ACCIDENT

Aircraft Type and Registration:	Cessna 501 Citation, G-VUEM
No & Type of Engines:	2 Williams International FJ44-2A turbofan engines
Year of Manufacture:	1981
Date & Time (UTC):	19 November 2010 at 1535 hrs
Location:	Birmingham Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A 1 (Minor)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	7,200 hours (of which 3,000 were on type) Last 90 days - 127 hours Last 28 days - 50 hours
Co-pilot's Flying Experience:	1,785 hours (of which 735 were on type) Last 90 days - 85 hours Last 28 days - 38 hours
Information Source:	AAIB Field Investigation

Synopsis

The accident occurred during an ILS approach to Runway 15 at Birmingham Airport. The weather conditions were clear over the aerodrome but there was a bank of fog affecting the final approach. The aircraft descended below the Decision Altitude (DA), without the crew having achieved the required visual references, and struck the glideslope antenna. A fire broke out on the left wing and the aircraft crashed onto the grass to the right of the runway. By this time, the fog was affecting the whole of the airfield and, in poor visibility and wet ground conditions, the Airport Rescue and Fire Fighting Service (RFFS) had some difficulties locating and accessing the aircraft. However, the first vehicle was at the scene within three minutes, the fire was extinguished rapidly and a fireman assisted the commander who was, for a time, trapped in his seat. Both of the flight crew survived the accident. Also, a transplant organ, which was being carried onboard, was recovered successfully.

History of the flight

The flight crew reported for duty at Liverpool Airport at 0845 hrs. Their original task was to fly to Belfast City Airport, collect a transplant organ, and take it to Cambridge Airport. However, on their arrival at Belfast

the transfer was no longer required, so they were given a new task to fly to Belfast Aldergrove Airport and collect an organ to carry to Birmingham Airport.

The aircraft departed Belfast Aldergrove at 1450 hrs with the co-pilot as pilot flying. The flight was uneventful and the aircraft was given a radar vector to intercept the ILS for a straight-in approach to Runway 15 at Birmingham.

The Runway 15 ILS course is 149°M. The autopilot was engaged and the aircraft was flying on a track of 135°M, 13 nm from the touchdown zone and at a groundspeed of 254 kt, when it crossed the localiser centreline. The aircraft then turned right onto a corrective track but once again passed through the localiser course. Further corrections were made and the aircraft passed through the localiser once more before becoming established at 5 nm. The co-pilot later reported that, because the autopilot was not capturing the localiser, he had disconnected it and flown the approach manually.

When the aircraft was at 10 nm, the radar controller broadcast a message advising of the presence of a fog bank on final approach and giving RVRs of 1,400 m at touchdown and in excess of 1,500 m at both the mid-point and stop end.

The airfield was sighted by the commander during the approach but not by the co-pilot. A handover to the tower frequency was made at around 8 nm. When the aircraft was at 6 nm, landing clearance was given and acknowledged. The tower controller then advised the aircraft that there was a fog bank over the airfield boundary, together with the information that the touchdown RVR was 1,400 m. The commander responded, saying: "WE'VE GOT ONE END OF THE RUNWAY".

The aircraft was correctly on the localiser and the glideslope at 4 nm. The Decision Altitude (DA) of 503 ft amsl (200 ft aal) for the approach was written on a bug card mounted centrally above the glareshield. Both pilots recollected that the Standard Operating Procedure (SOP) calls of "500 above" and "100 above" DA were made by the commander. However, neither pilot could recall a call of 'decision' or 'go-around' being made. At between 1.1 nm and 0.9 nm, and 400 ft to 300 ft aal, the aircraft turned slightly to the right, onto a track of 152°M. This track was maintained until the aircraft struck the glideslope antenna to the right of the runway some 30 seconds later (see Figure 3, page 11).

The aircraft came to rest in an upright position on the grass with a fire on the left side. The co-pilot evacuated through the main cabin door, which is located on the left side of the fuselage, and suffered flash burns as he passed through the fire. The commander was trapped in the cockpit for a time.

Fire and rescue

The aerodrome was Rescue and Fire Fighting (RFF) Category 9 at the time of the accident. The fire station is located to the east of Runway 15/33 (see Figure 1). At 1536 hrs, ATC reported the accident to the RFFS via the crash line. Initially, from the fire station some smoke could be seen above a fog layer but, as the vehicles deployed, the fire crews' visibility was restricted by the fog and the smoke could no longer be seen. Two fire-fighting appliances, accompanied by a fire command vehicle, deployed along Taxiway A towards the holding point for Runway 15. A further two appliances deployed onto the runway, via Taxiway T, and then travelled north along the runway. By now the fog was so thick that the fire crews could not immediately locate the accident site. The driver of one of the fire appliances, travelling north along the runway, glimpsed an orange glow at the

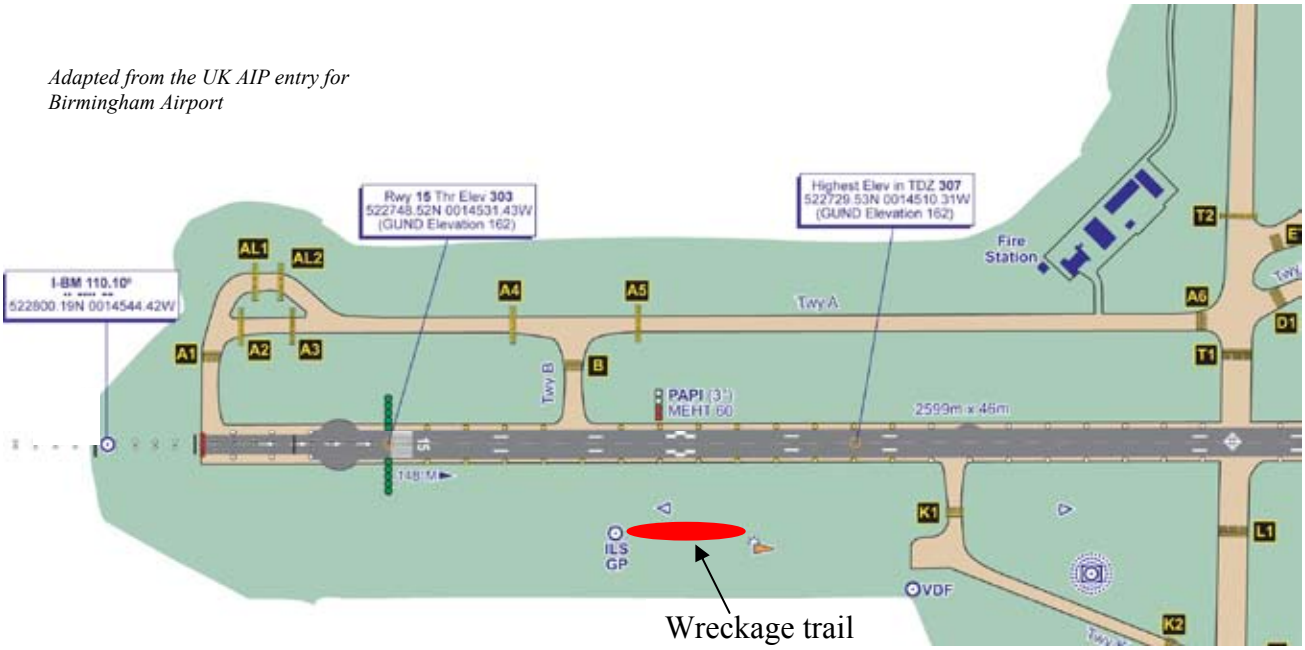

Figure 1

Accident site location

left side of the runway and turned towards it, onto the grass. The grass area was soft and made access difficult, but the vehicle reached the site at 1539 hrs and the fire crew applied foam to the left side of the aircraft. The fire was suppressed quickly and fire crewmen were able to approach the aircraft.

The other two appliances, together with the fire command vehicle, approached the accident site from the threshold of Runway 15. When one of the appliances turned off Runway 15 towards the aircraft, it became bogged down in soft ground due to the appliance's differential locks not being engaged. The other vehicles in this group altered their route, accessing the airfield perimeter track via Taxiway K, before finally reaching the accident site by driving through the airfield security fence. These vehicles arrived at the aircraft at 1542 hrs. The progress of the fire vehicles towards the crashed aircraft was recorded on the surface movement radar.

The co-pilot had vacated the aircraft and advised the fire crew that the commander was still inside. A fireman approached the aircraft and could see that the commander was moving, so he smashed the side windows to allow air into the cockpit.

When the aircraft had come to a stop, the commander realised that his right foot was trapped and he could not get out of the aircraft. Seeing the fire around him, he took hold of the portable fire extinguisher and discharged it around the cockpit. He then used his crew oxygen mask to enable him to continue breathing.

One of the firemen entered the aircraft through the right side emergency door but could not get right into the cockpit because of the confined space and the bulky nature of his breathing apparatus. However, the commander managed to free himself and crawl backwards to where he could be assisted from the aircraft. He was treated at the scene and then flown by air ambulance to a local hospital.

Another fireman went to the right side of the aircraft and noticed that the right engine was still running, so he went to get the co-pilot to return to the aircraft to assist. They were able to signal to the fireman inside the aircraft to shut down the engine. The fire crew were also able to recover the transplant organ from the cabin.

Accident site

The wreckage trail originated at the Runway 15 glideslope antenna tower, which was positioned 146 m laterally, to the west of the runway centreline, adjacent to the touchdown point (Figure 1). The 220 m long wreckage trail was oriented on a heading of 146°M. It consisted of fragments from the aircraft's nose and inboard section of the left wing, along with parts of the aircraft that had detached as it slid along the grass surface. The aircraft came to rest on its belly at the end of the wreckage trail, on a heading of 284°M and 138 m laterally from the Runway 15 centreline. Ground marks indicated that the aircraft had rotated approximately 225° to the left, whilst in contact with the ground, following the initial ground impact. The right flap and left main landing gear had detached from the aircraft before it came to rest.

The Runway 15 ILS glideslope antenna tower, which was 15 m tall prior to the accident, had sustained extensive damage due to being struck by the aircraft approximately 1 m from the top of the tower. The uppermost antenna had been detached from the tower during the impact, and the tower had been bent backwards by approximately 170°. The position light mounted at the top of the antenna tower had been torn off, exposing live electrical cables.

A section of inboard leading edge from the left wing, 80 cm in length, was found close to the base of the glideslope antenna tower. This piece of structure formed the forward skin of the integral fuel tank in the aircraft's left wing. It displayed surface witness markings indicating that the aircraft had struck the tower in a wings-level attitude.

The initial ground contact mark made by the aircraft was 57 m from the ILS glideslope tower. The left nose landing gear door and a pitot tube were found at a distance of 92 m from the ILS glideslope tower and a deep gouge in the ground surface indicated that a heavy nose impact had occurred at this location. The fibreglass nose cone, nose avionics rack and weather radar had detached from the aircraft at this point, and had been thrown 34 m forwards.

The grass surface of the wreckage trail exhibited sooting consistent with a short duration 'flash' fire of fuel vapour. The burned area extended from 3 m before the first ground mark, to the resting position of the aircraft and was approximately 15 m wide. Ground conditions at the accident site were very soft and waterlogged.

Wreckage examination

The left side of the aircraft had suffered extensive fire damage, fed by fuel that had leaked from the ruptured left wing fuel tank. The outer 80 cm of the left wing was bent upwards by approximately 25°, due to ground impact, and the fire had been severe enough to melt through the left wing's aluminium alloy structure completely. The left engine's fan blade leading edges were damaged due to the ingestion of debris whilst the engine was rotating.

The flap selector lever was in the landing position and inspection of the flap track rollers revealed that the flaps were fully deployed, at 40° deflection, prior to the accident. The aircraft's electrically heated anti-ice leading edges switch was in the OFF position. The landing

gear selector lever was in the DOWN position. The left main landing gear leg had broken away from the aircraft, from the extended position, as the aircraft slid sideways over the grass surface. The right main and nose landing gear legs had been forced upwards into their stowed positions, due to overload during the ground impact. The right wing trailing edge flap had detached from the aircraft whilst the aircraft was travelling backwards over the grass surface.

The left side of the aircraft's nose had struck the ground, pushing the left side of the forward pressure bulkhead rearwards by 30 cm. This deformation had also caused the commander's instrument panel, control column and rudder pedals to translate rearwards, trapping him in his seat. Both the commander's and co-pilot's seat mountings and restraint harnesses had withstood the accident's impact loads without failure.

Orange witness marks were visible on the left side of the fibreglass nosecone. These matched the orange paint on the upper section of the ILS glideslope antenna tower and the alignment of the marks confirmed a wings-level impact attitude with the tower. An area of fuselage skin beneath the commander's side windshield, measuring 55 cm long by 45 cm wide, had been torn rearwards during the tower strike, and wiring looms immediately behind this area of skin had been severed.

A detailed examination of the aircraft's flying controls was made following recovery of the aircraft and no pre-existing defects were identified.

Pilot information

The commander was experienced on the aircraft type and had flown G-VUEM on a number of previous occasions. The co-pilot had been flying the aircraft type with the operator regularly for several years but had not flown G-VUEM as frequently as their other two aircraft. There were no particular comments of relevance in either pilot's training records.

The commander had operated a three sector flight on 17 November, an 11-hour duty period which finished at 2115 hrs. He then had a rest day before reporting for duty at 0845 hrs on 19 November.

The co-pilot had operated a two sector flight on 18 November, which finished at 1725 hrs. He then had 15 hours and 20 minutes of rest before reporting for duty at 0845 hrs on 19 November.

Commander's recollections

The commander noted that the two flights carried out earlier in the day had been uneventful. The accident flight had also been routine and the weather reports received for Birmingham indicated good conditions for the approach. There were no technical faults with the aircraft but the commander recalled that the aircraft had not captured the ILS localiser on the first attempt and did not track it correctly. The co-pilot disconnected the autopilot and continued the approach, flying manually. The commander acquired visual contact with the airfield from some distance and then, during the later stages of the approach, he only had the second half of the runway in sight. A crosscheck of altitude had been made at 4 nm. At some stage, the co-pilot had asked whether he should go around but the commander had advised him to continue. The commander called "500 above" and "100 above" and looked out for visual references. He remembered noticing that the glideslope pointer had disappeared; then he saw an obstacle immediately ahead. He thought the co-pilot must have seen it too because he heard him make an exclamation. He did not make a 'decision' or 'go-around' call.

The commander's impression when he was interviewed was that there had been a very short time, in the order of a few seconds, between his calling "100 above" and the impact. His initial impressions were that the aircraft had descended below the glideslope.

Co-pilot's recollections

The co-pilot thought that the aircraft had entered cloud at around 2,000 feet and the rest of the approach had been in IMC. He had noticed that the autopilot was not tracking the localiser but, instead, passed through it several times. He disconnected the autopilot and flew the remainder of the approach manually. He heard the commander give a "500 above" and a "100 above" call. He didn't hear a 'decision' call. At around the time he heard the '100 above' call he realised that he was no longer maintaining the localiser and asked the commander if he should go around. He recalled hearing the commander say, "no, go left". He remembered being confused by this instruction. He then caught a glimpse of the antenna ahead, too late to attempt to avoid it.

Meteorological conditions

At 1535 hrs the aerodrome was on the southern margin of an area of low cloud and fog. Earlier in the day the airfield had been affected by fog but the RVRs had not dropped below 1,500 m since 1135 hrs, four hours before the accident. In the intervening time the sky had been clear with the sun visible.

It is not known what forecast the pilots accessed before the flight to Birmingham. However, the TAF issued for Birmingham at 1059 hrs was: '*1912/2012 18005KT 0300 FG VV/// BECMG 1912/1915 6000 NSW SCT005.'* There were two fog warnings issued for Birmingham Airport before the flight left Belfast. One was issued at 0902 hrs and a second at 1116 hrs, valid from 1200 to 1600 hrs, both reported *'Fog (visibility less than 600m) expected'*. The Birmingham METAR issued at 1420 hrs, 30 minutes prior to departure, was '*12004KT 090V160 9999 4500NW FEW007 09/07 Q1011.'*

The crew received ATIS information 'E' broadcast from 1450 hrs, which stated: Runway 15 in use, surface wind from 160° at 5 kt, visibility 10 km or more, few cloud 700 ft, temperature +9°C, dew point +7°C, QNH 1011 mb.

The Instrumented Runway Visual Ranges (IRVRs) recorded for Runway 15 are reproduced in the table below:

Time	RVR (m)	RVR (m)	RVR (m)
	Touchdown	**Mid-point**	**Stop-end**
1530	1400	> 1500	> 1500
1531	> 1500	> 1500	> 1500
1532	1400	> 1500	> 1500
1533	1100	> 1500	> 1500
1534	500	> 1500	> 1500
1535	500 375	> 1500	> 1500
1536	300	> 1500	> 1500

The surface winds broadcast by ATC on the tower frequency were:

Time	Surface wind °M/kt
1520	160/5
1522	150/3
1525	050/2 040/3
1529	020/5
1531	020/4
1532	020/4

Other flight crew reports

There were a number of aircraft movements at around the time of the accident. The commander of an aircraft which landed at 1523 hrs reported that they had flown an autopilot coupled approach to minima. Just above their DA of 503 ft amsl they had flown into the top of a fog bank, through which they could see the approach lights, and then passed straight out again into clear visibility. He estimated the top of the fog to have been at between 250 ft and 280 ft aal.

The commander of an aircraft which landed at 1524 hrs reported that most of the runway was visible throughout their approach but that there was a very clear line of fog, through which the approach lights could be seen. The aircraft just entered the fog momentarily on the approach. The co-pilot commented that because there had been a deflection of the localiser during the approach he had flown the latter part visually. He noted that the aircraft had appeared to be "surfing" down the front, sloping face of the fog.

Another aircraft, inbound on a diversion from East Midlands Airport, landed at 1527 hrs. The commander reported that they had flown over a solid bank of fog or overcast cloud en-route. The edge of the fog could be seen and appeared to be moving upwind, that is in a southerly direction. He thought that they had entered the fog before reaching their DA but that he had maintained sight of the runway and it was clear for landing.

There was one departure at 1530 hrs and another at 1532 hrs. The second departing aircraft encountered fog when taxiing northbound along Taxiway A. The commander commented that it appeared to be moving towards the aircraft at around 4 kt. When the aircraft was lined up prior to takeoff, the fog was very thick and the commander commented that he could see only a limited number of runway lights ahead.

One aircraft was on the approach behind the accident aircraft. The crew could see the far end of the runway and a bank of rolling fog, but not the aircraft ahead. At 5 nm they noticed that the glideslope signal had been lost and accordingly reset their minima for a localiser only approach. They didn't enter the fog and when they were at around 800 ft aal they were instructed by ATC to go around.

Those present at the airfield described the weather conditions around the time of the accident as very unusual. Of particular note was the sharp definition between the fog and the clear area where the sun was shining and, secondly, the speed with which the fog covered the airfield.

Air Traffic Control information

The bank of fog and low cloud to the north of the airfield was seen from the Visual Control Room (VCR) but was not, at first, directly affecting airfield operations. At 1523 hrs ATC requested Airfield Safeguarding[1]. At Birmingham the time taken to complete safeguarding is normally between 15 and 20 minutes; the procedures had not been completed by the time of the accident.

At 1531 hrs there was a discussion within ATC about whether there should be a change of the runway in use to Runway 33. At 1533 hrs the tower controller broadcast a reduction in touchdown zone RVR to 1,100 m. The call was not acknowledged by G-VUEM. The controller was expecting to see the aircraft land at any moment when he noticed, on the screen in front of him,

Footnote

[1] Airfield Safeguarding is the term used to describe the protective measures that must be in place before fully protected Low Visibility Procedures can commence.

that the RVR had reduced to 500 m. He decided not to pass this information on to the landing aircraft because he thought it could cause a distraction at a critical time. He then saw a flash of orange and a pall of smoke. He activated the crash alarm and carried out the aircraft accident procedures using a dedicated checklist. He reported that by this time the whole of the airfield was obscured by fog.

At the time of the accident there had just been a change of radar controller. The oncoming controller thought that the following aircraft had been changed to the tower frequency. However, this was not the case. The tower controller was expecting the following aircraft to have been given go-around instructions, when he realised that it was continuing its approach he requested that the aircraft be sent around. The following aircraft was given go-around instructions by the radar controller when it was at 2 nm on final approach. Other inbound aircraft were instructed to enter holding patterns and diversions were then co-ordinated.

Aerodrome information

Runway 15 at Birmingham has an LDA of 2,279 m, with a width of 46 m. The landing threshold is displaced by 320 m from the start of the runway and the touchdown elevation is 303 ft amsl. The lighting at the time of the accident was selected to 100 % brightness and consisted of full (914 m) CL5B[2] approach lighting, PAPIs, Runway Centreline lights at 15 m spacing and Runway Edge lights. There was a Category III ILS installation for Runway 15. The applicable Category I minima for the NDB ILS DME approach to Runway 15 were: DA 503 ft amsl and visibility 550 m.

A flight inspection of the localiser was carried out the day after the accident and it was found to conform with the required standards.

The Runway 15 ILS glideslope antenna tower

Design requirements relating to ILS glideslope antennae towers are specified in International Civil Aviation Organization (ICAO) Annex 14 *'Aerodrome Design Manual'*. This document requires that ILS glideslope antennae towers must be located a minimum of 120 m laterally from the runway centreline. The Runway 15 glideslope antenna tower, located 146 m from the runway centreline, complies with this requirement. The manual also specifies frangibility criteria for air navigation equipment located in close proximity to runways. However, ILS glideslope antennae towers are not subject to frangibility requirements, owing to the conflicting requirements of making the antenna tower frangible versus maintaining the glideslope beam alignment in strong winds and in icing conditions.

The glideslope antenna tower manufacturer constructed the tower in four separate vertical sections that were bolted together. When struck by the aircraft, the two uppermost bolted joints gave way (Figure 2), allowing the tower to fold in the direction of the aircraft's flight path. This progressive deformation of the tower, achieved in the absence of frangibility requirements, reduced the deceleration imposed on the aircraft.

The accident site

The aerodrome's grass surface at the accident site was observed to be waterlogged when the accident occurred. The closest rainfall monitoring station to the accident site was Coleshill, 2.9 nm north-east of Birmingham Airport. Rainfall accumulation records for this station were obtained from the UK Met Office (Table 1).

Footnote

[2] Calvert System comprising centreline and 5 cross bars (CL5B).

Figure 2

Runway 15 ILS glideslope antenna tower after the accident

Period (dates are inclusive)	Recorded rainfall accumulation (mm)	Average accumulation (mm)	Difference from average
1/11/10 – 19/11/10	50.2	42.7[3]	+17.6%
1/08/10 – 31/10/10	236.4	190.8[4]	+23.9%

Table 1

Rainfall accumulation totals

Footnotes

[3] 19/30ths of the monthly average for November, recorded over a ten year period between 2001-2010.

[4] The quarterly average for the period August-October inclusive, recorded over a ten year period between 2001-2010.

The figures show that the rainfall recorded during the period of November 2010 preceding the accident was higher than average. In addition, the rainfall recorded in the period between August and October 2010 was also above average. It is, therefore, considered that the above average rainfall accumulations contributed to the waterlogged grass surface at the accident site.

Aircraft information

The operator's fleet comprised three aircraft; the Cessna Citation 501, G-VUEM, and two Citation 550s. G-VUEM was usually operated as a corporate aircraft and the other two aircraft were used mainly for charter. The co-pilot noted that he normally flew the charter aircraft and seldom flew G-VUEM. There were a number of differences between G-VUEM and the other two aircraft, including the instruments, operation of cockpit displays and equipment, engine management and aircraft performance.

G-VUEM was fitted with an autopilot which was capable of flying a coupled ILS approach. Other pilots who had flown this aircraft advised the AAIB that to intercept and track a localiser course successfully, with the autopilot engaged, the speed would need to be reduced to around 180 kt. The aircraft was fitted with three altimeters; one primary altimeter for each crew member and a standby altimeter that was installed on the co-pilot's instrument panel. All three altimeters were set to the airfield QNH. None of the altimeters were equipped with 'bugs' for setting minima. There was a flight director available for the commander but the co-pilot's side did not have this facility. The bug card was completed with the correct information and minima; the calculated approach speed was 104 kt.

The aircraft departed Belfast with 3200 lbs of fuel on board and the estimated fuel burn for the sector was 1,000 lbs.

After the accident both primary altimeters were returned to the manufacturer for functional testing. Both units passed the manufacturer's acceptance test procedures and were determined to be serviceable.

Recorded data

Flight recorders

The aircraft was not equipped with either a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR). It had previously been equipped with a CVR but this was removed when the aircraft was transferred onto the UK register in 1998.

G-VUEM was not required to carry recorders under the regulations for turbine-powered aircraft applicable at the time of manufacture, since its maximum certified takeoff mass was below the specified 5,700 kg, and its maximum approved passenger seating configuration was less than the 10 specified. However, in the latest edition of Part 1 of Annex 6, *Operation of Aircraft,* (International Standards and Recommended Practices) to the Convention on International Civil Aviation[5], the International Civil Aviation Organization (ICAO) requires as a Standard that, from 1 January 2016, all newly type certificated turbine-powered aircraft with a takeoff mass of 5,700 kg or less be equipped with recorders. For aircraft that are built after 1 January 2016 but to a pre-2016 type certificate, ICAO also recommends that recorders should be fitted.

Radar

Recorded radar data from the Clee Hill radar head gave positional information for G-VUEM every eight seconds during its approach to Birmingham Airport.

Footnote

[5] Ninth Edition (July 2010) which incorporates all amendments adopted by the Council prior to 27 February 2010 and supersedes, on 18 November 2010, all previous editions of Part 1 of Annex 6.

The aircraft was fitted with a Mode S transponder, so this radar data included altitude information which, for this installation, had a resolution of ±50 ft. Figure 3 illustrates the approach to Runway 15 from about 5 nm out, with the last radar return (1535 hrs) placing the aircraft about 100 m from the glideslope antenna (shown).

Figure 4 plots the approach of G-VUEM relative to the 3° glideslope and localiser (½ dot deviation lines are indicated). The aircraft's (calculated) groundspeed and intercept angle at the points where the track crosses the runway centreline are also shown, together with any significant R/T extracts. With about 3 nm to touchdown, there is a reduction in the precision and predictability of the flight path, consistent with a change from autopilot to manual flying. This point is highlighted.

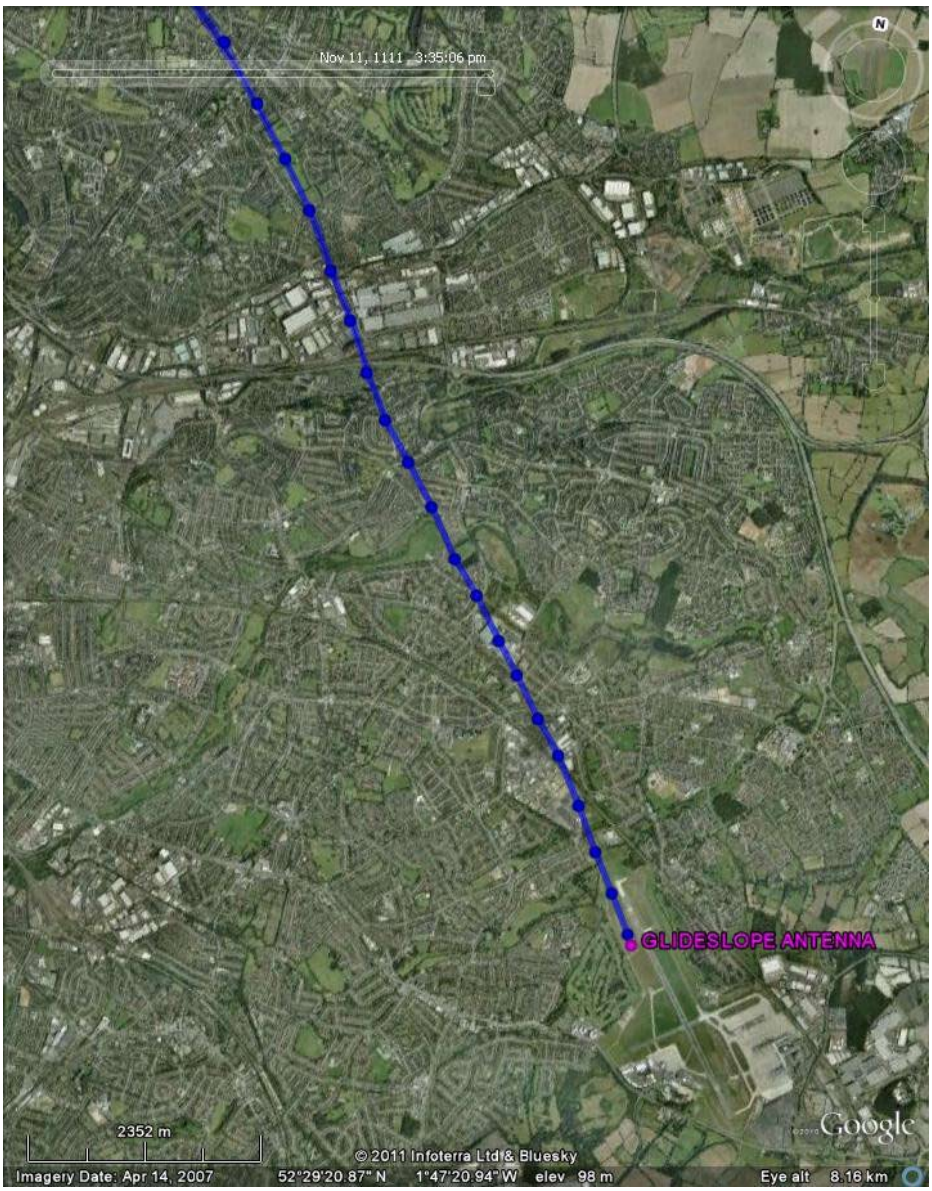

Figure 3

Approach to Runway 15 from about 5 nm of G-VUEM based radar information

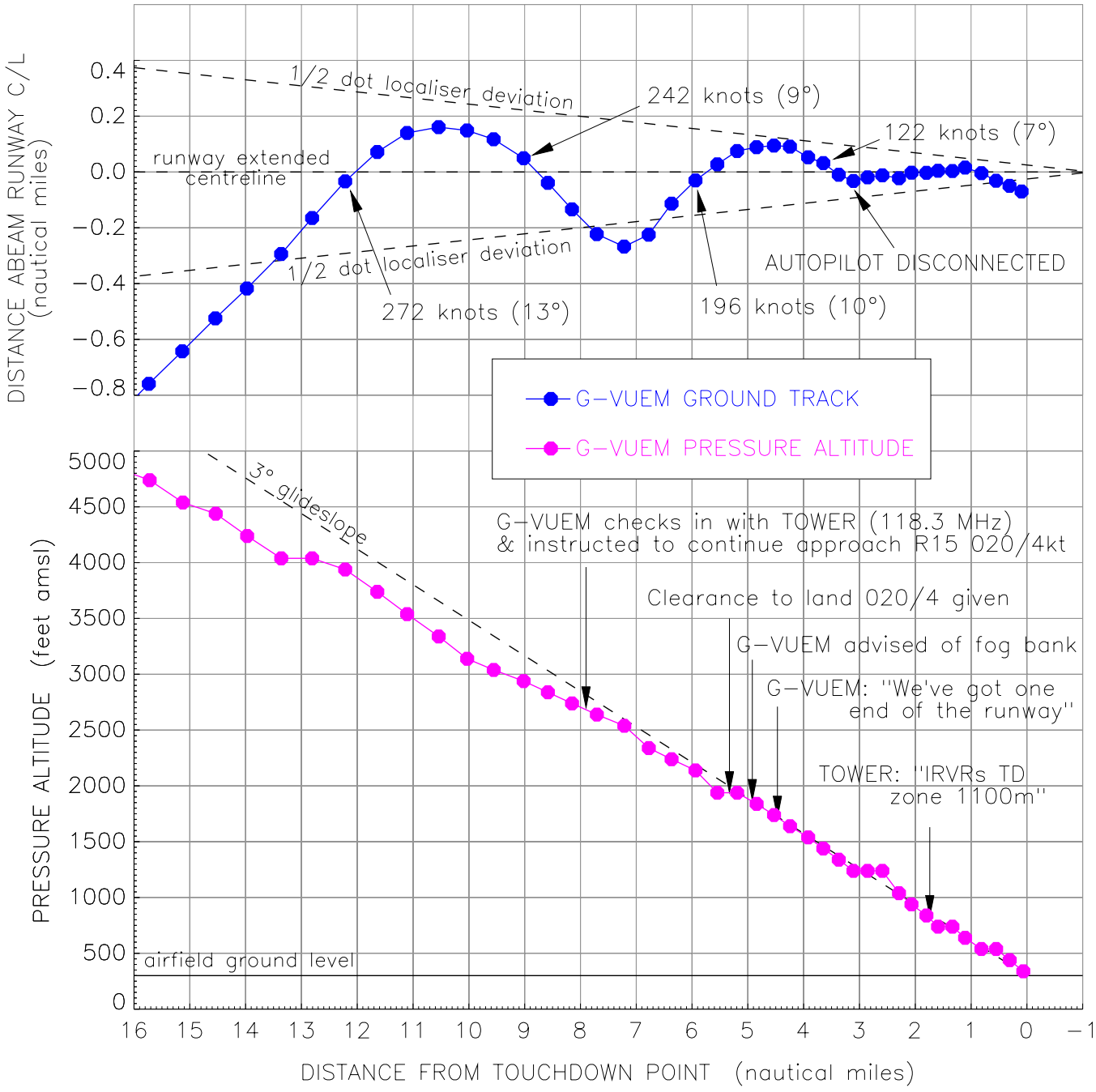

Figure 4

The position and height of G-VUEM relative to the glideslope and localiser (based on radar information) during the approach to Runway 15

Surface movement radar

Surface movement radar recordings were also available to the investigation. However, these recordings were of little use since their coverage did not include the area to the side of the runway where the accident happened. The radar coverage itself does cover the airfield but the information displayed to the tower controllers, and subsequently recorded, is masked and only shows movement on the taxiways and runways.

CCTV

CCTV footage, taken from below the ATC tower, captured images in the direction of the crash site shortly after the landing, one of which is illustrated in Figure 5. This figure shows the extent of the fog bank over the northwest corner of the airfield.

Operator information

The operator provided Standard Operating Procedures (SOPs) in their Operations Manual (OM). There were no specific extra weather minima laid down for co-pilots to conduct approaches; such decisions were left to the discretion of the commander.

Stable approach criteria were published as follows:

> *'ALL approaches are to be made such that by 1,000 ft the aircraft is wings level, in the landing configuration at not more than Vref+10 KIAS, established on the published final approach course, and be unambiguously achieving the published (or nominal) descent slope without frequent or significant deviations in speed or rate of descent.'*

Figure 5

Frame from CCTV footage showing the fog bank and mushroom cloud from the post-crash fire

The following information was provided concerning an approach ban:

> *'Once past the Outer Marker or equivalent position the approach may be continued to landing irrespective of reported RVR/Vis provided that the required visual reference has been established at the DA/DH or MDA/MDH, and is maintained.'*

The OM stated that it was the non-handling pilot's (NHP) responsibility to monitor the approach and make the SOP calls. Standard calls to be made by the NHP on approach were: at the Outer Marker or 4 miles, as appropriate, an altitude crosscheck; a *'500 feet above'* DA call; a *'100 feet above'* DA call, and a '*decision*' call at the DA. There was also provision for calls for deviations from an expected profile. For example, with the beambar at half scale and increasing, the call was *'Beambar – go right (or left)'*.

Analysis

The TAF for Birmingham indicated there was a likelihood of fog in the morning followed by an improvement after 1200 hrs, although a fog warning remained effective up to 1600 hrs. The 1420 hrs METAR reported good visibility. En-route to Birmingham, ATIS 'E' was obtained by the crew and it also reported good visibility, with some cloud at 700 ft agl. On the approach, the commander sighted the airfield from some distance and the stable approach criteria were met by 1,000 ft aal. Thus, the circumstances were such that the crew could reasonably have expected to complete the approach in visual conditions.

In fact, the conditions were not as expected. Witnesses at the airfield described the weather as extremely unusual, both for the sharp delineation between the fog and the area of clear visibility, with blue sky and sunshine, and for the speed with which the fog engulfed the airfield. Between 1522 hrs and 1525 hrs the wind changed in direction from southerly to northerly. The fog stayed to the north of the airfield for as long as the southerly wind prevailed, but when it changed the fog moved towards the field and eventually covered it. Between 1532 hrs and 1535 hrs, the visibility at the touchdown instrumented runway visual range (IRVR) transmissometer reduced from 1,400 m to 375 m. The threshold for Runway 15 is displaced, therefore the reduction in visibility would have affected the final approach a few minutes earlier.

Airfield safeguarding was in progress, in anticipation of the introduction of LVPs and a possible runway change. However, at the time of the commencement of G-VUEM's approach, the recorded IRVRs, indicated that the conditions were still better than required for Category 1 operations.

The initial attempt to capture the localiser was made at an intercept angle of 15° and a groundspeed of 254 kt. Although on a suitable track, the airspeed was probably too fast for the autopilot to be able to capture the localiser course and the aircraft overshot the centreline several times before the co-pilot disconnected the autopilot and intercepted manually. The speed reduced steadily and the required approach speed was achieved by 1,000 ft aal. Once established on the approach, the localiser and glideslope were followed down to a height of around 300 feet aal, a point which corresponded to the SOP '*100 feet above*' call.

At this time, the aircraft was displaced slightly to the left of the localiser and a corrective heading of 7° to the right was made. The aircraft then continued on this heading, while maintaining the same rate of descent on

the glideslope, until the point of impact. There were no changes to the aircraft's flightpath below 300 ft aal, which suggests that no further control inputs were made from around this time. The evidence from the wreckage examination is that, at the point of impact, the aircraft was approximately wings level and continuing on a steady track, thus no attempt had been made to go around.

Both pilots recalled the '*500 feet above*' and the '*100 feet above*' SOP calls being made but both were clear that there had been no '*decision*' call. The '*decision*' call should have been made about 10 seconds after the '*100 feet above*' call. The time from the aircraft being at a height of 300 ft aal ('*100 feet above*') to its impact with the mast was in the order of 25 seconds. Therefore, the approach had continued for a period of some 15 seconds with the aircraft descending below minima, without visual reference being obtained.

It was considered whether the SOP calls relating to the minima could have been incorrect. The post-crash evidence showed that the altimeter subscales were set correctly and that the minima recorded on the bug card were also correct. The absence of altimeter 'bugs' makes it more likely that an error may be made, causing SOP height calls to be missed. However, there were several indications that this was not the reason for the accident and it is thought probable that the minima were correctly interpreted.

The evidence suggests that the top of the fog bank coincided with the '*100 feet above*' point on the approach. Up to that point the commander probably had good external visual references, although the touchdown zone would not have been in view. The co-pilot, as the handling pilot, would have had all his attention focused on the instruments. The commander reported having looked outside the aircraft to try to acquire visual reference after making the '*100 feet above*' call. It is probable that at about this time the aircraft entered the fog and all external visual references would have disappeared suddenly. Although the approach lights were at full brightness, they were not seen. The commander may have become absorbed with seeking visual reference, in the unexpectedly altered conditions, and thereby distracted from the primary task of monitoring the approach and making the SOP '*decision*' call. He had no perception of the passage of time from the '*100 feet above*' call, believing that only a few seconds elapsed before he saw the glideslope antenna ahead of the aircraft. In fact, the elapsed time would have been around 25 seconds.

The co-pilot's task of flying the approach would have become increasingly demanding as the aircraft descended and it is probable that his attention was fully absorbed by this. This was confirmed by his erroneous perception that the aircraft was in IMC from below 2,000 feet amsl. The co-pilot reported that during the final stages of the approach, when he noticed he had lost the localiser indication, he had asked the commander whether he should go around. The response he reported he heard of "no, go left" was not what he had expected, and may correspond to the time from which no further control inputs were made. The commander could not recall having given any instructions to the co-pilot after the '*100 feet above*' call.

It is likely that the crew commenced the approach with an expectation that it would be completed visually. However, the weather conditions were unusual and the aircraft entered IMC unexpectedly, late in the approach. As an aircraft gets closer to a runway the localiser and glideslope indications become increasingly sensitive and small corrections have a relatively large effect. The

task for the flying pilot becomes more demanding and the role of the monitoring pilot has greater significance. A successful outcome relies on effective crew co-ordination, based on clear SOPs. The monitoring of this approach broke down in the latter stages and the crucial 'decision' call was missed, which led to the aircraft's descent below minima.

Ignition source of the fire

The nature of the sooting pattern left on the accident site's grass surface indicates that a short duration 'flash' fire of vaporised fuel had occurred, following rupture of the aircraft's left wing fuel tank. A longer duration fire, fed by fuel continuing to leak from the damaged left wing, caused considerable damage to the left side of the aircraft. This fire continued for approximately three minutes, until extinguished by the RFFS.

Since the area of burned grass originated 3 m closer to the ILS glideslope antenna tower than the first ground impact mark, it is possible that the fire could have started immediately after the aircraft's collision with the tower. Possible ignition sources in this scenario include electrical arcing from the tower's exposed electrical cables, sparks caused by metal-to-metal contact during the collision, and fuel vapour ingestion into the left engine.

However, another possible scenario was that the fire started at some point following the aircraft's initial ground impact. If this were the case, the fuel vapour released following the aircraft's collision with the tower could have ignited, causing the sooting pattern observed at the accident site.

Fire-fighting appliance access to the accident site

The area of ground where the aircraft stopped was within the runway strip and, at the time of the accident, this grass area was soft due to recent rainfall. The omission by the driver of one appliance to engage the vehicle's differential locks, prior to driving on the soft grass surface, led to this appliance becoming bogged down. The other three appliances were able to traverse the difficult ground conditions successfully with their differential locks engaged.

Safety action

After the accident, the aircraft operator considered whether changes to their operating procedures might be made to prevent the possibility of a similar accident occurring again. A flight crew notice was issued concerning the conduct of instrument approaches. The significant changes were that all IMC approaches should, where possible, be flown with the autopilot engaged. Should this not be possible, then use of the flight director should be made. This would require the left seat pilot to act as pilot flying because there is no flight director available on the right hand instrument panel.

The Air Traffic Services provider at the airport conducted their own internal investigation. Several safety actions were identified, to be followed up. One action was for the airport operator to give consideration to the provision of recording raw surface movement radar data.

The aerodrome's RFFS personnel, who receive annual off-road driver training, have been reminded of the importance of ensuring that their appliances' differential locks are engaged before the vehicle leaves a paved surface, in the event that they are required to respond to an 'off-road' situation.