaces is detected. Roll control is accomplished by the combination of an aileron and spoiler in each wing that are directly connected to each other via a cable and pulley system. The aircraft also has a roll/yaw control interconnect, which is a mechanical system that applies appropriate rudder deflection when aileron is commanded and accordingly applies aileron when the rudder is commanded (ie, left rudder results in left aileron and vice versa). This allows for co-ordinated flight in turns commanded by only the use of wheel.

The left aileron and the rudder have trim tabs that are controlled by electric actuators. The aileron trim actuator is commanded by a pedestal-mounted switch in the cockpit, while the rudder trim actuator is commanded by a control wheel mounted switch. Both elevators have trim tabs that are mechanically operated either manually, by a trim wheel, or electrically, from a control wheel mounted switch via a servo motor under the cockpit pedestal.

The aircraft's autopilot operates in two axes, roll and pitch, and consists of an autopilot computer, an air data computer, a mode controller, a set of gyros and three electric servos. A roll servo controls the ailerons and spoilers, a pitch servo controls the elevator and the pitch trim servo controls the elevator trim tab. The autopilot has no control over the aileron or rudder trim tabs. A fourth servo controls the rudder and functions as a yaw damper. This is commanded in response to signals from the yaw rate gyro processed by the autopilot computer.

The aircraft is equipped with a pneumatic de-ice system that inflates boots on the wing leading edges, elevator horns, horizontal stabiliser and vertical tail. An electrical de-ice system protects the propeller, and an inertial separator is used to protect the engine air inlet from ice and debris. The separator consists of two electrically actuated movable vanes. When the inertial separator is turned on the vanes are repositioned to cause the inducted air to execute a sharp turn. Under the effect of centrifugal force this causes the denser particles to separate from the air and be discharged overboard. It is normal procedure to activate the inertial separator as part of the 'before landing' checklist.

The fuel system includes a fuel tank in each wing and a manual/electric fuel tank selector. When the system is set to manual the pilot selects the fuel tank via a 'pull and turn' wheel selector on the pedestal rear face. The selector, which controls the fuel unit, has three positions: left, right and off. When the system is set to automatic an electronic sequencer commands an actuator connected to the fuel unit, which then physically rotates both the unit and selector. This automatic selection allows the engine to feed from one tank or the other, in predetermined sequences, without pilot intervention.

Maintenance history

The last maintenance performed on the aircraft was a 100 hour/annual inspection, which was completed on 8 July 2003. The spoiler cable tension was adjusted but no defects requiring any major work were found during the inspection. The aircraft, engine and propeller had all logged 401 hours at the time of this maintenance. The aircraft had been maintained in accordance with Federal Aviation Administration (FAA) regulations and was in compliance with all relevant Service Bulletins. At the time of the accident the aircraft, engine and propeller had all logged approximately 483 hours.

Accident site examination

The aircraft had struck the ground in a field alongside the A44 on the south side of the Oxford Airport boundary. The aircraft wreckage was located 180 metres to the west of the Runway 01 threshold as shown in Figure 1. The initial impact marks and wreckage distribution were consistent with the aircraft having struck the ground upright in a nose low attitude, with a slight left bank and with a steep flight path angle. The marks and damage to the aircraft also indicated that the aircraft was in a sideslip to the left. After striking the ground on its nose and left side, the aircraft bounced, broke up into large sections and then immediately came to rest. The approximate final ground track of the aircraft, based on the wreckage distribution, was 320°(M).

All the aircraft wreckage and impact marks were located in a small 17 by 22 metre area, Figure 3, and this, together with the nature of the wreckage, indicated that the aircraft had a very low forward speed at impact.

Initial wreckage examination

The left wing had detached from the fuselage and the left wing fuel tank was completely ruptured. The right wing had remained attached to the fuselage wing box but the wing box itself was almost completely detached from the rest of the aircraft structure. The right wing leading edge had suffered a puncture such that any of its contents were likely to have drained out and the empennage was folded back with only the lower skin attached to the fuselage. The nose and left main landing gear had separated at impact but the right main landing gear was in good condition and was found in the extended and locked position. The right wing flap was fully extended and the right wing aileron and spoiler moved freely. The left wing was too badly damaged for such an assessment to be made on site.

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

Detailed examination

Flight controls

A thorough examination of all the control cable and control rod runs was carried out. Flight control continuity was established from the ailerons and the spoilers to the wing root in each wing. The cables had separated at the wing roots, but each was characterised by 'broomstraw' ends, consistent with overload failures of the type to be expected as a result of the impact disruption of the left and right wings. Flight control continuity was also established from the control wheels aft to the roll lever in the wing root. No disconnections or obvious signs of a control restriction were found in the roll control mechanism. The only anomaly was a missing safety pin from the lower spoiler cable turnbuckle used to adjust the tension in the cable. It is possible that this pin was missing prior to the accident but the cable end was still secure inside the turnbuckle and therefore was not a factor in the accident.

The upper rudder cable was continuous and still attached to the bellcrank between the rudder pedals and to the rudder bellcrank in the tail. The lower rudder cable was also continuous and attached at the rudder bellcrank in the tail but had separated from the forward bellcrank between the rudder pedals. The separation was consistent with an overload failure and consistent with impact disruption. No pre-accident disconnections or obvious signs of a control restriction were found in the rudder control mechanism.

The elevator control system consisted entirely of control rods, levers and bellcranks. Two control rods had failed due to overload between the wing root and the cockpit, but the control runs were otherwise continuous and no disconnections or obvious signs of a control restriction were found.

The aileron trim was determined to be neutral (0°) based on the aileron trim actuator position. The rudder trim was determined to be 1° right (normal range –9.5° to +13.5°) based on the rudder trim actuator position, but this would only have caused a slight left rudder deflection in flight. Both elevator trim tab actuators had equal extension corresponding to a deflection of approximately +3.5° (trim tab up, normal range –20° to +15°), representing an aircraft nose down trim[1].

Flaps

The right wing flap had sustained relatively little damage and was found in the fully extended landing position. The left wing flap was bent in places and had detached from its inboard roller and

[1] A flight test by the manufacturer determined that this corresponded to an 'in trim' condition for the aircraft fully configured for landing at a speed of between 111 and 114 KIAS (assuming power between 0% and 20% TQ). An additional flight test determined that at the normal final approach speed of 80 kt, with the CG position the same as on the accident flight, the pilot would be holding between 11 and 13 lbs of force on the control wheel, in an aft direction, to maintain this speed (see section on Operational analysis for further detail).

track assembly. The rollers in the outboard track assembly were in the fully extended position and the separated roller and track assembly also showed the rollers in the fully extended position. The extension of all four screw jack arms (two on each flap) was also consistent with full landing flap extension. It was concluded that at the point of impact both flaps were in the landing position.

Autopilot

The autopilot computer had sustained impact damage but, after re-soldering a broken resistor back onto the circuit board, the computer was connected to a test rig and passed its functional test. All three autopilot servos and the yaw servo were rig tested and passed their specification tests. The breakout forces required to overpower the servos were measured and these conformed to specification. The yaw rate gyro and yaw servo were connected to the autopilot computer and movement of the yaw gyro by hand resulted in the yaw servo responding in the correct direction. The autopilot mode controller operated correctly when connected to the test rig. To the extent that it was possible to conduct meaningful testing, no faults or anomalies were found in the primary autopilot system hardware.

Fuel tank selection system

It is standard procedure in the TBM 700 to set the fuel selection system to automatic and allow the electronic sequencer to automatically switch between left and right tanks. Any failure of the automatic fuel selection system should trigger an AUTO SEL caption and any fuel asymmetry would be detectable by a split between the two needles of the fuel tank quantity gauge. The automatic fuel selector switch was found set to manual but, as this is an unguarded switch, it was possible that it could have been knocked from the automatic position at impact or during the recovery by emergency service personnel. The fuel tank selector wheel was found set to the left tank position.

The three primary components of the fuel selection system, the electronic sequencer, the electric tank selector actuator and the fuel unit (which houses the valve that controls the fuel flow) were tested and examined. When connected to a test rig, the sequencer functioned normally but the actuator only operated in one direction, from left to right. The problem was traced to a slight miss-alignment of an internal micro-switch. However, the actuator exhibited visible impact marks and it is probable that impact forces had slightly dislodged the micro-switch. The fuel unit was strip examined, but no anomalies were found, and the internal valve was found in the left tank position.

De-icing system

There was significant disruption to the pneumatic hoses and damage to the de-icing boots as a result of the impact and, thus, the complete system could not be tested. It was considered possible, however, that any significant failure of the airframe de-icing system would most likely be caused by a fault in the electronic de-icing timer or the de-icing distributing valve. Therefore, these components were sent to their respective manufacturers for test and examination. Both operated correctly and passed all the functional tests. The inertial separator actuator was found in the ON position, which is the normal position for landing regardless of icing conditions.

Cockpit controls

The engine power lever was found close to the IDLE position, and the (blue) propeller control and (red) fuel control lever were fully forward. The manual override lever, used in case of fuel control unit failure, was found fully aft in its normal deactivated position. (These lever positions were not necessarily representative of pre-impact positions, as disruption of the forward fuselage during the impact sequence could have pulled on the engine control cables.) The flap selector lever was in the landing position gate and the landing gear lever was selected to DOWN.

Instruments

The directional gyro was indicating 287°(M) and the altimeter was set to 1032 mb. This was close to the QNH value of 1029 mb contained in the Meteorological Office's aftercast for Oxford for the time of the accident. The QFE setting would have been approximately 1019 mb.

Bulb filament examination

Examination of all available filament light bulbs in the wreckage indicated that impact forces had not been sufficiently high to identify any that may have been illuminated at the moment of impact. For example, the three green landing gear 'down and locked' lights had un-stretched filaments, despite there being good evidence that the landing gear was in fact down and locked. Therefore, no useful information was gained from this examination.

Powerplant examination

The engine was shipped to Canada where it underwent a detailed strip examination by the engine manufacturer's Air Safety Investigators, under the supervision of the AAIB. The significant findings were as follows:

- The propeller shaft had fractured due to torsional overload.
- The power turbines and power turbine guide vanes displayed circumferential rubbing consistent with mutual contact at impact whilst the turbines were rotating.

- The compressor shroud displayed circumferential rubbing consistent with the compressor blades having made contact with the shroud while rotating at impact.
- The fuel nozzles passed their functional test.
- The engine accessories, including the fuel control unit, the fuel pump, the propeller governor, the overspeed governor, flow divider, torque limiter, oil to fuel heater, and bleed valve were all either tested for functionality or disassembled for examination. No defects were found with any of these accessories.

In summary, the engine displayed no indications of any anomalies or distress that might have precluded normal engine operation prior to impact, and the rotational contact signatures inside the engine were characteristic of the engine developing low power at the time of impact.

Propeller examination

The propeller was disassembled and examined by one of the propeller manufacturer's Air Safety Investigators, again under the supervision of the AAIB. The No 1 and 2 propeller blades were both mildly bent aft and were twisted leading edge aft. The No 3 blade was sharply bent aft through approximately 90° at a position roughly 2/5 of its span from the root. The No 4 blade, however, was bent forwards through approximately 20° at roughly 3/5 span and it was also bent aft and twisted leading edge aft at about 2/5 span. Tip impact with forward bending typically drives the pitch change mechanism toward a higher blade angle, while aft bending typically drives the pitch change mechanism towards a lower blade angle. According to the propeller manufacturer, when an aft bent blade has been twisted leading edge aft it indicates that the blade was rotating at the time of impact. All four blades exhibited nicks in their leading edges and rotational scoring on their camber (forward facing) surface.

However, the overall extent of the blade damage was considered relatively mild, which was consistent with the propeller having been under low power at the time of impact. All of the propeller mechanism damage was also consistent with being occasioned during the impact and no discrepancies were found that would have precluded normal operation. In summary, all of the evidence from the propeller examination strongly indicated a low power condition at impact.

Analysis

General

The accident occurred at the end of a 67 minute flight, which appeared uneventful. The pilot had reported the runway in sight and had been cleared to land from a visual approach. Other pilots airborne in the local area reported the weather as benign at the time of the accident. However, as the aircraft crossed the airfield boundary, it began to roll to the left. There was a degree of confliction in evidence from some of the witnesses as to the subsequent manoeuvres of the aircraft. Initial evidence indicated that the roll continued left almost through 360° with the nose of the aircraft pointing towards the ground as it did so. However, the initial impact marks and wreckage distribution were consistent with the aircraft having struck the ground upright in a nose low attitude with a slight left bank and a steep flight path angle. This evidence would be consistent with the account of Witness A (the cyclist) who saw and heard the aircraft continuously in the last few moments of flight. The aircraft came to rest in a distance of less than 20 metres, which indicated that the aircraft had a very low forward speed. Witness marks also indicated that the aircraft was in a sideslip to the left which was consistent with uncoordinated flight following a stall. Regardless of the exact manoeuvres, there was no doubt that there had been a left roll and/or a loss of control. The investigation considered possible technical and/or operational reasons for a left roll or loss of control at a late stage in flight.

Engineering analysis

The cause of the left roll and subsequent loss of control, observed by witnesses while the aircraft was on short final approach, could not be explained from an examination of the aircraft wreckage. No disconnections or obvious signs of a control restriction were discovered during an examination of the roll, pitch and yaw control systems. There was no evidence of a flap asymmetry as all four flap jack screws were found fully extended. No faults or anomalies were found during testing of the autopilot system hardware and normally it is possible to override any autopilot control by opposing control force from the pilot. There was no evidence of a trim runaway as the rudder, aileron and elevator trim tabs were determined as having been close to their mid positions. The fuel contents in each wing at the time of the accident were unknown, as both fuel tanks were ruptured at impact. As the fuel tank selection system was found set to MANUAL, the possibility of an unintentional fuel asymmetry occurring in flight was considered. However, no pre-impact fault of the automatic fuel tank selection system was found, which suggested that the switch might have been knocked to MANUAL during or after impact. The evidence from both the engine examination and the propeller examination was consistent with a low power condition at impact and this was also consistent with the 'as found' position of the power lever. No pre-impact faults were found in the engine, the engine accessories or the propeller. The aircraft had been maintained in accordance with FAA Regulations and was in compliance with all relevant Service Bulletins.

In summary, no technical evidence was discovered of any malfunction which could have resulted in the left roll or loss of control just prior to landing.

Operational analysis

At the stage the aircraft started to roll to the left, the pilot should have been established at his target approach speed and with all his landing checks complete. Post crash examination of the aircraft revealed that the aileron and rudder trim settings were close to neutral. The pitch trim, however, was found at a position consistent for a fully configured aircraft at between 111 and 114 KIAS (assuming power between 0% and 20% TQ). Therefore, the aircraft would have been out of trim at a normal approach speed of 80 kt; at this speed the pilot would have been applying an aft force to the control wheel to counter the aircraft's nose down tendency. The manufacturer determined from flight test that this force would have been between 11 and 13 lbs. If this were so, then any abnormal flight condition that the pilot may have experienced could have been made worse by this out-of-trim condition.

With no obvious technical reason for a left roll at that stage of the approach, the investigation reviewed other possible reasons for such a manoeuvre and looked at the evidence for and against these possibilities. These included pilot incapacitation of some degree, a distraction, fuel imbalance, icing, wing stall and loss of control during a go-around.

Pilot incapacitation

The pathologist concluded that there was no evidence of any medical condition in the pilot, which may have caused or contributed to the accident. Indications from witnesses, one of whom was a colleague and friend who had flown with him on the immediately preceding flight, was that the pilot was his normal self prior to the accident flight. However, the circumstances of the accident to N30LT could be explained by some form of brief and temporary incapacitation of the pilot without this necessarily leaving any evidence.

Distraction

There was no evidence of any distraction outside the aircraft, such as other aircraft or birds. All the known aircraft were well clear of N30LT but the possibility remains that the pilot might have been distracted by a bird. It is also possible that he was distracted by something occurring within the aircraft. At a late stage on final approach, any distraction could have serious consequences.

Fuel imbalance

If there had been a fuel imbalance, this would have become more apparent as the airspeed reduced for landing. It could not be determined whether the fuel was closely balanced in each wing at the time of the impact and, indeed, wreckage examination indicated the possibility that the fuel could have been manually selected to the left tank. Evidence indicated that the aircraft was full of fuel on departure from Brussels and use of the automatic fuel tank selection system, which was the normal operating procedure, had been uneventful on the flight from Liege to Brussels. Also, no pre-impact fault was identified with the automatic fuel tank selection system during the investigation. Therefore, there was no reason for the manual system to be used and there should have been cockpit indications to alert the pilot to any fuel imbalance. Additionally, calculations showed that the maximum imbalance that could have occurred would have been approximately 67 US gallons. Although this was in excess of the normal maximum of 25 US gallons, a flight test indicated that this should not have resulted in an uncontrolled left roll at normal approach speed. Together with the fact that, at the time of the accident, the aileron and rudder trims were close to neutral, it was therefore considered unlikely that fuel imbalance was a factor in the accident.

Icing

The weather forecast for the flight was such that the aircraft may have experienced a degree of ice accumulation at some point during the flight. Although there were no reports from other aircraft of unusual or extensive icing conditions, there was no way of knowing what, if any icing was experienced by N30LT. However, the aircraft had comprehensive de-icing equipment and post crash examination indicated that the timing and distribution valves were serviceable. Furthermore, the aircraft had been below any possible icing level for at least four minutes before the accident. It was therefore considered unlikely that the roll to the left was caused by residual ice.

Wing stall

The aircraft would have stalled in normal landing configuration, with idle power and zero bank angle, at about 61 KIAS, and an audio stall warning was installed which should have activated some 10 kt before this airspeed. In the TBM 700, a stall would almost invariably result in a left roll/wing drop. For this to have happened to N30LT, the speed would have been some 19 kt below the normal approach speed of 80 KIAS. Radar information indicated that the average groundspeed for the aircraft over the last one minute and 41 seconds of flight was 93 kt; this would equate to an average airspeed of about 107 kt. Therefore, it was likely that the pilot was reducing his airspeed from the last radar recorded position, when the aircraft was at about 1,500 feet agl, and also likely that he would have reduced engine TQ for this descent. An approach with a higher than normal descent rate at low engine TQ and with reducing airspeed is difficult to judge and any misjudgement near the ground could have resulted in a rapid reduction in airspeed. However, the aircraft was fitted with a stall warning system and this, together with the aircraft's profile, with a long nose ahead of the cockpit, should have provided both audio and visual warning to the pilot of an approaching stall. Nevertheless, a stall must be considered a possibility.

Loss of control during a go-around

It was possible that the pilot had decided to go-around at a late stage of the approach. There may have been some sort of distraction, or the pilot may have decided to apply power because of airspeed/ height considerations, but a rapid application of engine power would have induced a left roll because of the engine TQ. This would normally be easy to counter but, if the airspeed had been low, and the application of engine power had been accompanied by an increased elevator demand, any roll tendency would have been increased, with associated control difficulty. This could have resulted in a stall. It may also be relevant that a turboprop engine is not as responsive to a rapid increase in throttle as a piston engine. Although the pilot was experienced in the TBM 700, most of his recent flying experience was in piston-engined aircraft. Furthermore, the inertial separator was determined to have been ON for the intended landing and this would have further slowed the engine response. In a previous TBM 700 accident (N45PM, 15 December 2000), the pilot commented on an apparent slow engine response.

There was some subjective witness evidence to indicate that the aircraft was initiating a go-around but this could not be confirmed as fact. The cyclist was the only witness who commented on an increase in engine noise. While this may have been an actual increase in power, it could also have been an apparent increase in noise as the aircraft passed overhead. The cyclist indicated that the aircraft had rolled almost level after the initial roll and then lost height before impacting the ground. If accurate, this would indicate that the pilot may have recovered from the initial roll but then stalled the aircraft. It is difficult to then understand why engine power was at a low level at impact, but this may have resulted from an instinctive reaction to the imminent impact. Loss of control during a late go-around must be considered a possibility

Conclusions of the investigation

Despite an extensive investigation, no definite conclusion could be reached as to why N30LT crashed on a visual approach to Oxford (Kidlington) Airport. No technical evidence was found which would explain the uncontrolled roll but there were certain operational possibilities. Without hard evidence, however, none could be fully supported, but loss of control resulting from an unknown distraction, or during the application of power for flight path adjustment or an attempted late go-around, must be considered as possibilities. The lack of a crash protected data, voice or image recording system on N30LT made it impossible to successfully determine a specific cause or causes of this accident.

Crash protected image recording system

In October 1997 a Cessna 208B operated in the United States by the Department of the Interior experienced a loss of control and collided with the terrain. The pilot and eight passengers were fatally injured. In October 2002 a Beech King Air crashed on approach, killing all eight people on board. Neither aircraft was equipped (nor was required to be equipped) with either a flight data recorder (FDR) or cockpit voice recorder (CVR). These are two examples but the NTSB has reported that investigations of numerous accidents involving similar aircraft types have been hampered by the lack of CVR and FDR information.

In some instances, radar data and/or on board global positioning systems, where available, did not provide sufficient detail concerning the aircraft's flight path or flight conditions. This has also proved to be the case with regard to the accident to N30LT. The installation of an FDR on smaller aircraft is likely to be economically impracticable due to the intrusive nature of the installation itself whilst a CVR, although invaluable as an accident investigation tool, yields little parametric data. An image recording system could record audio like a CVR but, as a minimum, would capture images of parametric data from the flight deck instrumentation and possibly a part of the external, forward view. Advancements in the development of image recording now makes these systems technically and economically more viable for fitting to small aircraft.

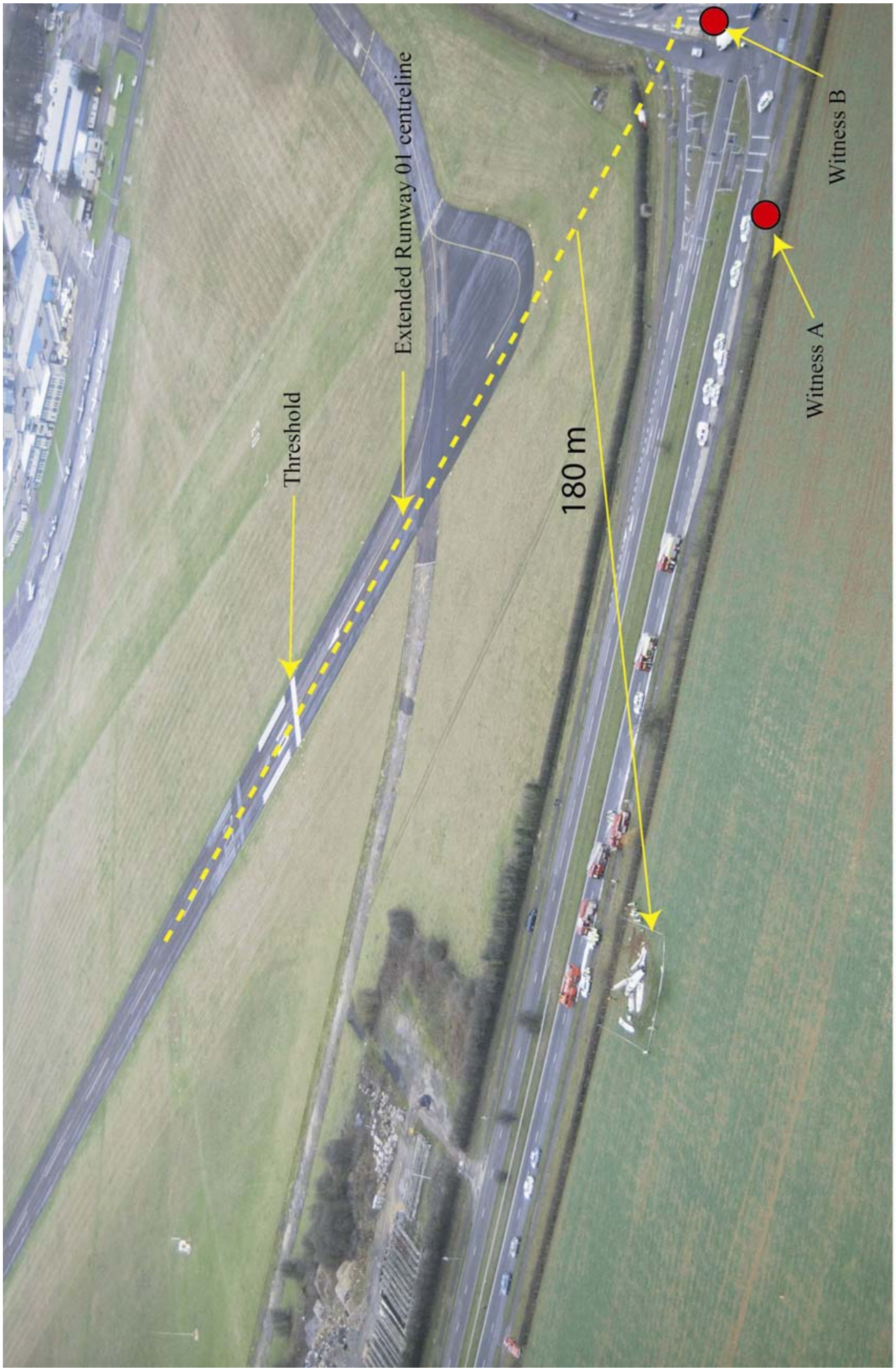
As a result of the Cessna 208B accident, the NTSB made recommendation A-99-60 on 8 February 2000, which requires:

> *'within 5 years of a technical standard order issuance, the installation of a crash-protected video recording system on all turbine-powered non experimental, non-restricted category aircraft in 14 Code of Federal Regulations Part 135 operations that are not currently required to be equipped with a crashworthy flight recorder device'.*

The international aviation community is aware of the safety benefits of crash-protected image recorders. The International Civil Aviation Organisation (ICAO) and Flight Recorder (FLIREC) Panel, specifically dealt with the need for standards and recommended practices concerning such recordings. The panel agreed that the use of these recordings in aircraft cockpits would be very useful and noted that the European Organisation for Civil Aviation Equipment (EUROCAE) was developing minimum operational performance specifications. In March 2003, EUROCAE issued a technical standard for a crash-protected image recording system. The NTSB has recommended that the Federal Aviation Administration (FAA) incorporate this standard (ED-112, Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems) into a Technical Standards Order (TSO).

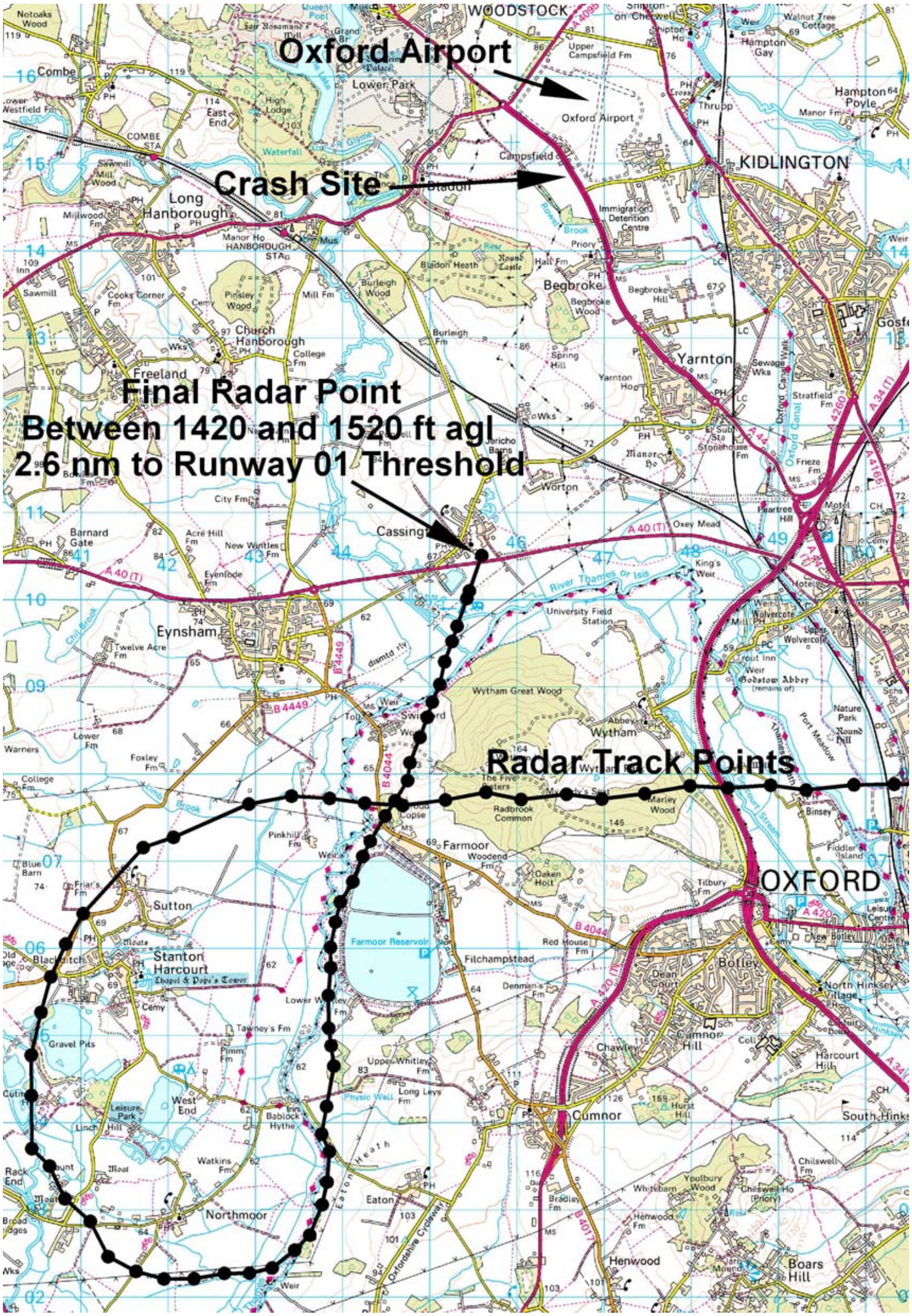
In Europe, the Joint Airworthiness Authorities (JAA) also are considering the requests of accident investigation bodies and have jointly sponsored research into the use of image recorders on the flight deck. Additional work is also ongoing to determine the requirements to protect such recordings against use outside accident investigation, a necessity to prevent them being employed for punitive means. The AAIB fully supports the introduction of such technology and is satisfied that the industry is working towards providing this additional source of information for accident investigators. As a result, the AAIB sees no need to make additional recommendations on the subject at this time. It is considered likely that, had a crash-protected airborne recorder been available to the N30LT investigation, some of the uncertainties surrounding the events of this accident may have been resolved.

Figure 1



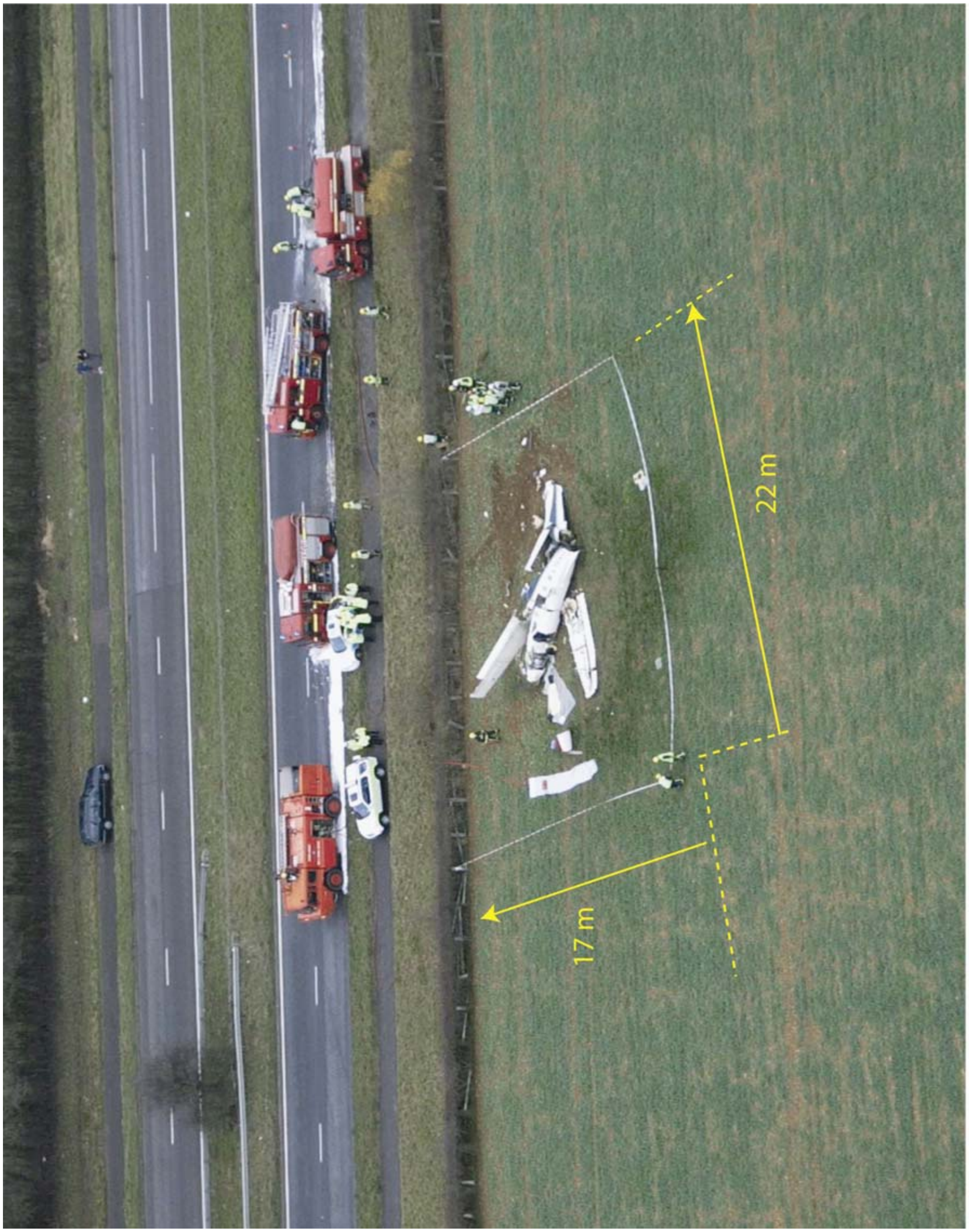
N30LT - Accident Site Location

Figure 2



Final radar track of N30LT

Figure 3



N30LT - Accident Site Details