AAIB
Air Accidents Investigation Branch

# AAIB Bulletin 10/2015

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*Cover picture courtesy of Richard Ross*



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AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

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AAIB
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# AAIB Bulletin 3/2015 *SPECIAL*

**ACCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Hawker Hunter T7, G-BXFI |
| **No & Type of Engines:** | 1 x Rolls-Royce Avon Mk 122 turbojet engine |
| **Year of Manufacture:** | 1959 (Serial no: 41H-670815) |
| **Location:** | Near Shoreham Airport, West Sussex |
| **Date & Time (UTC):** | 22 August 2015 at 1222 hrs |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - 1 (Serious) Passengers - N/A<br>Other - 11 (Fatal) |
| **Nature of Damage:** | Aircraft destroyed |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 51 years |
| **Flying experience:** | 14,249 hours (of which 40 hours were on type)<br>Last 90 days - 115 hours<br>Last 28 days - 53 hours |
| **Information Source:** | AAIB Field Investigation<br>All times in this bulletin are UTC |

**The investigation**

The AAIB was notified of the accident at 1235 hrs on Saturday 22 August 2015 and immediately initiated a Field Investigation. This Special Bulletin is published to provide preliminary information gathered from ground inspection, radar data, recorded images and other sources.

## Synopsis

The aircraft was taking part in an air display at Shoreham Airport during which it conducted a manoeuvre with both a vertical and rolling component, at the apex of which it was inverted. Following the subsequent descent, the aircraft did not achieve level flight before it struck the westbound carriageway of the A27.

## History of the flight

The Hawker Hunter aircraft was scheduled to carry out a display of aerobatic manoeuvres at the Royal Air Forces Association (RAFA) airshow at Shoreham Airport in West Sussex. The pilot had flown his light aircraft to North Weald Airfield in Essex where the Hunter was based. The Daily Inspection, valid for 24 hours, had been carried out the previous afternoon by an engineer and on the day of the flight the pilot carried out a pre-flight inspection and signed the aircraft Technical Log. There were no reported defects. He requested the aircraft to be refuelled to full and this was carried out by the two ground crew. The pilot was described as being in good spirits and looking forward to the flight.

The weather was good and, at the time of departure from North Weald, the nearest recorded actual weather was at Stansted Airport with a surface wind 150° at 14 kt, no cloud below 5,000 ft, visibility more than 10 km, temperature 28°C, dewpoint 16°C and the QNH 1014 hPa.

When all preparations were complete, the pilot occupied the left seat and secured his harness before putting on his helmet. The engine start was normal and the aircraft took off from Runway 02, which had a downslope, with a tail wind of approximately 8 kt. The takeoff run was longer than usual, probably due to the ambient conditions and, once airborne, the aircraft flew to Shoreham.

The flight towards Shoreham was uneventful and, having descended to 1,000 ft above mean sea level (amsl) the aircraft carried out a left orbit offshore at Brighton between 2,300 ft and 2,500 ft amsl. The pilot was cleared to commence his display and, remaining offshore, flew along the coast towards the airfield. At 1220 hrs Shoreham Airport reported that the wind was from 120° at 12 kt, with no significant cloud and visibility of more than 10 km. The surface temperature was 24° C, dewpoint 17°C and QNH[1] 1013 hPa.

The pilot flew parallel to the coast in a gradual descent during part of which he flew inverted. This may have been to check that there were no loose articles in the cockpit before his display.

**Footnote**

[1] Barometric pressure adjusted to sea level.

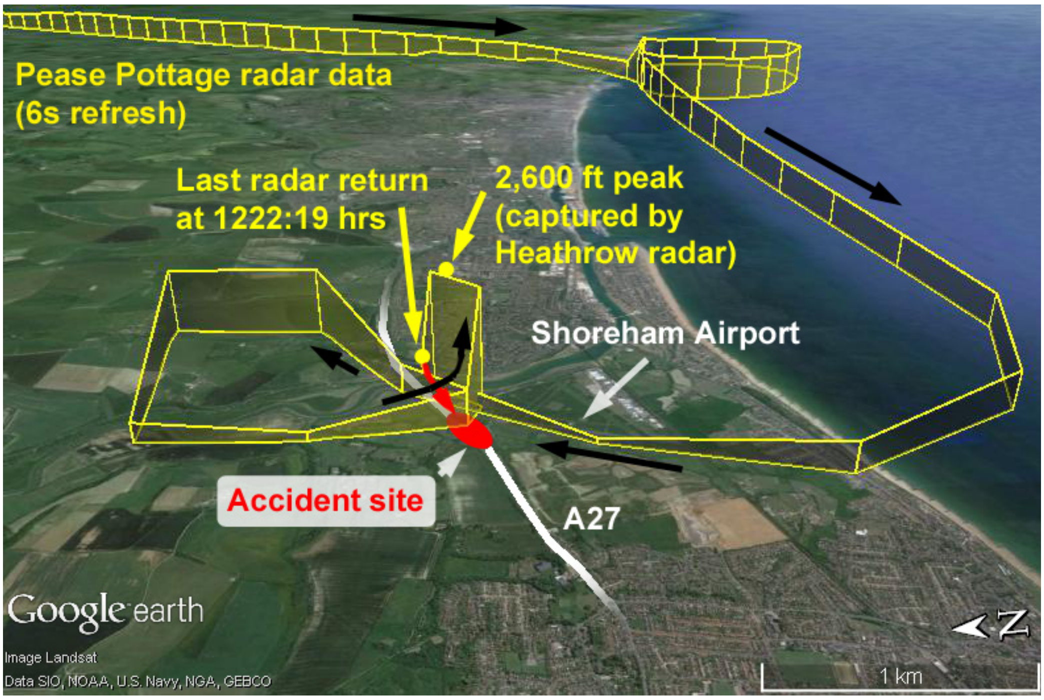


**Figure 1**

Approximate flight path derived from Pease Pottage radar data

Having rolled upright and wings level, the descent was continued to 800 ft amsl and a right turn made to line up with the display line to the west of Runway 02/20 at Shoreham (see Figure 1). The aircraft remained in a gentle right turn with the angle of bank decreasing as it descended to 100 ft amsl and flew along the display line. It commenced a gentle climbing right turn to 1,600 ft amsl, executing a Derry turn[2] to the left and then commenced a descending left turn to 200 ft amsl, approaching the display line at an angle of about 45º. The aircraft then pitched up into a manoeuvre with both a vertical component and roll to the left, becoming almost fully inverted at the apex of the manoeuvre at a height of approximately 2,600 ft amsl. During the descent the aircraft accelerated and the nose was raised but the aircraft did not achieve level flight before it struck the westbound carriageway of the A27 at its junction with Old Shoreham Road.

**Footnote**

[2] A 'Derry turn' is executed by rolling the aircraft 270° about its longitudinal axis in the direction opposite to that of the desired turn. When the roll angle reaches 270°, the roll is stopped and nose up elevator is applied to pull the aircraft into the turn.

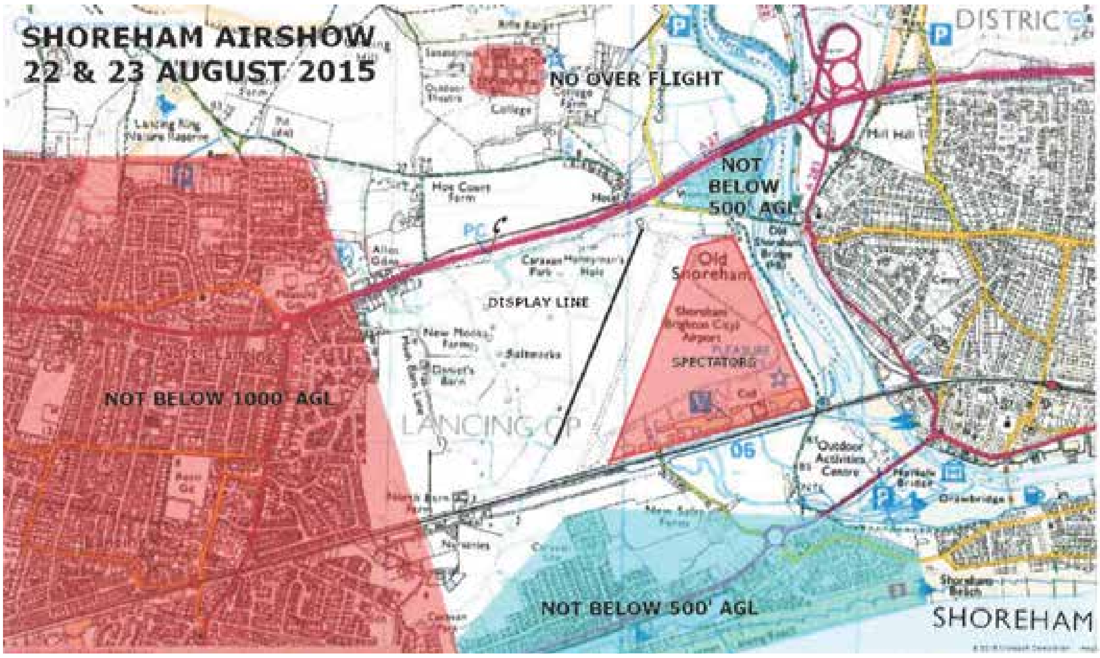


**Figure 2**

The Shoreham Airport display map

## Aerodrome information

Shoreham Airport is located 1 nm west of Shoreham-by-Sea. The aerodrome has three runways: an asphalt surfaced main runway orientated 02/20, 1,036 metres long with a width of 18 metres; and two grass runways, 07/25 and 13/31. The aerodrome is 7 ft above mean sea level.

A large organised air display was being undertaken with the required minimum separation from the crowd determined according to aircraft speed and the type of display being flown. The relevant display axis for G-BXFI was 230 m from the crowd line, parallel with, and on the other side of, the main runway. The extended centreline of the display axis therefore passed through the junction of the A27 and Old Shoreham Road.

Local restrictions were in place directing pilots not to overfly Lancing College buildings, residential areas at Lancing below 1,000 ft, or Shoreham Beach below 500 ft.

A copy of the of the Shoreham Airport display map is shown at Figure 2 above.

## Pilot's qualification and experience

The pilot had received flying training in the Royal Air Force and had served as an instructor and fast jet pilot before entering commercial aviation. He held a European Union Airline Transport Pilot's Licence (ATPL) which was valid for the lifetime of the pilot. An Aircraft Type Rating Exemption (Full) was issued by the United Kingdom Civil Aviation Authority (UK CAA) on 27 August 2014 enabling him to fly the Hawker Hunter, Jet Provost Mk 1-5 and Strikemaster aeroplanes, valid until 27 August 2015. He held a European Union

Class 1 Medical Certificate with no limitations, issued on 20 January 2015 and valid until 31 January 2016. He held a valid Display Authorisation (DA), issued by the UK CAA, to display the Hawker Hunter to a minimum height of 100 ft during flypasts and 500 ft during Standard[1] category aerobatic manoeuvres. He had also met the requirement stipulated in Schedule 2 of his DA to have flown:

> *'three full display sequences, one of which was on the aircraft to be displayed, not more than 90 days prior to the flight in question.'*

From the pilot's electronic logbook, it was established that the pilot had flown a total of 40.25 hours in the Hunter since 26 May 2011, of which 9.7 hours had been flown in the last 90 days and 2.1 hours in the last 28 days. He had also flown air displays in other types of aircraft, and the investigation will study his other logbooks for further information.

## Engineering investigation

*Recorded Data*

The aircraft was not fitted with a flight recorder and no flight path information was recovered from the aircraft GPS.

The accident flight was recorded by the NATS radar facility at Pease Pottage. The maximum altitude recorded during the final manoeuvre was 2,600 ft amsl (recorded by Heathrow radar), which may not reflect the peak altitude achieved because the radar data was not continuous.

The investigation is analysing audio recordings of air traffic control communications.

Two image recording cameras were mounted within the cockpit. One was located on the aft cockpit bulkhead between the two seats, giving a partial view of the pilot and instrument panel, and a view through the cockpit canopy and windscreen. To date no abnormal indications have been identified. Throughout the flight, the aircraft appeared to be responding to the pilot's control inputs. The other video camera was mounted at the base of the windscreen, looking over the nose.

Cockpit imagery is being analysed to help understand the final manoeuvre in more detail and to provide system status information. Initial findings indicate that the minimum air speed of the aircraft was approximately 100 KIAS whilst inverted at the top of the manoeuvre. The associated audio recording is being analysed for information relating to the aircraft systems.

The AAIB has received a large amount of video footage and photographs of the aircraft, many of which were taken in high resolution, from a variety of locations on and around Shoreham Airport. An analysis of the information using photogrammetry techniques will be undertaken to establish the parameters of the aircraft manoeuvres, including flight path and speed.

**Footnote**

[1] As defined in Chapter 6 of Civil Air Publication (CAP) 403 – *'Flying displays and special events: A guide to safety and administrative Arrangements'* published by the UK CAA.

*Aircraft description*

The Hawker Hunter T7 is a single-engine advanced military jet trainer capable of speeds close to the speed of sound. G-BXFI was built in 1955 as a single-seat aircraft, but subsequently it was modified to a two-seat trainer in 1959[1]. Both pilot positions were fitted with ejection seats. It remained in military service until 1997, when it was transferred to the civilian register. Figure 3 shows the aircraft during the 'fly past' at the commencement of the display.

**Figure 3**

Hawker Hunter G-BXFI during the initial 'fly past'.

(Photo courtesy N Watkin)

*Pre-flight technical activity*

The aircraft was operated on a CAA-issued Permit to Fly and its current Certificate of Validity was valid until 10 March 2016. There were no technical defects recorded in the aircraft Technical Log.

The aircraft and its two under-wing tanks were fully fuelled before the flight. Ground crew reported that the pre-flight checks and engine start were normal and that the safety pins for the pilot's ejection seat had been removed and placed in the stowage provided prior to departure to arm the seat and its associated systems.

*Accident site and wreckage recovery*

The aircraft crashed on to the westbound carriageway of the A27 road near its junction with Old Shoreham Road and Coombes Road, which is close to the northern perimeter of Shoreham Airport. During the impact sequence, the aircraft struck vehicles and persons

**Footnote**

1 This information is based on research completed to date. The year of manufacture stated at the beginning of this Special Bulletin corresponds to the '*year built*' as recorded by the UK CAA.

around the road junction. Traffic light stanchions, road signs and a crash barrier in the vicinity were also struck.

The ground marks and photographic evidence show that the aircraft struck the road in a nose-high attitude on a magnetic heading of approximately 230°. The first ground contact was made by the lower portion of the jetpipe fairing, approximately 50 m east of the road junction. During the impact sequence fuel and fuel vapour from the fuel tanks was released and then ignited. The aircraft broke into four main pieces which came to rest close together approximately 243 m from the initial ground contact, in a shallow overgrown depression to the south of the A27.

During the initial part of the impact sequence the jettisonable aircraft canopy was released, landing in a tree close to the main aircraft wreckage. During the latter part of the impact sequence, both the pilot and his seat were thrown clear from the cockpit. The pilot sustained serious injuries. The investigation continues to determine if the pilot attempted to initiate ejection or if the canopy and pilot's seat were liberated as a result of impact damage to the cockpit.

Most of the aircraft wreckage has been recovered and transported to the AAIB facilities at Farnborough where it will be subject to further detailed examination. Work continues to recover smaller wreckage from the accident site.

**Further investigation**

Further investigation by the AAIB will examine the aircraft and its maintenance records to determine its condition before the accident. It will also explore the operation of the aircraft, the organisation of the event with regard to public safety, and associated regulatory issues.

The AAIB will report any significant developments as the investigation progresses.

*Published 4 September 2015*

## AAIB Field Investigation Reports

A field investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

**SERIOUS INCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Boeing 747-443, G-VROM |
| **No & Type of Engines:** | 4 General Electric CF6-80C2B1F turbofan engines |
| **Year of Manufacture:** | 2001 (Serial no: 32339) |
| **Date & Time (UTC):** | 29 December 2014 at 1334 hrs |
| **Location:** | Near London Gatwick Airport |
| **Type of Flight:** | Commercial Air Transport (Passenger) |
| **Persons on Board:** | Crew - 18 Passengers - 447 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Damage to right wing landing gear door and strike board |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 47 years |
| **Commander's Flying Experience:** | 12,279 hours (of which 9,771 were on type)<br>Last 90 days - 162 hours<br>Last 28 days - 95 hours |
| **Information Source:** | AAIB Field Investigation |

## Synopsis

The aircraft departed from London Gatwick Airport for a scheduled flight to Las Vegas. Following retraction of the landing gear after takeoff, low quantity and pressure warnings occurred on hydraulic system 4, due to a hydraulic fluid leak. The required checklists were completed and the aircraft returned to land at London Gatwick Airport. As the landing gear extended during the approach, the right wing landing gear struck the gear door, preventing the gear leg from fully deploying. The crew carried out a go-around and, following a period of troubleshooting and associated preparation, a non-normal landing was successfully completed. It was subsequently determined that the hydraulic retract actuator on the right wing landing gear had been incorrectly installed. Four Safety Recommendations have been made.

## History of the flight

The flight was scheduled to depart at 1120 hrs on 29 December 2014. Three pilots were rostered for the flight, a commander, a co-pilot and a relief co-pilot. The pre-flight planning was uneventful and no defects on the aircraft were advised to the crew.

On their arrival at the aircraft the flight crew learned that maintenance had been carried out overnight. The relief co-pilot, who conducted the pre-flight walkround inspection, noticed that the landing gear locking pins were still in place and a request was made for these to be removed. Passenger boarding was completed on time and the aircraft was ready to depart on schedule, but there was a short delay while final maintenance paperwork was completed. The aircraft pushed back from the stand at 1129 hrs.

The aircraft commander, occupying the left seat, was the Pilot Not Flying (PNF) and the co-pilot, occupying the right seat, was the Pilot Flying (PF). The relief co-pilot was seated on the flight deck jumpseat.

The takeoff commenced from Runway 26L at 1143 hrs. As the aircraft climbed towards 1,000 ft aal, with the landing gear retracted and the autopilot not engaged, there was a 'HYD QTY LOW 4' Engine Indicating and Crew Alerting System (EICAS) advisory message. The pilots checked the associated hydraulic system synoptic page and noted the system 4 hydraulic quantity was decreasing rapidly. As the aircraft climbed, the flap retraction was carried out and the autopilot was engaged.

The relief co-pilot started to review the paper Quick Reference Handbook (QRH), but as he was doing so the 'HYD PRESS SYS 4' EICAS caution activated. The checklist for this failure was called for and actioned as the aircraft continued to climb to FL320. Once all the required checklist actions had been completed, the crew reviewed the status of the aircraft. They determined that the failure had been contained and that it would be possible to continue to their destination.

The relief co-pilot contacted the operator's maintenance control department on the company communication frequency and advised them of the hydraulic system problem. The operator requested that the aircraft should return to London Gatwick Airport.

The aircraft was too heavy for an immediate return to land, so the crew advised Air Traffic Control (ATC) of their intention and subsequently held for around 40 minutes as fuel was jettisoned.

During this time the crew reviewed the QRH to understand the procedures that would be required for landing and to calculate the required landing distance. The inoperative items associated with the loss of hydraulic system 4 are shown in Figure 1.

The cabin crew and passengers were briefed on the situation and when the fuel jettison had been completed, the crew notified ATC that they were ready to return to London Gatwick Airport. The weather conditions were clear with a surface wind from 280° at 6 kt, CAVOK, temperature 4°C, dewpoint 1°C and pressure 1040 hPa. A 20 nm final approach was requested to allow time for the anticipated slow flap extension and alternate gear extension. At 1325 hrs the crew started to configure the aircraft for the approach.

The aircraft was on the extended centreline for Runway 26L, with flap deployed to 10°, when the alternate gear extension procedure was started. The QRH procedure for alternate gear extension is shown in Figure 9.

**System 4**

**Note: Inoperative Items**

**Right outboard elevator inop**
Pitch control is reduced.

**Outboard trailing edge flap hydraulic operation inop**
Trailing edge flaps move in secondary mode. Secondary extension from flaps 1 to 5 requires approximately 4 minutes. During approach, allow extra time for flap extension.

**Two inboard spoiler panels on each wing inop**
Roll rate and spoiler capability are reduced.

**Wing gear hydraulic extension and retraction inop**
Alternate gear extension is needed.

**System 4 normal brake source inop**
System 1 and system 2 alternate brake sources are available.

**Autobrake inop**
Manual braking is needed.



**Figure 1**

Hydraulic System 4, inoperative items (from QRH)

After the procedure was carried out the flight crew realised that the right wing landing gear had failed to lock down. The aircraft was levelled at 3,000 ft and continued to fly straight ahead. The commander made a radio call to ATC to advise they had experienced a problem with the landing gear and requested a visual inspection as they passed in front of the tower. The flight crew were advised by ATC that the right wing landing gear was not visible.

The aircraft was given radar vectors to an area south of the airport where an extended period of troubleshooting took place. The QRH checklist for alternate gear extension (see Figure 9) did not offer an option for the case where all the gear are not DOWN after extension. The flight crew discussed this inconsistency and decided to select the landing gear lever DOWN. A GEAR DISAGREE EICAS message was generated.

The flight crew contacted the company Integrated Operations Control Centre (IOCC), who were able to establish direct contact with an advisor from the aircraft manufacturer. The flight crew consulted the onboard manuals, liaised further with the IOCC, briefed the cabin crew and the passengers on the aircraft status, and briefed themselves on how the approach should be conducted and the handling implications. They commented afterwards that having an additional pilot was very helpful in the task sharing process.

The crew read through the '*GEAR DISAGREE*' QRH checklist, part of which required the gear lever to be selected UP. They decided not to action this item but instead, as recommended by the manufacturer through the IOCC, selected the gear lever to OFF and recycled the alternate gear extend switches. This had no effect. Several unsuccessful attempts were made to lock the gear out by manoeuvring the aircraft, in a climb, a descent and in turns. Following these manoeuvres the crew prepared for a non-normal landing on the available landing gear in accordance with the '*GEAR DISAGREE*' and *'Emergency Landing'* QRH checklists.

The commander was concerned that the fuel should be reduced to a minimum level whilst leaving sufficient for a go-around if required, and aimed for approximately one hour endurance. He also considered it preferable to land in daylight; sunset was at 1601 hrs. Accordingly the aircraft remained in a holding pattern until sufficient fuel had been consumed, and the time of sunset was approaching.

Once again a 20 nm final approach segment was requested and the second approach started at 1540 hrs. The commander assumed the PF role, in accordance with their briefing, at around 10 nm inbound and the aircraft landed at 1545 hrs. On the landing roll the aircraft maintained the runway centreline and came to a stop, in a right wing low attitude of approximately 4°. The commander assessed the situation and decided that a passenger evacuation was not required. The passengers were requested to remain seated while the aircraft was given an external inspection, first by the attending fire crews and subsequently by the operator's maintenance personnel. The engines were shut down and the crew liaised with the Rescue and Fire Fighting Service (RFFS) on frequency 121.6 MHz.

The passengers remained on-board while the aircraft was checked for stability, to ensure that the disembarkation could be completed safely. The aircraft remained on the runway and disembarkation started under the supervision of the RFFS at 1630 hrs and was completed an hour and a half later.

**Initial aircraft inspection**

Once the passengers had been disembarked, an initial inspection of the landing gear was conducted. The right wing landing gear door was partially open, with the outboard rear wheel of the wing gear resting on the outboard section of the door. The outboard section of the door was significantly deformed, but the door itself was still firmly attached and the gear was securely held in a partially deployed position. (Figure 2) Evidence of leaking hydraulic fluid was found around the upper section of the gear leg, but there was no obvious damage to the wing gear in the areas visible during initial inspection. The lower section of the strike board in the right wing landing gear bay was missing.


**Figure 2**

Right wing landing gear door and gear leg as found just after landing.

The left wing gear door was in the fully open position, as were the two body landing gear doors. None of the landing gear doors showed evidence of contact with the ground. Both the body landing gears and the left wing landing gear were undamaged, although the uneven weight distribution caused by the non-weight bearing right wing landing gear, meant the aircraft was canted over to the right, such that the outboard wheels of the left wing landing gear were no longer in contact with the ground. This also resulted in the engine nacelle of the number three engine on the right wing being significantly closer to the ground than normal. However, no evidence was found that the engine had contacted the ground during the landing.

### Detailed inspection of the wing landing gear

The aircraft was recovered from the runway and towed to the operator's hangar for further investigation. The damaged wing landing gear door was removed and the right wing landing gear leg fully extended. The right wing landing gear actuator was found installed 180° out of alignment. The hydraulic port boss fitting on the head end of the actuator was distorted and damaged (see Figure 3).


**Figure 3**
Damaged hydraulic port on landing gear actuator

### Missing strike board

Approximately three months after the incident, an object was found by a farmer in his field near Tonbridge in Kent. He reported this to the CAA, who recovered the item. Whilst there were no identification numbers on the component, it was visually confirmed as a strike board from a Boeing 747, and was passed to the AAIB. Using data from radar and the aircraft FDR, a comparison of the flight path and timing of the original gear extension showed this coincided exactly with the location where the strike board was found, giving a high probability that the recovered item was from G-VROM.

## Recorded data

*Flight Recorders*

The aircraft was fitted with a solid state flight data recorder (FDR) and cockpit voice recorder (CVR). These were downloaded at the AAIB where the recordings were analysed. The duration of the CVR was two hours and consequently the recording only captured the latter two hours of the flight (which lasted just over four hours) starting at 1348 hrs when G-VROM had descended to 3,000 ft, and was in a holding pattern.

Relevant data from the FDR is presented in Figure 4 for the whole flight although for the landing gear, these were restricted to gear lever position, all gear down and locked, and gear disagree discretes. Alternate gear selection or individual gear positions were not recorded. The radar track for the flight is presented in Figure 5.

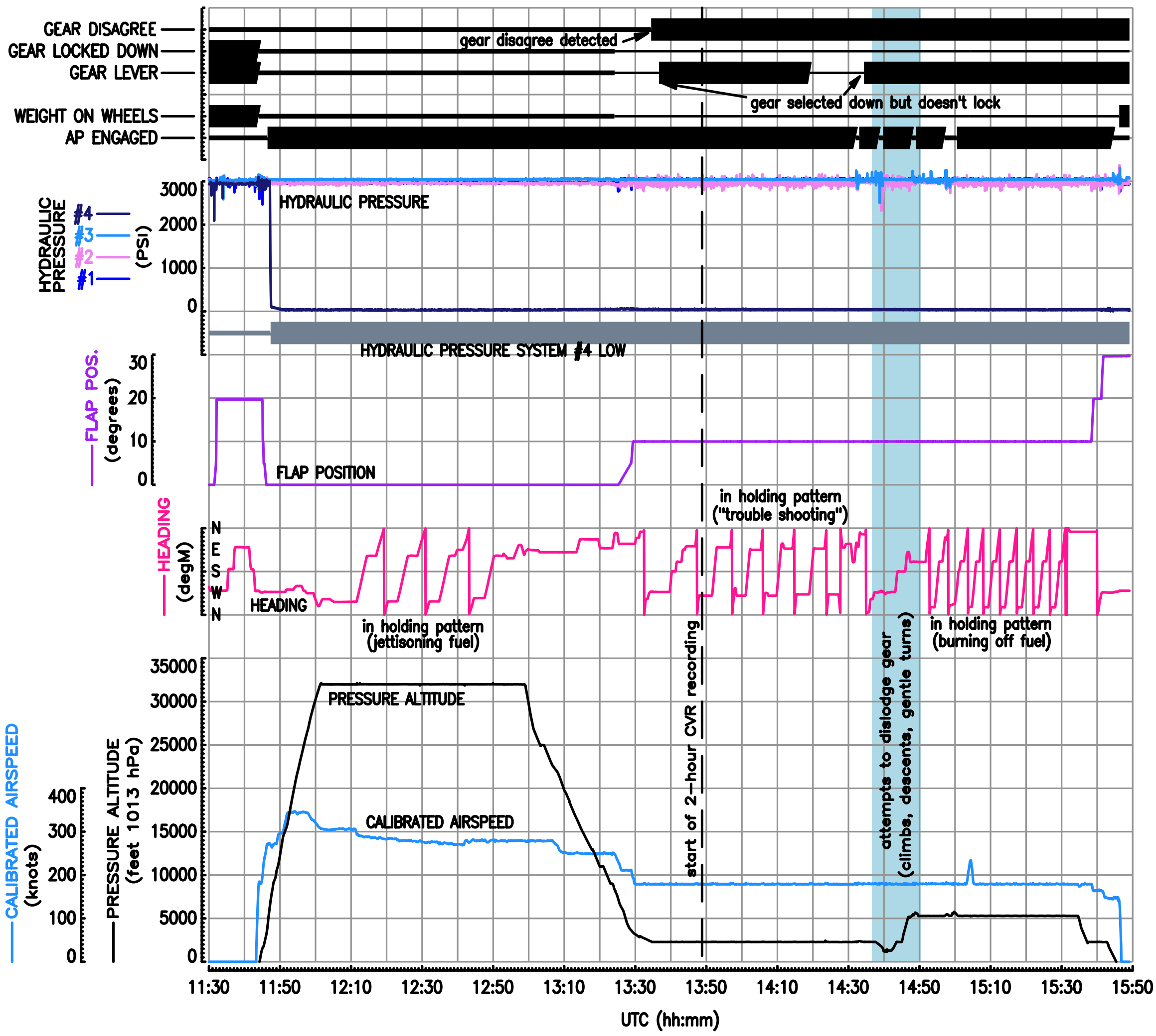


**Figure 4**

Salient data from FDR

The analysis of the recorded data provided the following timeline:

| | | | |
|---|---|---|---|
| ● | 1129 hrs | - | G-VROM pushback from stand at London Gatwick Airport |
| ● | 1144 hrs | - | G-VROM airborne |
| ● | 1147 hrs | - | Climbing through 6,000 ft amsl, hydraulic system 4 starts to lose pressure, falling from 3,000 psi to 120 psi in 30 seconds |
| ● | 1201 hrs | - | Levels off at FL310 |
| ● | 1212 hrs | - | In holding pattern for about 40 minutes |
| ● | 1259 hrs | - | Start of gentle descent reaching 3,000 ft 35 minutes later |
| ● | 1334 hrs | - | Gear disagree as G-VROM levels off at 3,000 ft and remains in this state for the rest of the flight |
| ● | 1337 hrs | - | Gear lever selected gear down – gear does not lock down |
| ● | 1344 hrs | - | In holding pattern as crew attempt to troubleshoot problem |
| ● | 1419 hrs | - | Gear lever selected gear up/off |
| ● | 1434 hrs | - | Gear lever selected gear down – gear does not lock down |
| ● | 1438 hrs | - | Descent to 2,000 ft then climb to 6,000 ft with gentle turns in an unsuccessful attempt to lock the gear down |
| ● | 1451 hrs | - | In holding pattern to burn off fuel |
| ● | 1535 hrs | - | Begin approach to land |
| ● | 1546 hrs | - | G-VROM touches down in a right-wing low attitude of about 4° |

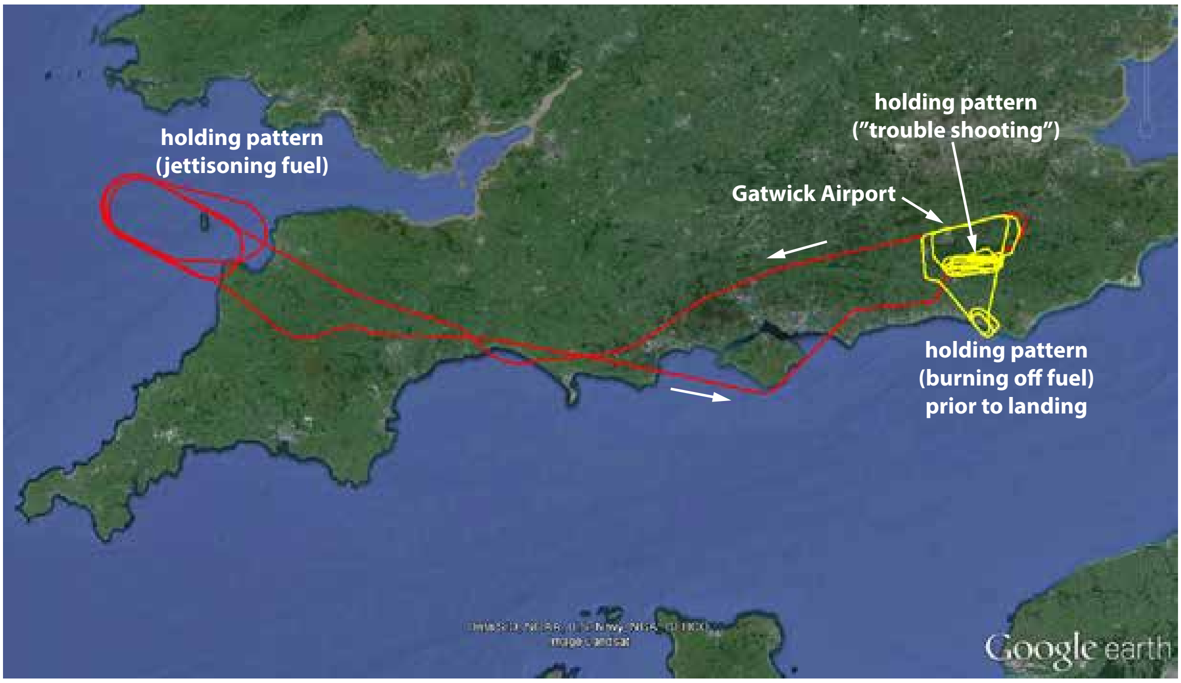


**Figure 5**

Radar track with portion of flight when the gear disagree was detected highlighted in yellow

## Communications

The Radiotelephony (RTF) communications with ATC were straightforward. The RTF communications, on the shared[1] frequency of 131.42 MHz, with the IOCC were often interrupted and broken. A lot of time was spent, and several misunderstandings occurred, as the crew tried to describe the EICAS information being displayed. The crew considered the option of using the onboard satellite telephone but in the event decided it was not required.

The Flight Service Manager[2] (FSM) was briefed directly by the flight crew and liaised with the rest of the crew and the passengers. The commander also made a number of passenger announcements during the flight. Most passengers reported that they had both heard and understood these announcements from the flight deck.

## Aircraft information

*Hydraulic system*

The aircraft has four independent hydraulic systems. Hydraulically actuated components, such as flying controls, landing gear extension and retraction and wheel braking systems are distributed between the four hydraulic systems, such that a loss of one hydraulic system does not result in a complete loss of function of the component system. Landing gear extension and retraction and the associated gear door actuation is distributed between systems 1 and 4, with the nose and body gear powered by system 1 and the wing landing gear powered by system 4. However, in the event of system 4 being inoperative, with the landing gear retracted, the QRH check list requires the crew to use the alternate extension system for all the landing gear. Other systems which become inoperative with the loss of system 4 are shown in Figure 1.

*Wing landing gear actuator*

Extension and retraction of a wing landing gear leg is achieved by means of a hydraulically powered actuator piston. The head of the actuator is attached to a hanger within the structure of the wing, with the rod end of the actuator attached to the gear leg trunnion. When the gear leg is in the retracted position, the actuator piston is also retracted and fits within an enclosed location created by 'walking beams', which run either side of the actuator, and the top of the landing gear bay (see Figure 7). The actuator is a large component weighing approximately 85 kg. In order to accommodate movement of the actuator body during the extension/retraction cycle, the actuator is attached to the aircraft hydraulic system by means of two braided flexible hoses. Each hose is connected to a port on the body of the actuator, one located on the top and the other on the bottom at the opposite end of the actuator body. The port at the head end of the actuator is labelled 'UP' and is located on the bottom of the actuator, whilst the port labelled 'DN' is located on the top of the actuator at the opposite end. Apart from a bleed valve on the opposite side of the head of the actuator to the port, there are no other distinguishing labels or features on the actuator to assist with orientation.

**Footnote**

1 Frequency used by several airlines for internal company communications messages.
2 Senior cabin crew member on-board.

**Figure 6**

Wing landing gear actuator

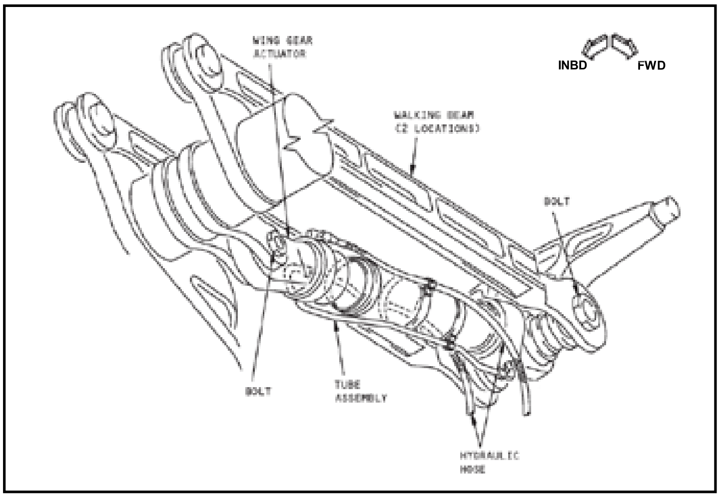


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**Figure 7**

Wing landing gear actuator location

*System status indications*

Hydraulic controls and indicators are located on the overhead hydraulics panel, on which discrete lights illuminate in the event of system faults. Hydraulic systems status information is displayed on the EICAS hydraulic synoptic display and also on the status display. Information is provided to the crew about the landing gear status on the EICAS gear position indicator and gear synoptic display.

The low quantity warning for each of the hydraulic systems is triggered by a sensor within the respective hydraulic fluid reservoir. A significant loss of fluid will result in a loss of pressure, making the system inoperable, despite some fluid remaining distributed within the system pipework and components.

*Landing gear alternate extension system*

The alternate system for extending the landing gear allows the landing gear legs to extend under gravity until they lock in place. There are two switches in the cockpit to initiate the process, one for the wing landing gear and one for the nose and body landing gear.

There are two position sensor switches in the alternate extension system associated with the operation of each wing gear door: a door-unlock switch, and a door-open-40 degrees-or-more switch. When the pilot selects the wing gear alternate extension, a valve in the hydraulic system allows hydraulic fluid to port to the system return pipe. The door actuator then unlocks, releasing the door. This triggers the door unlock switch to open, removing power from the alternate extension actuator and preventing the gear from extending. This provides a delay to allow the gear door to swing open under gravity. As the door passes the 40-degree position it closes the associated switch, triggering the door unlock switch to close again. The alternate extension actuator is then re-energized, unlocking the gear from the uplock hook and releasing the gear leg to extend under gravity. A pressure-operated restrictor valve in the hydraulic system functions to dampen and significantly slow the wing gear extension rate. The pressure-operated restrictor valve is designed with a pressure-induced time delay of approximately 6 seconds (after gear release from uplock), after which its internal bypass valve begins to open and allows flow back to return as normal.

The strike board mechanism, located in the landing gear bay, extends a strike board over the wing gear door as it opens, lifting it from vertical to approximately horizontal as the outer section of the door passes underneath, back to just less than vertical when the door folds into the fully open position (see Figure 8). The board is designed to guide the wheel past the door should contact occur during alternate system extension of the landing gear. Delaying release of the wing gear from the uplock hook until the door is open at least 40º helps to

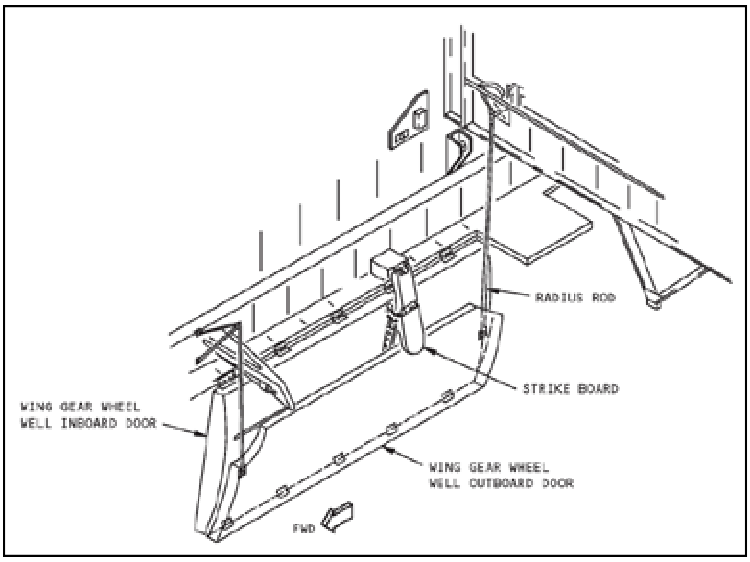


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**Figure 8**

Wing gear door and strike board (right door design is identical in mirror image) ensure the strike board is positioned properly, so that the gear door is pushed out of the way, if the tyre contacts the board. The hydraulic damping of the rate of extension helps to reduce the loads on the strike board during contact. The strike board is a solid aluminium structure weighing approximately 5 kg.

## Aircraft certification

During design and certification of the 747-400, a 'hang-up' of the wing landing gear leg on the gear door was considered as part of the aircraft System Safety Assessment. The design of the aircraft is such that only two of the main landing gear legs (wing or body)[4] are necessary to safely support the aircraft during a landing at maximum landing weight. The wing gear doors were designed with sufficient strength to support the weight of the landing gear should a 'hang-up' occur, to ensure that the door did not fail and release the gear in an uncontrolled manner at a critical point in the landing sequence. A landing with only two[3] or three of the four main gear legs deployed and locked was classified as 'minor' in the manufacturer's Functional Hazard Analysis. The airworthiness regulatory definition of 'minor' is provided below:

> *'Minor: Failure Conditions which would not significantly reduce aeroplane safety, and which involve crew actions that are well within their capabilities. Minor Failure Conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers or cabin crew.'*

## ICAO Annex 13 definition

Whilst the large aircraft certification regulations provide a framework definition for manufacturers identifying the risks to the airframe and passengers from failures, Annex 13 to the Convention on International Civil Aviation – *'Aircraft Accident and Incident Investigation'* provides a broader public safety definition of what constitutes an accident in the context of aircraft operations. It defines *'accident'*, in part, as follows:

> *'Accident: An occurrence associated with the operation of an aircraft with the intention of flight until such time as all such persons have disembarked, in which:*
>
> *a) a person is fatally or seriously injured as a result of:*
>
> *- direct contact with any part of the aircraft, including parts which have become detached from the aircraft'*

**Footnote**

[3] Two body gear, or two wing gear, or one body gear and one wing gear on opposite sides of the aircraft.

**Operations documentation**

The QRH provides guidance and procedures for landing with an abnormal gear configuration although it does not include a checklist for the specific circumstances of this event. The checklists for both the hydraulic system pressure loss and gear disagree are lengthy, comprising 7 and 5 pages respectively. A number of options dependent upon condition are provided which require careful reading. Additional guidance is provided in the Flight Crew Training Manual which includes the information:

> *'Failure of one wing or one body gear to extend will not cause adverse impact on directional control during touchdown and landing rollout.'*

The operator's QRH also provides a specific checklist entitled *'Emergency Landing'*. It is intended for use in any non-normal landing situation and contains information about briefings, checklists and emergency landing readiness.

**Alternate Gear Extension**

Landing gear lever . . . . . . . . . . . . . . . . . . . . OFF

Do not exceed the gear EXTEND limit speed (270K/.82M).

Action is irreversible

ALTN GEAR EXTEND WING switch . . . . . . . . . . . . . . . . . . . . ALTN

Action is irreversible

ALTN GEAR EXTEND NOSE/BODY switch . . . . . . . . . . . . . . . . ALTN

Reduction of speed to below 0.60 Mach may be needed for the wing gear to lock down.

**When** all gear are down:

Landing gear lever . . . . . . . . . . . . . . . . DOWN

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**Figure 9**

QRH procedure for alternate gear extension

**Engineering documentation**

The Approved Maintenance Manual (AMM) task for removal/installation of the wing landing gear actuator is detailed in chapter 32-32-01 PB 401. In Paragraph 1 'General', section D of this task states:

> *'The actuator for the wing landing gear is between the trunnion and the walking beam and the hanger. You must remove the walking beam before you remove the actuator. Because the actuator is very heavy, you must use a hoist adapter to remove it.'*

Paragraph 2 'Wing landing gear actuator removal' Section G, items 6 and 7 continues:

> *'(6) Install the wing gear retraction sling.*
>
> *(7) Use the fishpole hoist to remove the load.'*

Paragraph 3 'Wing landing gear actuator installation' section G has a warning and a caution note at the start:

> *'WARNING: Make sure the attach point for the hoist is correctly in the keyhole slot. Failure to do this can cause the hoist to fall and cause injury to persons and damage to equipment.*
>
> *CAUTION: Make sure the hydraulic ports are in the correct location. You can cause damage to the actuator if you do not install the ports correctly.'*

Item 1 then states:

> *'Use the wing gear retract actuator sling and the fishpole hoist to put the actuator in the correct position between the trunnion and the hanger*
>
> *NOTE: You must put the actuator in the position with the rod end adjacent to the shock strut trunnion. The UP port faces must be on the lower side of the actuator. The DN port faces must be on the top side of the actuator.'*

**Pre-flight maintenance activity**

G-VROM had a history of hydraulic fluid leakage from the gear actuator piston rod gland seal on the right wing landing gear. In order to rectify this, a Technical Services Work Order (TSWO) was raised by the operator's engineering department. The actuator removal and installation was scheduled to be carried out in the operator's hangar at London Gatwick Airport, during the day shift on Sunday 28 December. The certifying engineer who led the day shift team stated that he spent considerable time trying to locate the fishpole hoist specified in the AMM, but in the end withdrew a hoist designed for installation/removal of the aircraft Auxiliary Power Unit (APU) from the tool store. He reported difficulty in sourcing the correct tooling for other elements of the task as well and raised a Ground Occurrence Report (GOR) to highlight this to the operator's safety department. However, the team stated that the actuator was eventually removed from the aircraft without using either the sling or hoist. They identified that the AMM did not contain instructions on how to use the sling or how to use the hoist and sling combination to manoeuvre the actuator. Once the unserviceable actuator had been removed from the aircraft, the associated fittings were transferred to the replacement actuator on the work bench.

Delays caused by the late arrival of the aircraft to the hangar and a requirement for additional parts to be sourced for the replacement actuator, meant that it could not be installed by the day shift team, so the task was handed to the night shift team who came on duty that evening. An additional engineer, with some experience of installing a landing gear actuator, was reassigned to assist due to the additional workload this task placed on the team. The night shift team reported that the task handover provided by the day shift team was “excellent”.

The installation procedure commenced at approximately 2145 hrs and began with the team positioning a set of steps and a lifter platform, carrying the replacement actuator, underneath the aircraft. In order to install the actuator it had to be passed through a section of structure in the wing. The team positioned spill bags to prevent damage from any contact between the actuator and the wing structure. The sling and hoist were not used by the team, who instead manhandled the actuator between the two technicians standing in the lifter and the engineer standing on the steps. The weight of the actuator was then supported by the two technicians, while the engineer attempted to install the pin which secured the actuator to the hanger. After 20 minutes of unsuccessful effort, the team’s positions were rotated and they tried again to locate the pin for a further 10 minutes. Eventually the actuator was successfully secured in place by one of the technicians.

The team then continued to work through the night to reconnect the hydraulic hoses and leak check the hydraulic system. The AMM did not require a full operational test of the landing gear actuator following replacement, just a selection of the gear lever UP with the gear locking pins in place, to check the gear leg began to move before being restrained by the locking pin and to check for leaks. The aircraft was then prepared and released for service that morning.

### Other information

The passengers from the incident flight were offered the opportunity to complete an AAIB questionnaire after landing and information from the replies received was used in the investigation. The passengers had been briefed by the commander and were aware of a fault with a hydraulic system and initially were not unduly concerned. When the additional problem with the landing gear became apparent there was an increased level of concern. Much of this was mitigated by the frequent updates from the commander about the situation, and through the positive influence of the cabin crew.

### Safety actions

The operator conducted a detailed investigation following the incident and issued a comprehensive internal report. The report included 28 recommendations. The majority of these related to internal improvements in process, but a number also related to possible improvements in the aircraft manufacturer’s documentation to remove ambiguity.

## Analysis

*Operations*

The successful outcome of this event hinged on good communication and co-operation in a number of areas. The additional pilot on the flight deck enhanced the task sharing and reduced the workload on the co-pilot and the commander. The crew were able to spend time working through all the possible options available to them and to be sure that everything had been considered before the landing.

The consideration of available options was assisted by the input from the operator's IOCC facility. In being external to the aircraft the IOCC personnel were able to contribute from additional resources, which included expertise from the aircraft manufacturer. However, communication with the IOCC was not straightforward because of the interruptions and interference from other stations on the shared frequency. Shared frequencies for company communications are a normal arrangement and in most cases interruptions constitute a nuisance and are not critical. The Very High Frequency (VHF) frequencies allocated to aviation are a resource with limited capacity but it would have been useful in circumstances such as these to have been able to switch to a dedicated frequency.

Many of the questions from the IOCC needed to be repeated and it proved difficult for the crew to describe accurately information shown on a visual display. It would have been a useful facility to have been able to send and receive photographs from on-board the aircraft. This facility might also have been useful for the crew, as photographs were available in the public domain several hours before the eventual landing, showing the position of the landing gear.

The aircraft was airborne for a total of 4 hours. The first approach took place 1 hour 40 minutes into the flight and the second approach was 2 hours 15 minutes later. Frequent information updates and a calm professional manner on behalf of the crew contributed to the maintenance of a safe on-board environment.

*Engineering*

There are two separate aspects to this incident; the maintenance issues which led to the in-flight hydraulic leak, and the circumstances which resulted in the right wing landing gear becoming 'hung-up' on the gear door.

Maintenance issues

Replacement of landing gear actuators is not a common maintenance task on the 747-400. As such there is limited opportunity for individual maintenance organisations to develop internal "best practice" techniques or to identify and rectify weaknesses or missing information within the manufacturer's AMM instructions. The maintenance teams tasked with the replacement of the gear actuator on G-VROM faced a number of problems. They were not able to locate a number of the specialist tools required by the AMM, including the hoist which the manufacturer specified for safe lifting of the weight of the actuator whilst it was being manoeuvred into place. The operator's internal investigation has made a recommendation within the company to address this issue. However, the team identified that even if the hoist had been available, the manual did not specify how to operate the sling, or how best to utilise it together with the hoist in the difficult task of manoeuvring the actuator through the wing structure surrounding the actuator location. The AMM is the main source of guidance for completing any maintenance task. If specific guidance is not found in the AMM, then engineers and technicians might develop improvised techniques to accomplish a task, particularly outside normal office support hours such as during night shifts.

Ultimately, the maintenance team working on G-VROM elected not to use any form of mechanical support, thus greatly increasing the difficulty and risk associated with installing the replacement actuator. The result of this decision was that the task became so physically demanding that the maintenance team became entirely focused on just attaching the actuator to the aircraft, in order to relieve themselves of the 85 kg weight they had manually supported for over 30 minutes. As such, they had no remaining capacity to ensure they installed the actuator in the correct orientation. It was subsequently determined that they had rotated it 180° about its long axis during installation, effectively installing it upside down.

The significance of this maintenance error was that the hydraulic fluid ports on the actuator were now transposed, with the port at the head end of actuator facing upwards. The AMM did not require the gear to be fully cycled following maintenance. Consequently, the insufficient clearance between the hydraulic port and the top of the landing gear bay, when the gear was in the retracted position, was not identified until the first time the gear was retracted fully during the incident flight the following morning. The force exerted on the hydraulic port as the gear retracted, caused it to distort and release hydraulic fluid at the full system pressure of 3,000 psi. This rapidly depleted the reserve of hydraulic fluid in system 4, generating a low quantity and then low pressure warning in the flight deck.

Whilst the manner in which the actuator was installed by the maintenance team significantly increased the likelihood of a maintenance error occurring, the design of the actuator itself increased the probability of the error remaining undetected. The actuator was virtually uniform in shape and colour, such that there was no obvious top or bottom to it. The structural connections could be installed in either orientation and the use of flexible hoses meant the hydraulic connections could be made to fit an incorrectly installed actuator. Finally, the hydraulic port on the bottom of the actuator was labelled 'UP', with the one on the top labelled 'DN', which was inherently open to misinterpretation. As a result of these human factors issues being identified the following two Safety Recommendations are made:

**Safety Recommendation 2015-026**

It is recommended that Boeing amend the 747-400 Approved Maintenance Manual task for removal and installation of the wing landing gear actuator, to provide clear instructions for the safe manoeuvring of the actuator in or out of its location in the wing landing gear bay.

**Safety Recommendation 2015-027**

It is recommended that Boeing modify the 747-400 wing landing gear actuator to reduce the likelihood of incorrect installation occurring or remaining undetected.

*Failure of the wing landing gear to extend fully*

Due to the location of the leak on G-VROM, the right wing landing gear system was drained of hydraulic fluid. The landing gear alternate extension system is designed to work with hydraulic fluid present in the system. Most significantly for this event, the rate at which the gear leg descends, when deployed using the alternate system, is controlled by slowing the flow of hydraulic fluid around the system by means of a restrictor valve. When the hydraulic fluid is lost, the descent of the gear leg is undamped and accelerates under gravity. This has two potential implications for the wing landing gear, as demonstrated by the G-VROM event. Firstly, the gear door may not have fully opened prior to the arrival of the descending gear leg. Given the concertina design of the door, this will result in the gear leg becoming 'hung up' on the door, with no way of releasing it prior to landing. Secondly, as a result of the door being partially open, the strike board is mechanically held in the horizontal position when the tyre strikes it. The strike board attachment hinge was not designed to withstand the load imparted when the board is stuck in this orientation by an undamped gear leg. On G-VROM, this caused the hinge to fail and the board to be released from the aircraft. The aircraft was at an altitude of approximately 3,000 ft and travelling at 180 kt when this occurred. The 5 kg strike board would therefore have reached the ground with sufficient energy to cause significant damage or injury.

The aircraft manufacturer advised that they had considered the risks associated with the 'hang-up' of a gear leg following an undamped freefall of the wing landing gear in their System Safety Assessment for the aircraft, and assigned it a hazard severity classification of 'minor'. It was not clear whether detachment of the strike board from the aircraft was anticipated as part of this scenario. However, given that the certification design regulations only require manufacturers to consider the safety implications of a failure to the aircraft and its occupants, it is unlikely this would have altered the classification. The approach paths to London Gatwick Airport mostly overfly farmland, but many other airport approaches, pass over densely populated urban areas. Release of the strike board from an aircraft has the potential to cause serious injury or death should it hit someone on the ground, which constitutes an accident as defined by Annex 13 and is in any case undesirable. To prevent such an accident occurring, the following Safety Recommendation is made:

**Safety Recommendation 2015-028**

It is recommended that Boeing modify the design of the 747-400 wing landing gear door mechanism to prevent release of the strike board from the aircraft when the alternate gear extension system is used following a loss of hydraulic fluid.

During the G-VROM event, the crew did not know why the wing landing gear had not locked down correctly and subsequently spent almost 15 minutes performing flight manoeuvres in an attempt to use aerodynamic loads to force the gear to lock. The manufacturer confirmed it had anticipated the possibility of the landing gear becoming 'hung-up' on the gear door following an alternate system deployment due to a loss of hydraulic fluid, and designed the door to ensure that the gear remained in this position, should it occur. However, there was no guidance in the aircraft QRH checklists to make flight crew aware of this possibility. Therefore, the following Safety Recommendation is made:

**Safety Recommendation 2015-029**

It is recommended that Boeing amend the 747-400 Quick Reference Handbook to warn flight crews of the potential for, and provide guidance in the event of, an unsuccessful extension of the wing landing gear, when the alternate gear extension system is used following hydraulic system 4 low quantity and pressure warnings.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Saab-Scania SF340B, G-LGNL |
| **No & Type of Engines:** | 2 General Electric CT7-9B turboprop engines |
| **Year of Manufacture:** | 1991 (Serial no: 340B-246) |
| **Date & Time (UTC):** | 2 January 2015 at 0833 hrs |
| **Location:** | Stornoway Airport, Isle of Lewis |
| **Type of Flight:** | Commercial Air Transport (Passenger) |
| **Persons on Board:** | Crew - 3 Passengers - 26 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Extensive damage to the nose landing gear, powerplants and underside of the aircraft |
| **Commander's Licence:** | Air Transport Pilot's Licence |
| **Commander's Age:** | 46 years |
| **Commander's Flying Experience:** | 3,880 hours (of which 3,599 were on type)<br>Last 90 days - 98 hours<br>Last 28 days - 28 hours |
| **Information Source:** | AAIB Field Investigation |

### Synopsis

At approximately 65 KIAS during an attempted takeoff in strong and gusty crosswind conditions, the aircraft swung to the left and departed the paved surface. The power levers were not selected to GROUND IDLE and the aircraft came to a halt with a collapsed nose landing gear, 250 m after leaving the paved surface. There were no injuries.

### History of the flight

The aircraft had been prepared for a Commercial Air Transport flight from Stornoway Airport to Glasgow Airport with 26 passengers and three crew on board; the commander was the Pilot Flying (PF) and the co-pilot was the Pilot Monitoring (PM). At 0825 hrs the aircraft was taxied towards Holding Point A1 for a departure from Runway 18.

At 0832 hrs G-LGNL was cleared to enter the runway from Holding Point A1 and take off, and the ATC controller transmitted that the surface wind was from 270° at 27 kt. The commander commented to the co-pilot that the wind was across the runway and that there was no tailwind. As the aircraft taxied onto the runway, the co-pilot applied almost full right aileron input consistent with a cross-wind from the right, and the commander said to the co-pilot "CHARLIE[1], ONE HUNDRED[2], STRONG WIND FROM THE RIGHT". The commander advanced

**Footnote**

[1] See later section *Takeoff procedures*.
[2] The commander was referring to 100% torque.

the power levers, the co-pilot said "AUTOCOARSEN HIGH[3]" and the engine torques increased symmetrically. The commander instructed the co-pilot to "SET TAKEOFF POWER" to which the co-pilot replied "APR ARMED[4]". Approximately one second after this call, the engine torques began to increase symmetrically, reaching 100% as the aircraft accelerated through 70 kt.

During the early stages of the takeoff, left rudder was applied and the aircraft maintained an approximately constant heading. As the aircraft continued accelerating, the rudder was centralised, after which there was a small heading change to the left, then to the right, then a rapid heading change to the left causing the aircraft to deviate to the left of the runway centreline.

The pilot applied right rudder but although the aircraft changed heading to the right in response, it did not alter the aircraft's track significantly and the aircraft skidded to the left, departing the runway surface onto the grass at an IAS of 80 kt. The power levers remained at full power as the aircraft crossed a disused runway and back onto grass. During this period the nose landing gear collapsed before the aircraft came to a halt approximately 38 m left of the edge of the runway and 250 m from where it first left the paved surface.

After the aircraft came to a halt, the captain saw that the propellers were still turning and so called into the cabin for the passengers to remain seated. One of the passengers shouted for someone to open the emergency exit but the cabin crew member instructed the passengers not to do so because the propellers were still turning. The co-pilot observed that the right propeller was still turning so operated the engine fire extinguishers to shut down both engines. When the passenger seated in the emergency exit row on the right of the aircraft saw that the right propeller had stopped, he decided to open the exit. He climbed out onto the wing and helped the remaining passengers leave the aircraft through the same exit, instructing them to slide off the rear of the wing onto the ground. The left propeller was still turning at the time the right over-wing exit was opened and the passenger seated in the left-side emergency exit row decided not to open the left exit.

The crash alarm was activated by ATC at 0833 hrs. An aircraft accident was declared and the aerodrome emergency plan was put into action. When the Rescue and Fire Fighting Services (RFFS) arrived at the scene, passengers were still exiting the aircraft and the left propeller was still turning.

After leaving the aircraft, the cabin crew member confirmed to the RFFS that all passengers had exited the cabin and had been accounted for outside. The passengers were taken to the fire station and then on to the passenger terminal. There were no injuries.

Footnote

3 See later sections *Takeoff procedures, Autocoarsen system* and *Normal takeoff*.
4 See later sections *Takeoff procedures,* Constant *torque system* and *Normal takeoff*.

## Information from the crew

The commander had not flown for 14 days. He reported that he went to sleep at approximately 2230 hrs the night before the flight but woke at about 2345 hrs and was "very restless thereafter" until he arose at 0445 hrs.

The crew reported that, for a left-seat takeoff, the aircraft is kept straight on the runway to begin with by using nosewheel steering (NWS). The PF then transfers his left hand from the NWS wheel to the control yoke and calls '*my controls'* when he has sufficient rudder authority to maintain directional control.

Although the active runway was Runway 36, the commander elected to use Runway 18 because it was no less favourable for takeoff in the crosswind conditions. He decided to takeoff using 100% torque in case there were any gusts in the wind or the crosswind became partly a tailwind. He recalled that the FO held full right aileron as the aircraft began its takeoff run. He moved his hand from the NWS wheel to the control yoke when he felt he had rudder authority but the aircraft began to turn left "immediately and violently".

The commander could not recall calling for the takeoff to be rejected or reducing the power levers to GROUND IDLE. He reported that he said "emergency evacuation" to the co-pilot after the aircraft had come to rest. He did not recall whether the condition levers were set to OFF during the evacuation.

The co-pilot recalled that the loss of control occurred after the "handover of control" when the speed was between 60 and 80 kt.

The cabin crew member stated that, during the takeoff, the aircraft swung violently one way then the other before the ride became "very rough". When the aircraft stopped, she stood up and asked whether anyone was injured. She heard the commander shout that the propellers were still turning and for the passengers to remain seated. She, therefore, walked through the cabin to instruct the passengers to remain seated. Although she saw the red EMERGENCY cabin call light[5], indicating an emergency public address was being made from the flight deck, she did not hear an evacuation command. She saw that a passenger had opened the over-wing exit on the right side of the aircraft but, because the right propeller had now stopped and he was helping passengers to exit the aircraft, she let him continue.

## Examination of the accident site

Marks from all six tyres were visible on the runway from about 200 m after the taxiway where the aircraft entered Runway 18. These tracks diverged to the left and then departed the paved surface after another 100 m. The tracks remained visible on the unpaved surface beside the runway until the point where the aircraft came to rest, a further 250 m, but were not visible for the period when the aircraft crossed a disused paved runway (Figure 1).

**Footnote**

5 The cabin call lights are on the cabin attendant's panel immediately aft of the main entry/exit door.


**Figure 1**

General view of accident site

The rubber marks left by the tyres indicated that the tyres were not rolling straight ahead and, as the aircraft approached the side of the runway, the geometry of the marks indicated that the aircraft was progressively yawing to the right of its direction of travel (Figure 2). Calculations indicated that this yaw angle reached a maximum of approximately 14° just after the aircraft entered the grass beside the runway and it remained fairly constant until the aircraft reached the disused runway. There were no tyre marks across the disused runway but when they reappeared in the grass on the far side the aircraft was no longer yawed. Shortly after this point the ground markings indicated where the nose landing gear collapsed.

The runway surface was grooved and in good condition with no significant previous rubber deposits in the area of the tyre tracks from this event. Due to the rapidly changing environmental conditions a surface friction measurement was not carried out.


**Figure 2**

Tracks of the aircraft landing gear (Police Scotland)

## Examination of the aircraft

The aircraft came to rest with its nose on the ground as the nose landing gear had broken off rearwards under the fuselage. Both propellers had struck the ground and the outer portion of each propeller blade had broken off. The radome and lower forward fuselage sustained substantial damage including tears which allowed mud and water to be forced in to the lower fuselage and avionics bays. The damage did not affect the cabin area, emergency exits or passenger egress. There was no damage to any of the seats or their harnesses.

## Recorded information

The aircraft was fitted with a 2-hour CVR and a Flight Data Recorder (FDR) which recorded just over 52 hours of operation including the accident takeoff.

The FDR recorded a number of parameters, including lateral acceleration, aircraft heading and rudder pedal and surface position[6]. NWS angle, NWS wheel position, brake pressures and groundspeed were not recorded, nor were they required to be.

During taxi towards Runway 18, the flight crew performed a flight control check, consisting of applying full deflections of the control wheel and the rudder pedals. Due to the sampling rate of the FDR, full travel was not measured but the CVR recorded the flight crew reporting "FLIGHT CONTROLS CHECKED" with no reported problems. Upon completion of these checks, right roll was commanded on the control wheel, deflecting the left and right ailerons to -21.5° and +22° respectively (maximum travel is -21.5° to + 24°). This was maintained throughout the takeoff roll.

As the aircraft turned on to the runway heading, the power levers were slowly advanced, reaching full travel five seconds later, with engine speed and torque increasing symmetrically on both engines. During this period, left rudder was applied until the aircraft reached a recorded airspeed of approximately 40 kt (Figure 3). Over the next three seconds, the heading decreased from 182.1° to 179.3° followed by a reversal in direction to the right to a heading of 183.9° over the following two seconds. At this time, the aircraft was accelerating through approximately 65 kt with the rudder approximately centralised and right aileron still applied.

Over the next three seconds, the aircraft heading decreased to the left to 164.9°. As the aircraft began to turn, right rudder was commanded which increased the heading to 188° as the aircraft accelerated through 80 kt. During this heading change, fluctuations in the normal and longitudinal accelerations suggest that the aircraft had left the paved surface at an indicated airspeed of approximately 80 kt. Despite the heading indicating a turn to the right, the ground marks confirmed the aircraft departed the left side of the runway, yawing to the right. Right rudder was applied continuously throughout.

**Footnote**

[6] Note: Lateral acceleration is recorded at 4 Hz, rudder parameters 2 Hz and heading 1 Hz. This should be considered when reviewing Figure 3.

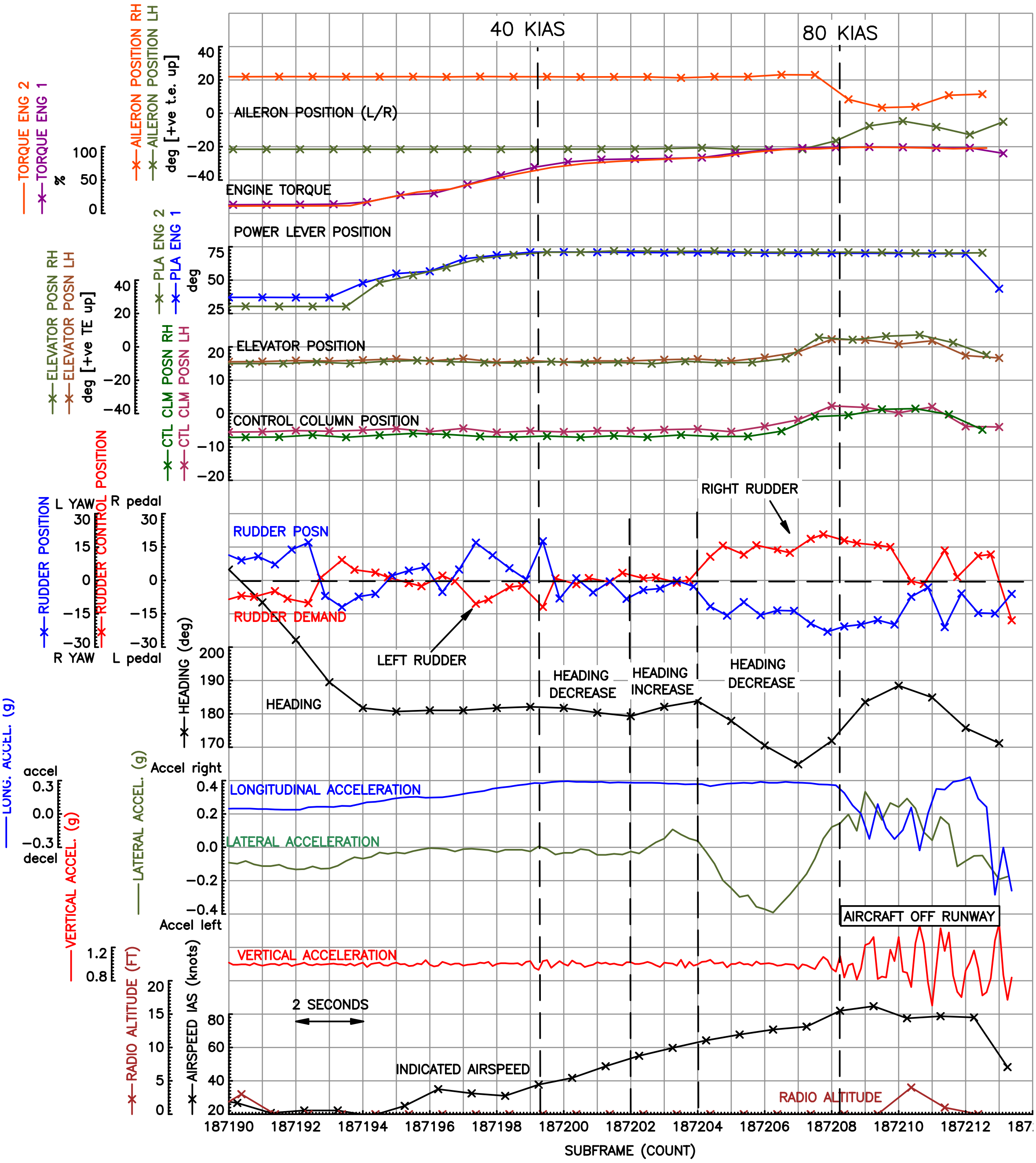


**Figure 3**

G-LGNL FDR data[7]

The FDR and CVR both ceased recording at the same time. The data shows the aircraft decelerating at approximately 48 kt with the power levers still fully advanced until the last recorded sample. The recording did not capture the engine shutdown or evacuation which suggests that the recordings terminated early[8]. Examination of the aircraft after the accident revealed significant damage and mud ingress in the forward avionics bay which was likely

**Footnote**

[7] Note: Rudder pedal position and rudder surface position are in the opposite sense.

[8] The FDR should remain recording with at least one engine operating, the CVR as long as electrical power is available from the aircraft's battery.

to have caused the premature end to the recording. Also, due to this significant damage, no system testing could be performed to confirm this.

Previous takeoff FDR data from G-LGNL was analysed to assess the takeoff acceleration profile. The accident flight acceleration fitted well with that of previous flights up to the point where the aircraft departed the paved surface suggesting no issues with dragging brakes.

**The nosewheel steering system**

The nosewheel steering (NWS) is hydraulically operated by a single actuator which is controlled by a wheel on the left side of the cockpit. To steer, the wheel must be pushed down to engage mechanically with the steering system and operate an electrical switch to open the steering hydraulic shutoff valve. When the wheel is released the hydraulic power is removed and the nosewheel castors unless it is deflected by more than 20º (+/- 5º) in which case a solenoid steering brake locks the steering system preventing further deflection (Figure 4).

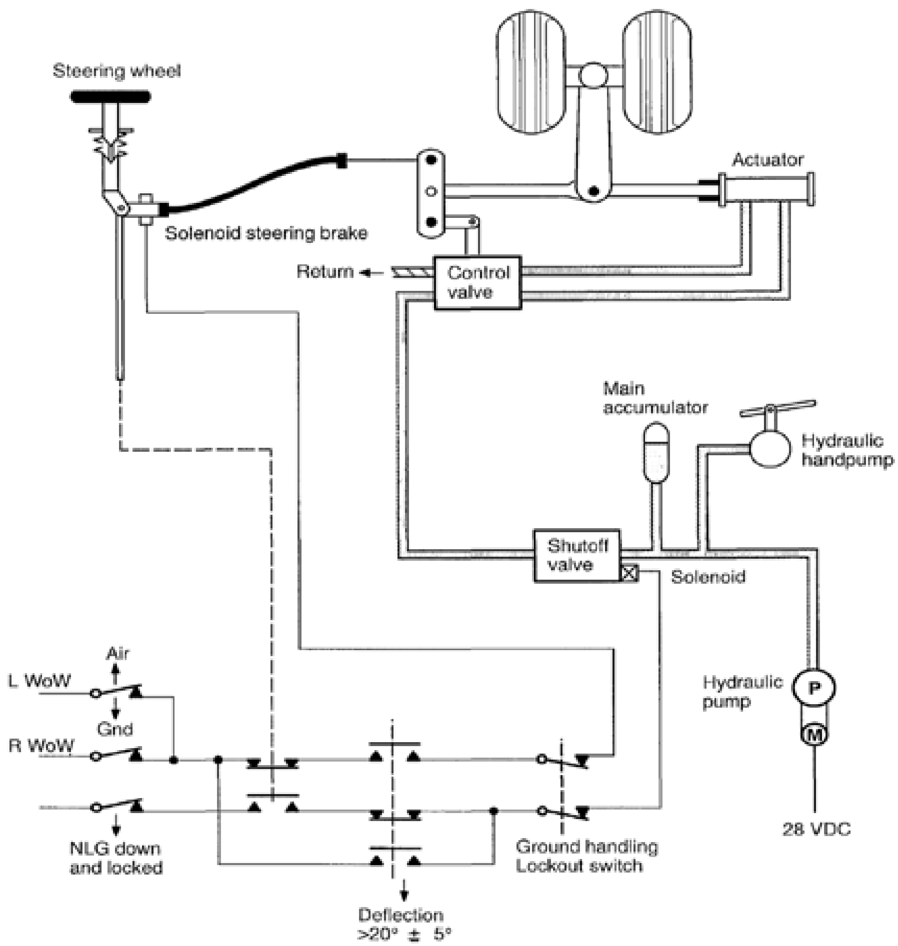


**Figure 4**

Schematic of NWS (from Aircraft Operating Manual)

Due to damage sustained, it was not possible to conduct a detailed check of the steering system and its rigging. However, a visual examination of the system did not reveal any pre-existing defects.

## Weather information

A Met Office Gale Warning was valid for the area forecasting west or south-westerly winds with a mean speed of 30 kt at times and with gusts of 43 kt.

The aerodrome recorded wind direction and speed from two anemometers on the aerodrome for the ten minute period leading up to 0840 hrs. The wind from the anemometer located near Holding Point A1 was:

> Wind direction between 261 and 291°M with an average direction of 273°M
>
> Wind speed between 14 and 27 kt with an average speed of 20 kt.

The weather at the aerodrome at 0839 hrs was wind from 270° at 20 kt, 25 km visibility with showers in the vicinity, few cumulonimbus clouds at 1,500 ft aal, temperature of 5°, dew point of 1° and a QNH of 1008 hPa.

## Information from the aircraft manufacturer

The aircraft manufacturer made the following comments in relation to this accident:

a. No parameters were recorded by the FDR which showed directly whether, or to what degree, NWS or differential braking had been used for directional control during the takeoff. However, had differential braking been used, it would probably have been recorded as fluctuations in the data for longitudinal acceleration and airspeed which did not appear to be present. This suggested that differential braking had not been used.

b. The lateral, longitudinal and normal accelerometers contained within the aircraft are located near its centre of gravity and their output is not affected significantly by rotations about their respective axes.

c. The aircraft has a natural tendency to veer to the left during takeoff due to propeller effects but this tendency is offset operationally by setting 1½ units of right rudder trim for takeoff.

d. The aircraft does not have a crosswind limitation for takeoff. Landings have been demonstrated in 35 kt crosswinds and operators often use 35 kt as a takeoff limit in case a return to the departure airport is required.

## Saab 340B Aircraft Operations Manual (AOM)

*Engine fuel supply*

When a condition lever is selected to FUEL OFF, the supply of high pressure fuel is shut off within the respective engine fuel system and the engine will stop almost immediately. When an engine fire handle is pulled, it closes the respective fuel shutoff valve within the wing thereby shutting off the fuel supply from the aircraft to the engine fuel system. The evacuation checklist requires both actions to be carried out during an emergency evacuation and, if the condition lever is not selected to FUEL OFF, the engine will continue to run until it has used the fuel downstream of the shutoff valve within the wing.

*Autocoarsen system*

An Autocoarsen system is installed in each powerplant to reduce propeller drag in case of engine failure. Green panel lights in the cockpit indicate whether it is armed in the low or high power mode. The high power mode is armed when both power lever angles are greater than 64°, the torque from both engines is greater than 50%, and both engine compressor discharge pressures are above 1,200 psi.

*Constant torque system (CTOT)*

The digital engine control unit (DECU) contains a constant torque system (CTOT) with an integrated Automatic Power Reserve (APR) function. When engaged, the system advances the power levers to the pre-selected takeoff torque value set using the CTOT control knob.

*Normal takeoff*

The AOM contains a note in relation to takeoff that states:

> *'maintaining directional control by use of rudder, with the NWS as a backup at low speed, will significantly decrease the wear on the nosewheel.'*

The AOM advises that a slight forward pressure should be maintained on the control wheel to keep the nosewheel rolling firmly on the runway. It also states:

> *'The aircraft has a tendency to veer to the left. Use rudder to maintain direction, assisted by NWS at low speed. Rudder is effective from 40 KIAS. Keep the hand on the NWS up to 80 KIAS to be prepared for NWS inputs at lower speed in case of rejected takeoff. Normally NWS should not be used above 60 KIAS.'*

In relation to crosswind takeoffs, the AOM states:

> *'Crosswind takeoff capability is good. The upwind wing will have a tendency to rise and aileron deflection should therefore be applied towards the wind. Directional control is maintained as during normal takeoff. As speed increases, aileron deflection requirement will decrease. The main objective is to keep the wings level. Maintain a slight forward pressure on the CW until rotation.'*

**The Operations Manual for the Saab 340B**

*Takeoff procedures*

The operator's Operations Manual details procedures for takeoff and gives three methods for setting takeoff power. The procedure for Method C, used in this instance, is as follows:

> *'With brakes on and Condition Levers MAX, set power levers to FLIGHT IDLE. Release brakes and advance power levers to approximately 15-20% below the selected CTOT value. Engage CTOT/APR by selecting ARM position on the CTOT panel before 60 KIAS.'*

For a takeoff by the left pilot (LP), the Operations Manual states:

> *'Once the Autocoarsen High light is observed the RP will call "AUTOCOARSEN HIGH". At … 15-20% below the target torque, the LP will call "SET TAKEOFF POWER". The RP will move the CTOT/APR switch to the 'Arm' or 'On' position and, assuming the APR lights appear, call "APR ARMED". Approaching 80 knots the RP will check that the target torque has been achieved and call "80 KNOTS – TAKEOFF POWER SET". The LP will retain control of the power levers until the call of $V_1$ at which point LP removes his hand from the levers and places it on the control column.'*

*Crosswind takeoff considerations*

The Operations Manual considers crosswind takeoff technique and states:

> *'Crosswind takeoff capability is good. Both the NWS and rudder are very effective and the aircraft is very stable in roll… The main area of concern … is directional rather than roll control … in high crosswinds. If the wings are kept level … directional control is maintained as during normal takeoff.'*

*Rejected takeoff*

The Operations Manual discusses circumstances which would lead the commander to reject the takeoff below $V_1$ including '*difficulties in maintaining directional control*'. The decision to reject the takeoff is indicated by the commander ordering "STOP STOP" after which he or she should:

> *'Immediately apply maximum foot braking and simultaneously move the power levers to ground idle initially – if symmetrical power is available and advisable i.e. one of the engines is not on fire or surged then use reverse power if stopping is a problem because of runway characteristics.'*

*Emergency evacuation*

After coming to a halt from a rejected takeoff, if an evacuation is necessary the commander will instruct the co-pilot to carry out the evacuation drill (see below). Once the commander has ensured that the co-pilot has completed the drill, he should use the PA system to issue the command "EVACUATE EVACUATE".

The Emergency Checklist states that the following actions are to be carried out by memory in the event of an emergency evacuation:

> *'LEFT PILOT:*
>
> *1. PARKING BRAKE ...................................................... SET*
> *2. "EVACUATION" .................................................... ORDER*
> *3. Ground/Tower ...................................................... NOTIFY*
> *4. BATTERY switches (both) ........................................... OFF*

*RIGHT PILOT:*

1. *CONDITION LEVERS (both)............................FUEL OFF*
2. *EMERGENCY panel switches......................................ON*
3. *FIRE HANDLES ....................................................... PULL*
4. *FIRE EXTINGUISHERS............................................. ON'*

**Analysis**

*The attempted takeoff*

During the attempted takeoff, the rudder was central from 40 kt and remained so until approximately 65 kt. Between approximately 52 and 65 kt, the aircraft turned right slightly before it turned left sharply at approximately 65 kt (Figure 3). Given that the rudder was central, this change of direction might have been caused by one, or a combination of the following factors:

a. Differential braking
b. Asymmetric thrust
c. A change in wind speed and direction
d. A NWS input

Data from the FDR showed that thrust was applied symmetrically throughout the takeoff run, and the manufacturer did not consider that the data for longitudinal acceleration and indicated airspeed supported the use of differential braking.

The crew reported that the swing to the left took place at the handover of control, as the commander released the NWS control and moved his hands to the control yoke, and there might have been a change in NWS input as the nosewheel began to caster. However, because the rudder was in the neutral position and would have had no effect, any NWS input prior to the swing was probably in the 'turn left' sense, to oppose the weathercock effect tending to turn the aircraft into the crosswind. In that case, any change in NWS input would have been in the wrong sense to cause a sharp swing to the left.

It was possible that, immediately before the commander released the NWS control, there was a marked drop in the wind speed. In this case, the extant left NWS input would probably have been more than that required to counter the lower crosswind and the aircraft would have begun to turn left. However, this possibility could not be confirmed as there was no data to show whether or not the aircraft had actually experienced a marked change in wind speed or direction.

As the aircraft moved towards the edge of the runway, the pilot applied right rudder in an attempt to return to the runway centreline. Figure 2 shows that, with the aircraft still on the runway, the nose of the aircraft began to turn right in response to the rudder input but the main landing gear maintained their track towards the runway edge. The track of the nose landing gear moved towards that of the right landing gear, indicating that the aircraft was skidding left as it departed the paved surface.

*Takeoff technique*

The technique for controlling the direction of the aircraft on the runway is to use rudder assisted by NWS at low speeds because the rudder has reduced effectiveness below 40 kt. Although the left pilot's hand should remain on the NWS control until 80 kt (for directional control in case of a rejected takeoff), NWS should not normally be used above 60 kt.

When rudder is used, the requirement for NWS to assist directional control will reduce progressively as speed increases above 40 kt and rudder effectiveness increases. It is likely that no assistance will be required by 60 kt and, therefore, there will be no step-change in NWS directional effect when the pilot releases the steering control. During this attempted takeoff, rudder was approximately neutral from 40 kt, the point at which it would have become effective, and directional control was probably maintained through NWS alone (asymmetric thrust or differential braking having been discounted). If rudder had been applied, there would have been a reduced NWS requirement at any given speed and therefore there would have been a reduced likelihood of a change directional effect when the NWS control was released. The lack of data showing NWS commands meant that these considerations could not be verified.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Agusta Westland AW139, G-LBAL |
| **No & Type of Engines:** | 2 Pratt & Whitney Canada PT6C-67C turboshaft engines |
| **Year of Manufacture:** | 2012 (Serial no: 31421) |
| **Date & Time (UTC):** | 13 March 2014 at 1926 hrs |
| **Location:** | Near Gillingham Hall, Norfolk |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 2 Passengers - 2 |
| **Injuries:** | Crew - 2 (Fatal) Passengers - 2 (Fatal) |
| **Nature of Damage:** | Aircraft destroyed |
| **Commander's Licence:** | Commercial Pilot's Licence (Helicopters) |
| **Commander's Age:** | 36 years |
| **Commander's Flying Experience:** | Approximately 2,320 hours (of which approximately 580 were on type)<br>Last 90 days - approximately 105 hours<br>Last 28 days - approximately 30[1] hours |
| **Information Source:** | AAIB Field Investigation |

### Synopsis

The helicopter departed from a private site with little cultural lighting at night and in fog. Although the commander had briefed a vertical departure, the helicopter pitched progressively nose-down until impacting the ground. The four occupants were fatally injured. Safety action has been proposed by the CAA, and two Safety Recommendations are made.

### History of the flight

Plans were made earlier in the day for a night departure from a private landing site in the grounds of Gillingham Hall to Coventry Airport, with the two pilots, the owner of the helicopter, and another passenger aboard. The planned departure time was originally 1830 hrs, but the passengers were not ready to leave until around 1920 hrs. By this time, dense fog had set in; witnesses at the departure site and in the local area described visibility of the order of tens of metres.

Shortly before the passengers arrived at the helicopter, the cockpit voice and flight data recorder (CVFDR) recorded a conversation between the two pilots[2]. One said:

**Footnote**

1 Detailed records were not available for part of the period.
2 Both had similar accents and in this instance their voices could not be distinguished during evaluation of the CVFDR recording.

"[unintelligible] I DON'T MIND TELLING YOU I'M NOT **** VERY HAPPY ABOUT LIFTING OUT OF HERE". The other replied: "IT SHOULD BE OK IT'S... I DON'T THINK IT IS BECAUSE YOU CAN STILL SEE THE MOON"[3].

The co-pilot, who was to be the pilot not flying, escorted the passengers to the helicopter and assisted them aboard while the commander, who was to be pilot flying, started the engines. The co-pilot remarked to the commander that he had informed the passengers of the urgent need to depart, and that if a further delay in their embarkation had ensued, departure would not be possible.

The engines were started at approximately at 1922 hrs.

**Figure 1**

The paddock and helipad (foreground) and accident site (in nearest ploughed field).
Yarmouth Road runs across the middle of the picture,
Raveningham Road joins it at the T-junction

The paddock (see Figure 1) was of irregular shape, with a helipad to one side. Although the centre of the paddock was unlit, floodlights had been installed at ground level to illuminate trees at its edges. Work had also been done to clear the area in the centre of the paddock of trees to allow for helicopter manoeuvring. It was usual for the helicopter to approach and depart to/from the middle of the paddock; the helicopter would be hover-taxied to and from the helipad. One of the usual departure routes was in the direction of the accident flight, taking advantage of lower trees on the perimeter of that side of the paddock.

The commander briefed the co-pilot: "RIGHT ALL I'M GOING TO DO, TAKE IT OVER TO THE CENTRE OF THE FIELD, AND THEN JUST PULL THE POWER, WE'LL GO VERTICALLY UP, I'LL GO FOR THE STROBE AND JUST MAKE SURE THE HEADING BUG IS CENTRAL FOR US IF YOU CAN". The recorded position of the heading bug was 298°. This briefing did not cover the manner in which transition to forward flight would be achieved and no heights or speeds were mentioned.

**Footnote**

3 The moon was waxing gibbous, at which 91% of its disc was lit, bearing 130°T from the helicopter's location, at an elevation of 37° above the horizon.

The helicopter lifted from the helipad into a hover at 1924 hrs, and hover-taxied to the middle of the paddock where it came to the hover again; the pitch attitude in the hover was slightly nose-up. The helicopter then began to climb, almost vertically at first. At a height of approximately 32 ft agl, its pitch attitude changed from the slightly nose-up hover attitude, pitching nose-down, before the helicopter began picking up forward speed, continuing to climb.

At about 120 ft above the ground and with a nose-down pitch attitude of approximately 15°, the co-pilot said "NOSE DOWN [COMMANDER'S FIRST NAME]". It could not be determined from the recorded voice whether this was to highlight the nose-down pitch attitude or a prompt for more nose-down pitch, but more forward cyclic input was applied. In the following second the helicopter crossed the boundary trees and started to descend with increasing ground speed, forward cyclic input and nose-down pitch attitude. Progressively more collective was also being applied, with the resultant increase in engine torques.

The co-pilot repeated the "NOSE DOWN" words; again it could not be determined whether it was an observation or a request and again a nose-down input was made. The cyclic inputs, whilst still in the forward sense became more erratic, with one aft input recorded in the final seconds. The nose-down pitch attitude started to reduce from the peak recorded value of 35° as the helicopter descended through 100 ft agl. The collective input progressed to 100%, the engine torques increased but the rotor speed could not be sustained at the nominal 102% and started to reduce. The last nose-down pitch attitude recorded by the combined voice and flight data recorder (CVFDR) was 25° with the helicopter 82 ft above the ground, descending at 2,400 ft/min, with a ground speed of 90 kt.

The helicopter impacted a line of large hay bales lying across a field. The cabin structure was destroyed and all the occupants were fatally injured in the impact sequence.

The EGPWS recorded a descent rate of 1,458 ft/min, and a mode 3 alert trigger, associated with sinking after lift-off. The final data point recorded included a radio altitude of 65 ft.

The last CVFDR recorded torques were 142% and 158% for the left and right engines respectively, the two values being separated by one second. The engine computers recorded that the rotor speed had dropped to just below 95% before contact with the ground.

Analysis of the CVFDR audio recording, which carried on after the data was lost, indicates that rotor speed had dropped to approximately 93% at the point of impact. The helicopter's heading remained in the range 297-305° from prior to commencement of the vertical climb until impact. No flight director modes were selected during the flight.

**Previous flights**

The helicopter and crew departed a private landing site in Northern Ireland at 1210 hrs, and landed at another private landing site and then at Peterborough Conington, where the helicopter was refuelled with 1,201 litres of Avtur. The helicopter departed Conington at 1535 hrs and arrived at Gillingham Hall at about 1720 hrs. The two pilots discussed the weather during their flight from Conington to Gillingham Hall.

Co-pilot: "IS HE AWARE OF THE WEATHER SITUATION IS HE"
Commander: "TOLD [NAME OF OWNER'S PERSONAL ASSISTANT]"
Co-pilot: "YEAH I KNOW THAT (BRIEF PAUSE) WHAT I'M SAYING IS ARE YOU GOING TO TELL HIM"
Commander: "NO... (PAUSE) **** IT IT'S DOWN TO THEM (PAUSE) IF HE ASKS I'LL TELL HIM (PAUSE) I SAID I'LL CHECK THE WEATHER WHEN I GET TO NORWICH AND GIVE THEM AN UPDATE (PAUSE) THAT'S WHAT I'LL DO"
Co-pilot: "IF I HAD MY CASE WITH ME I WOULDNT MIND YOU BEING SO BOLD (PAUSE) BUT (PAUSE) THE ONLY PEOPLE WHO'LL LOSE OUT IS PROBABLY ME AND YOU".

(It is probable that the co-pilot was referring to a case which he would carry with him if expecting to spend a night away from base.)

**Witness information**

Witness statements showed that there was some vehicular traffic on the roads around the paddock, showing headlights, as the helicopter transitioned away from the paddock. In particular, one car was travelling along Raveningham Road towards the paddock. It then turned right onto Yarmouth Road, and the driver saw the helicopter fly over the car.

Eyewitnesses at Gillingham Hall observed the helicopter's departure and one recorded video of it on a smartphone. The smartphone recording captured a discussion between two witnesses, during which one referred to the depth of the fog, noting that no stars were visible through it. Their view was towards the north-west. Throughout the recording, the helicopter's anti-collision beacon, navigation lights and landing light are visible.

**Recorded data**

The helicopter was fitted with a combined CVFDR. This recorded more than 25 hours of data and approximately 2 hours of audio from both crew channels and the cockpit area microphone (CAM). The CAM recording was of good quality with the engines running. However, not all quiet speech with low ambient noise prior to engine start was recorded intelligibly. A review of the cause of this is ongoing.

The CVFDR was fitted with Recorder Independent Power Supply (RIPS) designed to keep the audio recording of the cockpit area microphone working for 10 minutes after the loss of the main source of electrical power to the CVFDR. This resulted in recorded audio at the end of the accident sequence, after the initial impact, none of which was identifiable as other than mechanical in origin.

Data was recovered from the EGPWS, the engine Data Collection Units (DCUs) and the Central Maintenance Computer (CMC) card from Modular Avionics Unit (MAU) 1. The EGPWS recorded the parameters every second for the 20 seconds prior to the accident and the DCUs recorded sporadic event-driven snapshots just prior to the impact and during the subsequent seconds and is reported on in more detail in the engineering section of this report.

*Flight profile*

The recorded time stamps appeared reasonable and were used for the purposes of the following narrative. The audio recording of the accident flight started at 1920 hrs. Figure 2 shows the relevant recorded data and some extracts from the CVFDR. Figure 3 shows the flight profile relative to the departure point and accident site.

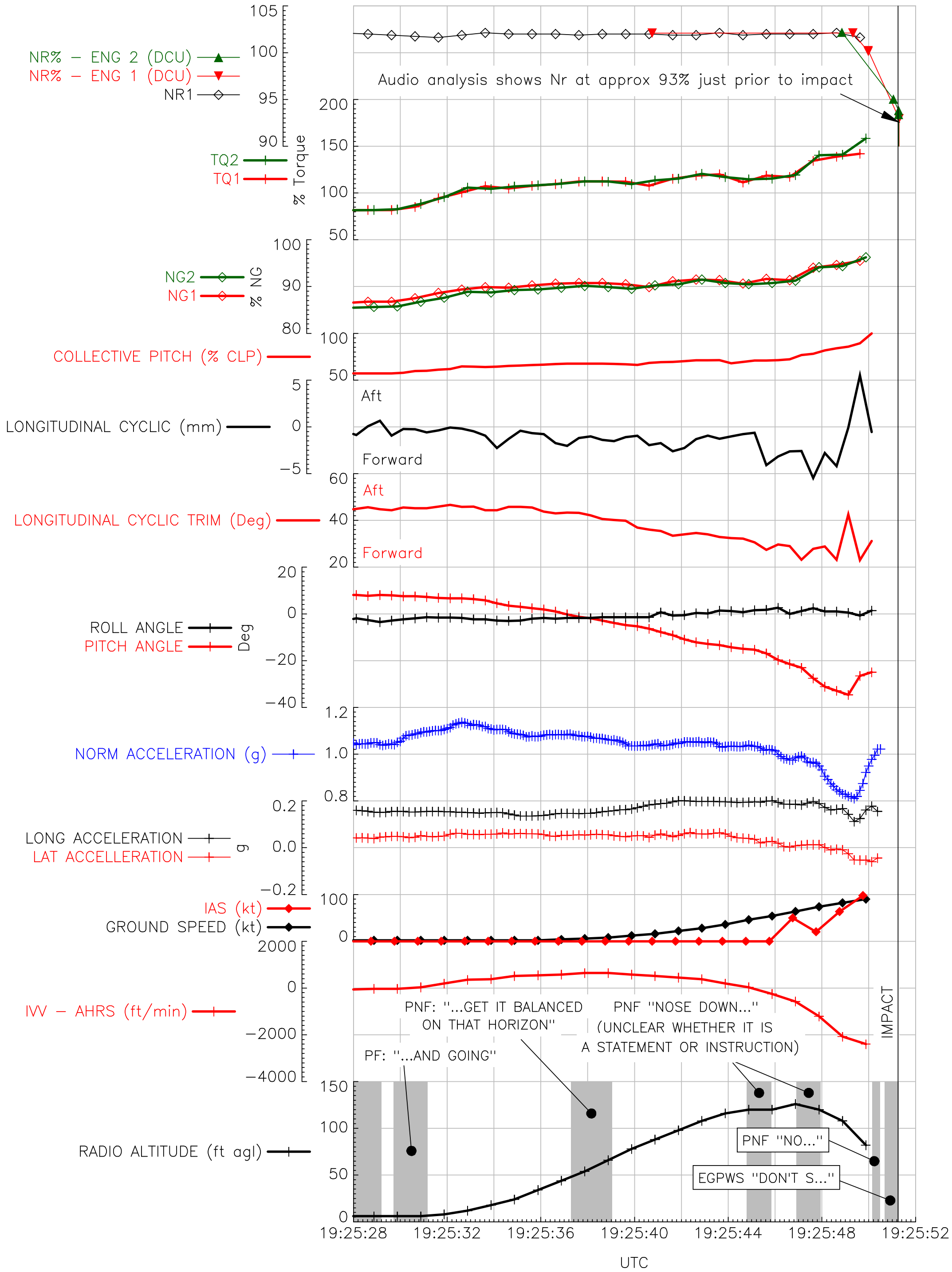


**Figure 2**

Pertinent engine DCU data parameters and CVFDR recorded data and transcript extracts.
The commander was the Pilot Flying (PF) the co-pilot was the Pilot Not Flying (PNF)

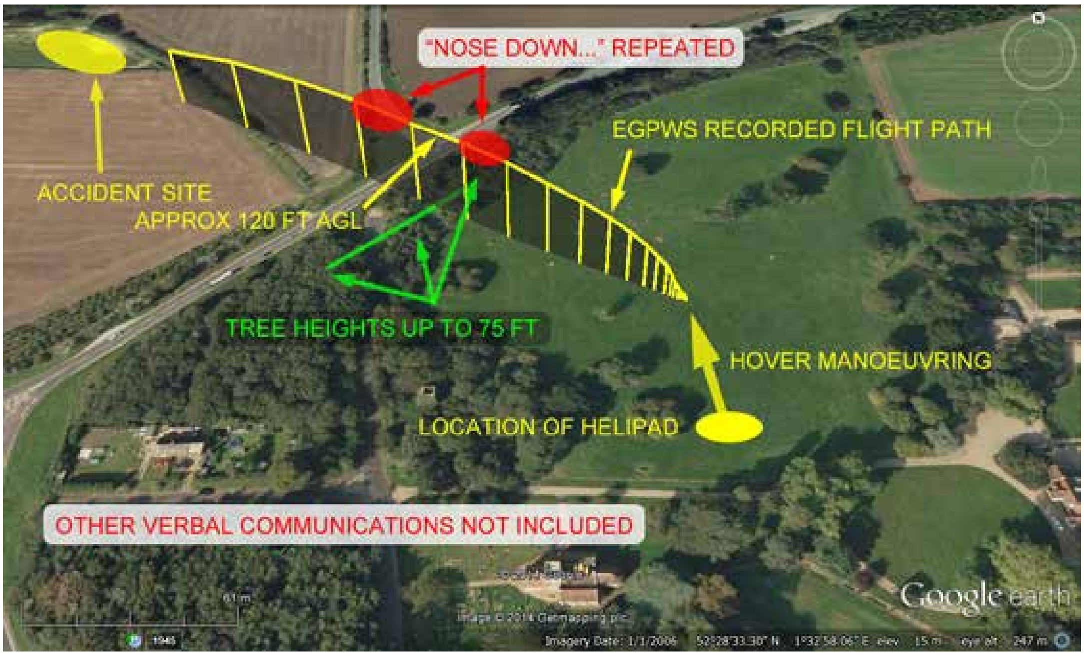


**Figure 3**
Flight path

The recorded data included parameters relating to cautions, warnings and system status. A gearbox torque caution was recorded by the CVFDR in the last moments of the accident flight. No other CVFDR warnings or cautions were recorded in the air. System status records were all attributed to normal operations for the given aircraft configuration.

The Autopilot Attitude Mode and Yaw Heading Hold were ACTIVE throughout the recorded flight. The data showed that trim release switches on the cyclic and collective controls, on which force must be applied against springs to achieve manual flight, were active throughout the flight.

The cyclic parameters were recorded twice a second. The sawtooth pattern of the parameter at the end of the flight indicates that a higher sampling rate would have been needed to capture accurately the dynamic behaviour of these parameters.

*Previous flights*

The CVFDR contained a recording of the previous flight and part of the one before that, in which the accident commander was also pilot flying and the co-pilot, pilot not flying. Briefings were absent or very short, and the habitual use of checklists and 'standard call-outs' were not in evidence.

*Flight dynamics*

The helicopter manufacturer declared that, based on their analysis of the recorded data, the helicopter responded appropriately to the crew inputs.

*Excessive pitch*

A comparison of the pitch attitude recorded during the accident flight with the previous flights recorded by the CVFDR is given in Figure 4. The maximum nose-down pitch attitude is not plotted as this graph uses a lower sample rate than the FDR data plot in Figure 2.

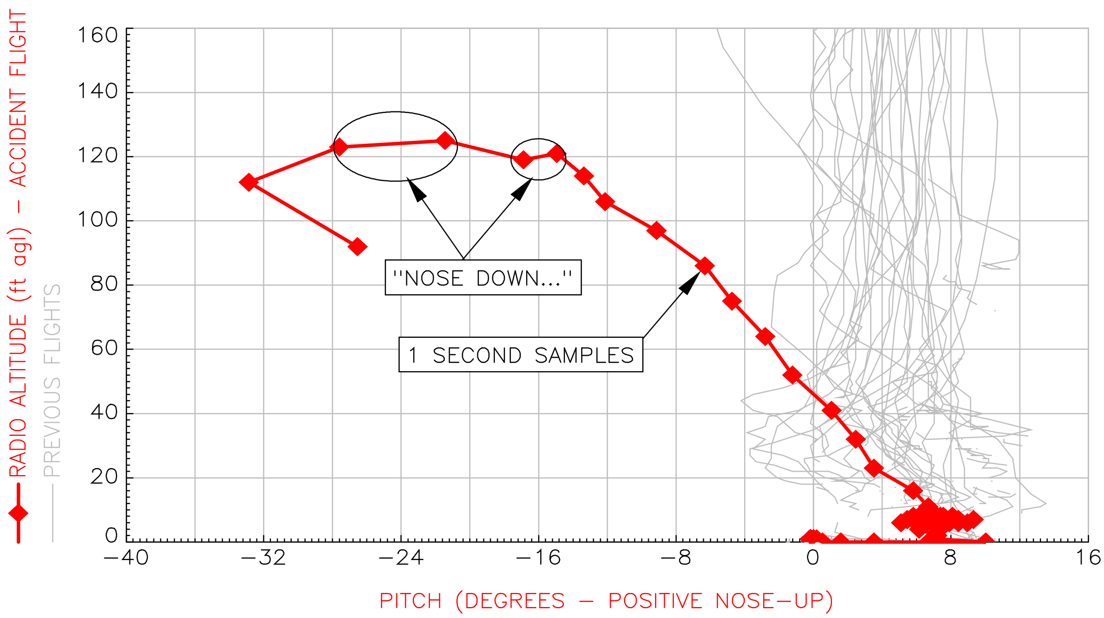


**Figure 4**

Radio altitude compared to pitch for the accident flight, compared with the previously recorded climb profiles

This shows that from approximately 50 ft agl in the climb the pitch attitude was becoming abnormally nose-down.

*Somatogravic illusion*

In the absence of visual cues, the "down" direction is sensed from accelerations experienced. This sensation can be compromised when gravity is no longer the only force being sensed, for example when an individual is within an accelerating body such as an aircraft. This somatogravic illusion is illustrated in Figure 5.

During the accident flight the helicopter had little movement in roll and so the recorded normal (vertical relative to the helicopter body) and longitudinal accelerations can be used to derive a model of "force vector pitch", ie, the pitch attitude perceived by an individual in the absence of visual cues.

The tri-axial accelerometers, located near the centre of gravity of the helicopter, are the primary source of acceleration data recorded by the CVFDR. However, smoothing of the data before recording causes the data to reflect the underlying acceleration trend and not the dynamic accelerations.

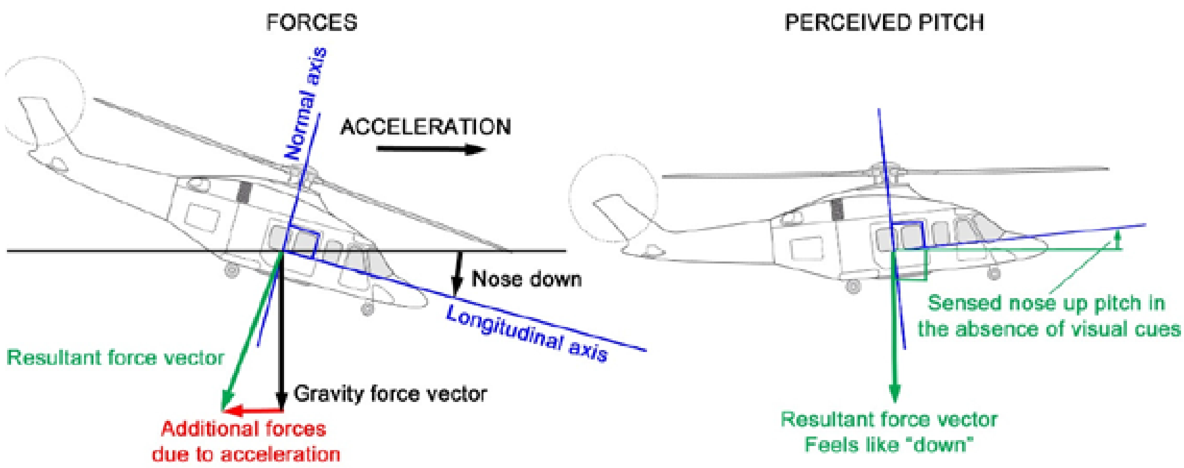


**Figure 5**

Effect of acceleration on perceived pitch in the absence of visual cues

The Attitude Heading Reference System (AHRS) also provides accelerometer parameters which are recorded in the CVFDR. These are not filtered to the same extent as the tri-axial accelerometers. These sensors are fitted in the nose of the helicopter, away from the centre of gravity, and therefore are affected by rotational motion. The attitude changes of the helicopter are not recorded at the same rate as the accelerations and so accurate correction for rotational motion during dynamic events, using the recorded data, is not practical. Neither data set is ideal but, given some of the dynamic pitch motion, the smoothed tri-axial data is the only set that can be used reasonably in this instance.

Figure 6 plots the radio altitude against the force vector pitch derived from the tri-axial accelerometer data and compares the plot with those of previous flights.

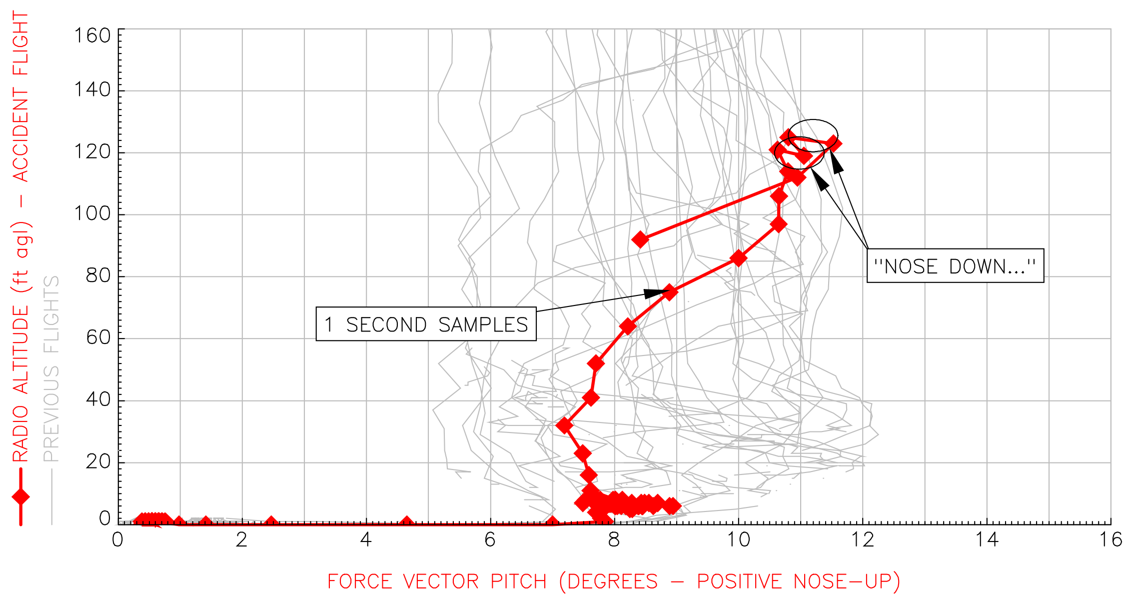


**Figure 6**

Radio altitude plotted against force vector pitch for the accident flight compared to previously recorded climb profiles

During the accident flight, the calculated force vector pitch remained comparable with previous flights for the first part of the flight. The first crew communication referencing the pitch of the helicopter was at a point in the flight where the calculated force vector pitch was more nose-up than the majority of previous flights for the given height.

*Indicated Airspeed*

Airspeed information is presented to the pilots by speed tapes on the left side of the primary flight displays. These are immediately adjacent to the electronic attitude display indicators which incorporate artificial horizon displays. The IAS parameter did not register until late in the flight. On the previous flights IAS began to register with lower ground speeds than on the accident flight. However, the data also showed that very early in the accident flight, the helicopter had more nose-down pitch for the given groundspeed than the previously recorded flights and this would have affected the sensing of IAS.

*Central Maintenance Computer (CMC)*

The CMC is a Modular Avionics Unit (MAU) card housed in the nose of the helicopter. It stores fault codes relating to the helicopter avionic systems in non-volatile memory (NVM). The MAU suffered impact damage but a full data download was achieved. The data was supplied to the MAU manufacturer for decoding.

The faults recorded on the CMC did not reflect any system issues relevant to the accident.

**Engineering**

*Initial examination*

The helicopter struck the ground in a gently rising field immediately ahead of a row of rolled hay bales (see Figure 7). These formed a boundary between the body of the field and a recently ploughed section, approximately 420 metres from the takeoff point. Inspection of the terrain under the flight path of the helicopter did not find any evidence that the helicopter had struck any of the trees or any other object during the flight.

The first ground marks, made by the lower nose of the helicopter and the nosewheels, indicated that the landing gear was DOWN and that the helicopter had struck the ground with approximately 25º of nose-down pitch on an approximate heading of 304º. Items recovered from the initial impact point included elements of the lower nose structure, forward fuselage and both cockpit entry steps. The helicopter then passed through the hay bales into the ploughed field. Four of the five main rotor blade tips were embedded in the ground to the right of the helicopter's flight path approximately nine metres beyond the initial impact point. Measurements indicated that the rotor blades had struck the ground between 50 and 60º 'nose-down'.

A second impact mark, which contained elements of the forward fuselage and passenger cabin structure, was identified 45 m beyond the first ground mark. Several items from the nose avionics bay, including both batteries, had been released between the first and second impact marks. The fuselage came to rest 18 metres beyond the second impact point facing

180º to its direction of travel. The ground markings and distribution of wreckage between the second impact point and the fuselage's resting place indicated that the helicopter had become airborne again after the second ground impact. During the impact sequence three of the five main rotor blades had detached from the rotor head.

**Figure 7**
General view of the accident site

The helicopter suffered significant disruption to the fuselage which had resulted in the failure of all the major structural elements of the cockpit and passenger cabin. The right fuel tank was intact, but the left tank and several fuel lines were found to be damaged. Approximately 400 litres of fuel were recovered from the fuel tanks and, based on tests carried out at the accident site, it is estimated that up to 1,000 litres of fuel may have leaked from the damaged fuel system.

Initial examination confirmed that both engines had been operating during the impact sequence and that the rotor head could be turned. The rotor head had suffered significant damage, consistent with the rotors turning under high power at impact. The damage observed to all of the main rotor blades was also indicative of rotation under power at impact.

Impact damage resulted in the failure of the tail fin and the tail rotor drive shaft at the base of the fin. Witness marks indicated that the tail rotor drive shaft had been rotating during the impact sequence. The tail rotor drive shaft was also found to rotate freely when the main rotor head was turned.

The CVFDR was removed from the fuselage and transported to AAIB headquarters for analysis prior to the recovery of the wreckage of the helicopter.

**Aircraft information**

The helicopter was a long-nosed variant of the Agusta Westland AW139 fitted with two Pratt and Whitney Canada PT6C-67C engines each rated at 1,100 hp and a maximum torque limit of 160%. Electrical power was provided by two engine driven generators and two batteries mounted in the nose of the helicopter.

Each engine was controlled by an Electronic Engine Control (EEC). Each engine was also fitted with a Data Collection Unit (DCU), designed to record a snapshot of engine parameters when the EEC detects an exceedence of engine parameters. When a recording snapshot is triggered, the relevant DCU records data relating to the engine, comparative data from the other engine and the position of the collective pitch control. Each snapshot is time-stamped against EEC running time and stored in one of three buffers; the Fault Buffer, the Event Buffer and the One Engine Inoperative (OEI) Buffer, depending on the triggering event. The EEC's and DCU's are powered by an engine-mounted generator and will record data while the gas generator module of the engine is operating at, or above, 40% rpm.

The helicopter was equipped with the Honeywell Primus EPIC integrated avionic system. The EPIC system comprises two MAUs, installed in the nose of the helicopter, consisting of a cabinet that contains a number of Line Replaceable Modules (LRMs). The MAU's function is to integrate the systems and sub-systems that supply the helicopter with navigation, communication, automatic flight, indicating, recording and maintenance capabilities. Operation is via cockpit controls, sensors, displays and integrated computers.

Engine parameters are acquired by the MAUs from the EECs. Each EEC collects data from sensors installed on its respective engine and digitises it. This data is then transmitted to both MAUs. Therefore, in the event of a MAU failure (caused, for example, by a power supply problem or a self-diagnosed shutdown), the data from both engines remains available. Data received from the EECs is referred to as 'digital' engine data. For redundancy purposes, some sensors are wired directly from the engine sensors to each MAU, bypassing the EECs. These parameters are referred to as 'analogue' engine parameters as they are acquired by the MAUs directly from the sensor. No 1 engine analogue parameters are only connected to MAU 1 and No 2 engine to MAU 2.

*FLIR*

The helicopter was fitted with a Forward-Looking Infra-Red (FLIR) system; live imagery from an IR camera mounted beneath the helicopter's nose could be selected on one of the displays in the cockpit. The status of the system was not recorded and the CVFDR contained no reference to the system by the pilots. It was not possible to determine whether it was active during the accident flight.

*Maintenance information*

Examination of the helicopter's maintenance records confirmed that it had been maintained in accordance with current airworthiness requirements. The final entry in the airframe log book, 4 March 2014, stated that it had accumulated 488.07 flying hours since manufacture. The last routine maintenance inspection was completed on 3 March 2014 at which time a main rotor blade damper was replaced. On 11 February 2014 a tail rotor damper was replaced during scheduled maintenance and the last annual inspection was completed on 13 October 2013 at 375.20 flying hours. No defects were identified in the helicopter's records which could have affected the outcome of the accident.

**Detailed examination**

Inspection of the rotor drive train confirmed that there was no evidence of a failure with either engine or any of the elements of the main and tail rotor drive trains. Reconstruction of the flying control circuits and examination of the main and tail rotor hydraulic actuators confirmed that all the damage was consistent with the impact forces and that there was no evidence of a pre impact defect or restriction within any of the flying controls.

Both engine DCU's were downloaded by representatives of the engine manufacturer at the AAIB. Initial analysis of the data showed that both DCU's had recorded a number of exceedence snapshots initially triggered by both engines exceeding the peak torque limit of 160%. A detailed analysis of the data was carried out by the engine manufacturer which confirmed that the left engine EEC had not recorded any defects in the 140 hours prior to the accident and the right engine EEC had no stored faults for 83 hours prior to the accident. Data recovered from both DCU OEI buffers showed that a snapshot was recorded 14.4 seconds prior to impact. This was triggered by both engines reaching the lower boundary of continuous OEI operation (111% torque). At 3.6 seconds before impact both engines were recorded reaching the lower boundary for 2.5 minute OEI operation (141% torque). Prior to impact both engines appear to have been performing normally with no EEC faults recorded. The analysis identified that at the point of impact both engines were delivering power, with torques above 160% and the collective pitch lever was above 98% of its travel. After impact a number of faults were recorded which were similar on both engines and were the result of the impact with the ground.

**Meteorology**

The investigation did not identify meterological reports or forecasts which the pilots had consulted before the flight, but it is possible that they used smart-phones or tablet devices (both were found on the accident site) to obtain this information, without carrying printed copies with them.

The Met Office chart of forecast weather below 10,000 ft valid at 1800 hrs for an area which included all of England, south of the Humber Estuary, was presented as follows:

| AREA | SURFACE VIS AND WX | CLOUD | 0 C |
|---|---|---|---|
| D | ISOL 12 KM NIL<br>WDSPR 7 KM HZ<br>OCNL (ISOL LAN TL 21 Z) 3000 M BR<br>ISOL (OCNL W) 600 M FG SEA COT<br>ISOL 200 M FG LAN FM20Z<br>OCNL HILL FG | OCNL BKN ST 000-005 / 015 SEA COT<br>ISOL (OCNL FM21 Z) BKN/OVC ST ...<br>...004-008 / 010 LAN (BASE 000 FG) | 070-XXX |

The Met Office explained that the term 'COT' is defined by the World Meteorological Organisation to mean 'at the coast', and has no more detailed definition.

The nearest locations for which aviation forecasts were available were North Denes Heliport, 11 nm NNE of Gillingham Hall, and Norwich Airport, 15 nm to the NW.

The North Denes forecast at 1702 hrs predicted light winds and a visibility of 200 metres in fog and broken cloud at 100 ft temporarily improving, between 1800 hrs and 2100 hrs, to 1500 metres in mist with scattered cloud at 100 ft.

The forecast for Norwich at 1702 hrs predicted light winds and a visibility of 6,000 metres with no significant cloud with the visibility reducing to 4,000 metres in mist between 1800 hrs and 2100 hrs and a 30% probability of a visibility of 200 metres in fog with broken cloud at 100 ft between 1800 hrs and 2100 hrs.

The actual observations at Norwich at 1920 hrs (six minutes before the accident) described 3 kt of wind from 070º, a visibility of 3,000 metres in haze, no significant cloud, temperature +5C, dewpoint +4C, a QNH of 1030 HPa with a temporary reduction in visibility to 200 metres in fog.

Additionally, the Met Office provided an aftercast of the conditions around Gillingham:

> *'…an area of high pressure was centred over the UK with very light winds affecting the area. It was a rather hazy afternoon with visibilities generally between 5000 M and 8 KM. Conditions deteriorated further through the late afternoon with much of Norfolk affected by mist, and in coastal areas, such as North Denes, dense fog developed between 1620 and 1650 UTC. On light east to northeasterly winds this dense fog gradually crept further inland reaching Norwich Airfield by 2020 UTC. This would suggest that visibility in the Gillingham area would have deteriorated in to fog prior to this time.'*

Eyewitness reports and CCTV recordings reinforced the findings in the aftercast that the area around the accident site was affected by dense fog which formed in the early evening.

**The operator**

The helicopter was owned and operated under the auspices of a limited company, incorporated in 1993, and ultimately owned by the principal passenger. For some years, the company had held an Air Operator's Certificate issued by the UK CAA. During the AOC-holding period, the company demonstrated that it met various regulatory requirements in excess of the requirements applicable to private flying. The owner was the accountable manager of the AOC operation. Under JAR-OPS 3, accountable managers were required to satisfy the CAA of their suitability to hold the post, and the owner had done so.

Since the cancellation of the AOC in 2008, operation of the company's helicopter was the responsibility of the senior pilot employed by the company; at the time of the accident this was the commander. A similar arrangement had existed prior to the AOC being granted. In the absence of an AOC, there was no regulatory requirement for an operations manual or safety management system for private flying. Some evidence suggested that an operations manual, including type-specific matters, procedures to be employed by pilots flying together, such as briefings and standard calls, and a safety management system had existed, at least in draft form, in recent years, but none was in use at the time of the accident.

The helipad at Gillingham Hall was one of the helicopter's regular destinations, and both pilots had flown to and from of it previously, by day and night.

**Previous accident**

In the 1990s, the operator used an S-76 helicopter in the same role as that in which the accident helicopter was engaged. The Irish Air Accident Investigation Unit (AAIU) investigated a fatal accident involving the loss of that helicopter in 1996, and published an 85-page report[4].

The report explained that the helicopter flew into terrain during an arrival to the helicopter's base in Northern Ireland. The helicopter's three occupants were fatally injured.

The report found that the primary cause was *'loss of situational awareness'* on the part of the pilot flying, and that secondary causes included:

'
- *The Commander of the Aircraft, the PNF, failed to make adequate preparation and take precautions to ensure the safety of the flight*
- *The crew embarked on the flight without proper planning or briefing*
- *The use of a locally produced GPS-based approach procedure which gave little margin for error, and which was inadequate to alert the crew to terrain dangers.*
- *The operation of this aircraft, in a corporate aviation role, in the private aviation category, in a demanding environment, without the benefit of external monitoring of the operation.'*

The report noted that:

> *'The flight used a navigation approach procedure that would not meet the standards required by the UK Authorities for public transport operations. However, this was not illegal because the flight was operated under private category rules'.*

An annex to the report contained a facsimile of the approach procedure found in the wreckage. A chart recovered from GLBAL depicted a similar approach to the same geographical area

**Footnote**

[4] Aircraft Accident Report 01/98: Report on the accident to Sikorsky S-76B G-HAUG at Omeath, Co. Louth 12 December 1996.

The AAIU report also noted:

> *'Operation of the Aircraft*
>
> *The operation was initiated by the owner, but it was organised by the Chief Pilot, who advised the owner on matters relating to the operation, and effectively managed it on a daily basis. Apart from the two professional pilots, no other aviation professionals were employed by the owner in the conduct of the operation.*
>
> *The aircraft was operated in the private category. As the aircraft was not used for any consideration, or hire and reward, it was consistent with UK Regulations to operate such an aircraft in the private category.'*

And:

> *'Operations Under Private Category Rules*
>
> *In the UK, corporate aviation is regulated under the rules pertaining to private aviation. Therefore the rules that applied to the operation of G-HAUG were those that apply to normal private category aviation. These rules govern, in the main, the operation of private pilots, largely in simple single-engined aircraft, with fairly basic instrumentation. Typical general aviation activity of this kind is owner flown and operated, and the owner is usually intimately involved with the operation and flying of the aircraft.*
>
> *The operation of G-HAUG was markedly different from these general aviation norms. The owner was not a pilot, and his prime requirement was that the operation should provide effective transportation in most weather conditions prevailing in the area. To achieve this he purchased a state-of-the-art aircraft and hired professional pilots to manage the operation. The evolving procedures generated by the pilots indicated a strong commitment to meeting the owner's requirements.*
>
> *This eventually led to use of an approach procedure… that relied heavily, and almost exclusively on GPS and fully exploited the potential of the aircraft's systems, with very little margin for error. It is not known what weather minima were in use at the time, but the lack of concern on the part of the PNF and the chief pilot when still in cloud, in the final stages of the flight, while below the height of mountains on both sides of a relatively narrow lough, indicates that the situation was not unusual and that the aircraft was still above the minima being used in the operation when it collided with the mountain.*
>
> *As a consequence of the fact that the operation was conducted under general aviation rules, there was very little external examination of the operation. In particular, this led to the use of approach procedures which would not satisfy the standards set by the CAA. Because the aircraft was operated in the private category, it was not illegal to use such approach procedures.*

*It appears anomalous that the rules pertaining to general private aviation should also apply to the all-weather operation, by day and by night, of a very sophisticated twin-engine helicopter equipped with a very capable avionics fit, which was engaged in the professional transportation of passengers, albeit of a limited number of persons.*

*It may be noted that some countries do legislate for corporate aviation, to a standard between the private category and full public transport category. There are some difficulties in determining the transition point between corporate and private aviation, but a definition of corporate aviation could use criteria such as the employment of professional pilots and the seating capacity of the aircraft.'*

The Irish AAIU made nine Safety Recommendations including:

'● *The UK CAA should consider the establishment of a special category for the operation of corporate aviation. (SR 7 of 1998)'*

This recommendation was accepted by the UK CAA, which supported work by the Joint Aviation Authorities (JAA) towards proposed regulation of corporate operations. That regulation did not materialise during the life of the JAA.

'● *The JAA Joint Working Group for JAR OPS 2, which reviews operation standards for aircraft operation in the JAA States, including the UK and Ireland, should consider the establishment of a special category for the operation of corporate aviation, to encompass the operation of aircraft such as G-HAUG. (SR 8 of 1998)'*

There was no response to this recommendation from the JAA. The UK CAA provided comment to the AAIU.

'● *The Irish Aviation Authority (IAA) and the UK CAA should bring to the attention of operators of corporate aircraft the safety benefits that would result from external vetting of their operations, pending the establishment of a suitable regulatory framework for corporate aviation activities. (SR 10 of 1998)'*

The UK CAA accepted this recommendation.

**Personnel information**

The commander held a CPL(H), with IR, issued by the UK CAA. It contained ratings on the A109 series, AB139 (sic), AS355, Bell 206 series, Hughes 269, R22, R44, and SK76 helicopters. His last proficiency check on the AW139 was conducted in G-LBAL on 7 May 2013. His flying experience is given in the header of this bulletin. His Class One medical certificate was valid. In the 14 days prior to the day of the accident, he had flown on a total of five days accumulating a total of 14 hrs 12 mins flying time.

The co-pilot held a CPL(H), with IR, issued by the UK CAA. It contained ratings on the A139 (sic), AS355, R22, and R44 helicopters. His previous licence contained a rating on the A109 series of helicopters. His last AW139 proficiency check was carried out in a simulator at the manufacturer's facility in Italy on 22 February 2014. The last completed page of his log book, dated 7 March 2014 showed a total flying time of 1,187 hours of which approximately 367 was on the AW139. His Class One medical certificate was valid. In the 14 days prior to the day of the accident, he had flown on two days accumulating a total of 8 hrs 36 mins flying time.

Both pilots had completed training for their initial instrument ratings at the same flying school. The chief flying instructor there gave an account of the training they had received for a type rating on a multi-engine helicopter, followed by the instrument rating. The CAA confirmed that the training provided was in keeping with the relevant requirements and reflected normal practice in the training community. The type rating was conducted entirely under visual flight rules. Screens were positioned inside the cockpit transparencies for the instrument rating to deprive the pilot under training or test of a view of the external environment. The instructor or examiner carried out the takeoffs and landings, with the student only having control of the helicopter at a safe height and at or above Vmini (the minimum airspeed for flight under IFR).

No evidence was found to show that either pilot had received training in vertical departures in low visibility.

Both pilots maintained single-pilot qualifications to operate the helicopter; they were not trained or tested as a crew of two. The helicopter was operated privately, therefore no flight crew duty limitations applied.

### Pathology

A specialist aviation pathologist carried out post-mortem examinations of both pilots. These found no pre-existing conditions which could have accounted for the accident, and toxicological tests returned negative results.

### Vertical departures with limited visual references

Discussions with British military helicopter pilots revealed that procedures exist in military aviation for vertical departures, flown with very limited external visual references, and military pilots are trained and tested in these techniques. In these circumstances, flight by sole reference to the instruments is permitted at speeds below Vmini. There was no evidence that either of the pilots of GLBAL had received training in these procedures.

### Vmini

The AW139 flight manual limitations section stated:

> *'Minimum airspeed for flight under IFR (Vmini) ...................... 50 KIAS'*

The CAA advised that Vmini was defined in FAA and EASA documents. The FAA stated that Vmini (Minimum IFR Speed) is *'The minimum speed for which compliance with the IFR handling qualities requirements has been demonstrated'* and that it *'should be established as a limit for IFR operations'*.

EASA Certification Standard (CS) 29 Book 1 Appendix B stated:

> *'Vmini means the instrument flight minimum speed, utilised in complying with the minimum limit speed requirements for instrument flight.'*

Discussions identified that Vmini should be interpreted as the minimum speed for flight by sole reference to the flight instruments, rather than under IFR, as this provision might otherwise appear to prohibit normal departure and arrival under IFR even in VMC. Practically-speaking, Vmini is the speed below which the helicopter should be flown with reference to external visual cues. During departure, the helicopter should be flown visually until Vmini is attained, after which flight by sole reference to the instruments may continue at or above that speed until the speed reduces below Vmini, when visual flight must be resumed.

**Regulations**

The CAA was asked to confirm the minimum visibility requirements relevant to private helicopter operations under IFR at private landing sites. It was established that no minimum visibility is set down for private helicopter operations at landing sites which do not have published IFR procedures. For commercial air transport operations the minimum visibility is 800 m; no cloud base is specified.

For private departures under IFR from aerodromes, the minimum RVR or visibility is 800 m.

**CAA paper 2007/03 *'Helicopter Flight in Degraded Visual Conditions'***

In September 2007, the CAA published its paper 2007/03 'Helicopter Flight in Degraded Visual Conditions'(DVE). The *'Overall findings'* of the report included:

> *'d) During the period 2000-2004 there were 4 fatal accidents involving private flights, representing 50% of the relevant private cases identified and resulting in 8 fatalities. They all involved spatial disorientation as a probable causal factor...*
>
> *e) Serious consideration must be given to the measures that need to be taken to reverse this trend, taking into account improvements to regulations, operating procedures and requirements or pilot training requirements.'*

The report noted that:

> *'When addressing requirements for visibility minima, factors such as the height that the aircraft should be permitted to fly at versus the available view over the nose of the aircraft should be taken into consideration. For a given cockpit view, the pilot's forward view diminishes with increasing aircraft height…'*

Under *'Pilot training issues'* the report noted:

> *'Pilots should be better trained to make informed decisions on whether 'to fly or not' in marginal conditions, or when IMC conditions are developing enroute. This might be achieved by developing a probability index based on factors that contribute to a high risk accident scenario (e.g. meteorological conditions, visual conditions, visual range, acuity of the visual horizon, aircraft configuration, aircraft handling qualities).'*

The report's concluding remarks included:

> *'Helicopters are difficult to fly at the best of times, i.e. in good visual conditions with plenty of outside world references and with stability augmentation… As visual conditions degrade, control becomes complicated (workload increases) by the interaction between stabilisation and guidance functions, and it becomes more difficult for the pilot to utilise tau cues coherently.*
>
> *The results [of the simulator investigations carried out] have highlighted just how precarious the balance between performance and safety is, and how small the safety margin can get, as visual conditions degrade. The accidents reviewed [7] also reflect this precariousness and the vulnerability of the 'average' pilot to the consequences of loss of spatial awareness. Hence, it is of concern that analysis of the data shows that the number of accidents resulting from spatial disorientation in a DVE is increasing… As noted previously, it is clear that timely consideration must be given to the measures that need to be taken to reverse this trend, including the recommendations given in the following section.'*

The report made eight recommendations, including:

> - *'Specification and adoption of FODCOM[5] training requirements for all civil helicopter operations that fall into the DVE[6] category.*
> - *Appropriate steps should be taken to raise pilot awareness of the problems associated with operations in the DVE, i.e. the interaction between vehicle handling qualities and visual cueing conditions.*
> - *Address the probability of pilots encountering DVE conditions by providing guidance on whether 'to fly or not' in marginal conditions with the potential for DVE encounters. This could be achieved using a simple probability index based on consideration of those factors that contribute to a high risk accident scenario, including:*

[5] Flight operations department communication.
[6] Degraded visual environment.

> i) *meteorological conditions (precipitation, cloud base etc.),*
>
> ii) *visual conditions (time of day, fog/mist/haze conditions, visual range, acuity of the visual horizon etc.),*
>
> iii) *aircraft configuration (navigation aids, flight instruments, cockpit view and layout etc.),*
>
> iv) *aircraft handling qualities (SAS, FCMCs).'*

The CAA published an Aeronautical Information Circular based on this paper in 2007 (P100/2007) which was updated in 2013 as P067/2013.

**CAP686 Corporate Code of Practice (Helicopters)**

In 1998 the CAA published a code of practice for helicopter operators. This was republished in 2009. The preface to the 2009 edition stated, among other things:

> *'The aim of the Code of Practice is to give guidance on owning and operating a helicopter for corporate purposes to those companies whose principle place of business is in the United Kingdom and the Channel Islands.*
>
> *The Code of Practice is mainly intended to apply to the operation of multi-engine IFR equipped helicopters operating with less than nineteen passengers and normally flown by a single pilot: it has also been structured to be easily adjusted to cover any corporate or aerial work flight.'*

The code offered guidance on compilation of an operations manual, safety management systems and risk assessments, and training. Application of the code was optional for operators.

**CAA action**

On 23 May 2014, the CAA published a safety notice entitled *'Private and Aerial Work Helicopter Operations – Guidance On Aerodrome Operating Minima For IFR Departures'* which stated:

> *'Any helicopter pilot landing or departing at an aerodrome needs to ensure that the site is suitable and that the prevailing weather conditions at the site are adequate to carry out all normal and emergency procedures. Whether a field site or a licensed facility, the aerodrome of departure will need to provide an environment where the flight can be commenced and safely continued into the en-route phase. In relation to this, the commander of the aircraft has certain legal and airmanship obligations to fulfil in relation to ensuring that the flight can be safely made whether day or night, under the Visual Flight Rules (VFR) or the Instrument Flight Rules (IFR).*
>
> *In contrast to helicopter Public Transport operations, private and aerial work flights are allowed more operational flexibility including a greater possible choice*

> *of take-off and landing sites. With that flexibility, however, comes the potential for increased risk and a need to exercise high standards of airmanship, decision-making and hazard assessment. This is of particular importance when planning to depart IFR, in Instrument Meteorological Conditions (IMC) or at night, from a site where instrument procedures and aids are not available or established.'*

It acknowledged the absence of a legal minimum visibility requirement for some operations, and continued:

> *'Where no IFR departure procedures have been established, it is recommended that private and aerial work flights apply the VFR night visibility minima of 3,000 metres for take-off'.*

**EASA Part NCC**

A series of EASA implementing rules will bring new regulation into force, and operations such as that of G-LBAL will fall under Part NCC, which covers non-commercial, complex, aircraft. Operators will be required to produce, and operate in accordance with, a suitable operations manual, and to have an appropriate safety management system.

The CAA issued Information Notice IN-2013/087 *'Future Flight Operations Other than for the Purpose of Commercial Air Transport'* on 7 June 2013, explaining that there is a transitional 'opt-out', and that the CAA has taken advantage of the full opt-out term. On 6 September 2013 the CAA published a further Information Notice on the same subject, IN-2013/143, to provide an:

> *'update on the progress of rule development which will lead to the introduction of European implementing rules affecting aircraft operations other than those for the purpose of commercial air transport.'*

The CAA has confirmed that Part NCC will come into effect within the UK on 25 August 2016.

**Decision making**

In its report of the accident involving a commercially operated complex helicopter[7] the AAIB noted that:

> *'…pilots will often be subject to pressures – real or perceived – to complete a task. These pressures might lead pilots to continue with flights in circumstances where otherwise they would not…'*

Discussion with industry participants during the investigation of the accident involving G-LBAL indicates that increased regulation is not a complete solution if these pressures cause pilots to operate a flight in violation of the regulations, and that mitigating the pressures themselves is necessary to improve safety.

**Footnote**

[7] Report on the accident to Agusta A109E, G-CRST, near Vauxhall Bridge, Central London on 16 January 2013.

## Analysis

*Engineering*

The ground marks and distribution of wreckage on the accident site indicate that the helicopter struck the ground approximately 25º nose-down with considerable forward speed. The nose-down attitude of the fuselage then increased rapidly to the point where the main rotor blades struck the ground. The process was probably accelerated by the fuselage passing through the rolled hay bales. The items recovered from the initial impact point indicated that the forward section of the fuselage had suffered significant damage during the initial impact which resulted in the release of the aircraft batteries and loss of power to the flight recorder.

The distribution of wreckage indicated that, immediately after the main rotor blades struck the ground, the helicopter continued on its heading but became airborne again and began to rotate clockwise about its main rotor head before striking the ground for a second time, 43 metres beyond the initial impact point. The debris recovered from the second impact site indicated that the lower fuselage structure had been severely compromised. After the second impact the fuselage became airborne for a second time before coming to rest 18 metres beyond the second impact point. It was estimated that the fuselage had rotated through approximately 540º before coming to rest.

The helicopter's records confirmed that it had been maintained in accordance with current airworthiness requirements and that there were no apparent defects which had a bearing on the accident flight. No evidence was found of any pre-accident defects or restrictions in the flying control systems or the main and tail rotor drive trains. The helicopter appeared to respond appropriately to control inputs. The analysis of the downloaded DCU data confirmed that both engines were operating at impact and performing in accordance with flight crew control inputs. The engine EECs had recorded no faults during the accident flight or in the 83 flying hours prior to the accident.

*Operations*

The accident flight

The helicopter was serviceable prior to the accident flight. The pilots were suitably qualified for their duties and were in current practice. They had experience of the helicopter and the site from which they were to depart, and no evidence suggested that they were not fit to fly. In the context of the operation, the proposed flight was routine.

Forecasters had correctly predicted deteriorating visibility and the onset of mist and fog through the afternoon and evening, and the co-pilot's questions to the commander during the previous sector, and the commander's responses, demonstrate that the pilots were aware of the forecasts and that the copilot was concerned that a plan to deal with the possibility of conditions too inclement for flight had not been made. Although the investigation did not establish what forecast information the pilots had accessed, it is clear from their dialogue that they were aware of the foggy conditions both before and after their onset.

The visibility deteriorated significantly in the time before departure, and departure at the original planned time might have been into less difficult conditions. For pilots, rapidly deteriorating weather, as a departure is delayed, presents challenges. In particular, it creates an unpredictable and dynamic environment in which a decision that flight is no longer an appropriate option may have to be taken promptly.

The CVFDR recorded the following pre-flight conversation between the pilots: "[unintelligible] I DON'T MIND TELLING YOU I'M NOT **** VERY HAPPY ABOUT LIFTING OUT OF HERE"; "IT SHOULD BE OK IT'S... I DON'T THINK IT IS BECAUSE YOU CAN STILL SEE THE MOON". The pilots had operated this helicopter from this helipad routinely, by day and night. The helicopter was serviceable, the load and planned flight were not unusual, and the wind was very light. The only novel aspect of the departure identified during the investigation was the fog. It is logical, then, that this exchange illustrates that one of the pilots remained concerned about the conditions into which the helicopter would depart, very shortly before it was due to do so. Whilst it was not possible to identify which pilot spoke which phrase, it is clear that both gave thought to the conditions.

The remark about the moon may suggest that, at that moment, the fog was not very deep. However, in foggy conditions, the difference between horizontal (surface), vertical, and slant visibility can be marked. This typically poses challenges for pilots when an airfield may be seen clearly from directly above in flight, but is not visible on a normal approach. The moon's elevation, 37°, clearly did not place it overhead, but nonetheless it was appreciably above the horizon. Moreover, fog is not always uniform, and visibility within it may vary significantly both with time and from one place to another, even over short distances.

The eyewitness remark, recorded on the video recording of the departure, that no stars were visible suggests that the fog may have been relatively thicker towards the north-west; the direction in which the eyewitness was looking.

Because the departure was from a private landing site, rather than an aerodrome at which meteorological observations were made, the pilots were not able to receive visibility and cloudbase information from an official source. It is possible that the availability of an official observation of the conditions might have prompted a decision not to depart.

The co-pilot's remark to the commander, that he had informed the owner and other passenger that they must now depart, suggests that the pilots had determined that further degradation in the visibility would render departure inappropriate.

### Briefing

The CVFDR recording of earlier flights showed that the pilots did not conduct formal briefings, but occasionally made short statements of their intentions. The commander's brief: "RIGHT ALL I'M GOING TO DO, TAKE IT OVER TO THE CENTRE OF THE FIELD, AND THEN JUST PULL THE POWER, WE'LL GO VERTICALLY UP, I'LL GO FOR THE STROBE AND JUST MAKE SURE THE HEADING BUG IS CENTRAL FOR US IF YOU CAN" suggests that a vertical departure profile was the intention. However, no evidence of a briefed height to be attained, or value for the height of takeoff decision point (TDP) was discovered, so comparison between the intended profile, and the helicopter's actual profile, is difficult.

The commander may have intended to climb the helicopter vertically until it cleared the top of the fog layer, or attained a particular height, or simply until he felt comfortable to carry out a transition into forward flight. His brief that "WE'LL GO VERTICALLY UP" suggests that it was not his intention to begin a transition into forward flight promptly after climbing away from the hover. This short brief did not refer to any previous discussion or briefing on the technique or parameters to be used, but it is possible that the pilots had spoken about the departure procedure to be employed before they boarded the aircraft and the CVFDR was activated. In which case, their shared understanding of the plan would have been more comprehensive than the available evidence suggests.

Appropriate training in vertical departures in reduced visibility would have enabled the pilots to plan and execute the proposed manoeuvre with a greater chance of success, (notwithstanding that it would not have been a legitimate manoeuvre in this civilian operation). No evidence was found to show that either pilot had received training in vertical departures in low visibility.

Crew co-ordination

There were no procedures to dictate how the two pilots should co-ordinate as pilot flying and pilot not flying, in particular with regard to which pilot should maintain visual references outside the cockpit or monitor the instruments. Additionally, the pilots had not been formally trained or tested operating as a crew of two. It is probable that a formal division of tasks and responsibilities, with pre-planned means of identifying and communicating normal or abnormal progress, could have assisted in achieving and maintaining better situational awareness, and preventing the progressive change in the flight path to the point at which the accident was inevitable.

Automatic flight systems

The commander referred to the heading bug before beginning the departure climb and, after the hovering portion of the flight, the active Yaw Heading Hold mode of the AFCS maintained the helicopter's heading very close to the bugged value. This indicates that the AFCS was controlling the helicopter in yaw. The cyclic and collective controls were manipulated by the commander throughout the accident flight; the automatic flight modes, which could have maintained pitch and roll, were not active. In other words, the aircraft was flown manually in pitch and roll. Flight in degraded visual conditions places additional demands on pilots. The appropriate use of autopilot functions can assist in minimising workload and allowing maximum attention to be devoted to monitoring the aircraft's attitude and path and other parameters such as speed and groundspeed. Greater reliance on the automatic flight capabilities of the helicopter might have prevented the development of the abnormal pitch attitudes during the departure.

Intended versus achieved profile

Without precise knowledge of the intended flight path, it is difficult to comment on the way in which the aircraft's performance deviated from the commander's plan. However, it is unlikely that, in the dark and in fog, he intended to fly a departure that would involve close proximity to the ground. This is evidenced by his briefing and the vertical manoeuvre which followed. The fundamental difference apparent between what is considered to be his intended profile and the profile achieved concerns the helicopter's pitch attitude.

If the helicopter had not progressively pitched down as it did, the departure would more likely have been successful. The investigation did not identify any malfunction of the flight instrument and display systems, and given the error messages or abnormal parameters which would have been found in recorded data if they had malfunctioned, it is deduced that they were operating correctly throughout the accident flight. However, it is not possible to know where the pilots' visual attention was directed.

Pilots' visual attention

The pitch attitude deviated from the 'normal' regime of attitudes versus height (Figure 4) as the helicopter climbed through 78 ft agl, and reached a maximum 35° nose-down, after which the deviation began reducing. The duration of flight with an increasing unusual pitch attitude was just over nine seconds. It seems likely that a pilot whose attention was focussed on the flight instruments for this length of time would have noticed the abnormal pitch attitude and, if flying, corrected it, or if not flying, drawn his flying colleague's attention to it.

Pilots flying close to the ground and/or obstacles avoid contact with them by monitoring the helicopter's relative position visually. The lift-off and hovering portion of the flight will have been conducted with the commander's visual attention outside the cockpit. There was no briefing as to when attention would be transferred to the flight instruments, though this would normally occur once Vmini was achieved. This highlights that the achievement of Vmini is an important objective during departure and it may be that attention was not to be fully given to the flight instruments until this time.

For these reasons, it seems probable that the pilots' visual attention was directed outside the cockpit.

Visual cues

Visual cues may be very compelling. In the darkness, and fog, the available outside cues were restricted to the lighting in the paddock and any other visible cultural lighting. In the direction of flight, and to the north and west of the departure route, there was little nearby habitation. The commander's view, from the right seat, was of these areas. Neither the Hall, nor the moon, would have been visible to him. Thus, his visual environment lacked cues.

Although there were lights illuminating trees in the paddock, these would have been progressively lost to view in a vertical climb above the ground, as the line-of-sight between the pilots' eyes and the lights was obstructed by the helicopter's structure. In dense fog, they might have been lost to view before the structure obstructed their view.

Amongst the few cues available, once the climb commenced, the headlights of the car travelling towards the paddock along Raveningham Road may have been apparent. This leads to the possibility that the pilot(s) saw those lights, but did not recognise that they were on a moving vehicle. This is considered in the context of the gradual loss, from perception, of the lights illuminating trees in the paddock.

An assumption (perhaps, a subconscious one) that the car's lights were fixed would have led to an illusory effect. As the lights moved progressively down the pilots' field of view, the illusion of the helicopter pitching nose-up would have been created. This could explain a compensatory nose-down pitch input.

The car driver recalled that the helicopter passed over his vehicle once he had turned right onto Yarmouth Road. The co-pilot could have perceived the relative downward motion of the car's headlights as an indication that the helicopter was pitching nose-up, and it is possible that the "NOSE DOWN" calls were prompted by loss of sight of the car's lights beneath the helicopter's nose.

Pitching for speed

If the commander had intended to adopt an accelerative attitude in order to achieve forward speed, the late registering of airspeed on the flight displays may have been of significance in two ways. First, if he had intentionally selected an accelerative attitude, failure to achieve the expected speed might have led to further nose-down pitch inputs in an effort to achieve the desired acceleration. Secondly, the absence of the expected speed indication might have caused more attention to be given to the ASI than would otherwise have been the case, possibly to the detriment of monitoring of other parameters including attitude.

If the pilots had adopted a procedure by which the pilot not flying announced when the airspeed began indicating or achieved a nominal value, it would have enabled the pilot flying to concentrate his efforts on external cues until Vmini was, or was about to be, achieved. In the absence of this habit the pilot flying would need to cross-refer from external cues to the speed presentation, to determine when Vmini had been achieved.

The meteorological information suggests that a slight tailwind may have affected the helicopter during its departure; this would be one cause of a late registering of airspeed in comparison with other, into-wind, departures. A recognition of the easterly wind might have led to a decision to depart towards the east, into wind, rather than towards the west. However, the westerly departure was the usually favoured departure route on account of the relatively lower heights of tree-tops and the direction of the intended flight. Alternatively the late registering of airspeed in a downwind departure could have been anticipated and briefed by the pilots.

Another possible cause of the late registering of airspeed was identified as the nose-down attitude adopted, and its effect on the pitot-static system; thus the late registering could have been both a cause and a consequence of the pitch attitude profile of the flight.

Somatogravic illusion

Somatogravic illusion could have led to the progressively abnormal attitude of the helicopter 'feeling' normal to the occupants. It is notable that the point at which the co-pilot began prompting the commander about pitch attitude ("NOSE DOWN") corresponds with the points in Figure 6 when the value of force vector pitch for height is close to outlying the other plotted data. Until then, there was nothing abnormal about the value of force vector pitch, even though the pitch attitude itself had deviated substantially from its usual range of values.

Recognition of the abnormal progress of the flight

The helicopter's pitch attitude became progressively nose-down from shortly after the beginning of the climb from the hover. The longitudinal cyclic inputs were consistently in the nose-down sense and of small amplitude until the point at which the co-pilot stated "NOSE DOWN". The longitudinal cyclic input then showed a brief, but marked, nose-down input. This was followed by a further, similar input at the time the phrase was uttered for a second time. So, although analysis of the CVFDR did not establish whether the co-pilot meant that the pitch attitude was too nose-down, or was suggesting that it needed to be more nose-down, it is possible that the commander interpreted the latter and reacted to it. Alternatively, the same cues or reasoning which caused the co-pilot to make his prompt, may simultaneously have led the commander to make a nose-down correction.

Around this time, the amplitude of the cyclic inputs increased significantly. The collective was also brought up to its maximum position, commanding maximum available torque. This appears to reflect a recognition that the flight was not progressing as planned. The torque increased but was not sufficient to prevent a reduction in rotor rpm. The CVFDR did not record any exchange of control between the pilots, but even so, it is not possible to exclude the possibility that the co-pilot may have intervened on the cyclic or collective, or both.

Incapacitation

The post-mortem examinations showed no signs that incapacitation occurred or was likely to occur. The CVFDR recording contained nothing suggesting incapacitation. If the commander had become physically incapacitated (as opposed to disorientated), it is probable that he would have ceased making smooth control inputs and/or would have stopped applying pressure to the trim release switches. However, these were held in throughout the flight. The co-pilot's verbal prompt shortly before impact indicates against incapacitation in his case. Thus, it is unlikely that physical incapacitation was a factor.

EGPWS

The helicopter's EGPWS provided a warning immediately before impact, but not in sufficient time for the pilots to react. The limitations of EGPWS in rotary-wing operations are understood and work by the UK CAA and others is seeking to optimise the system's functionality. The rapid onset of the abnormal flight profile, such as in this case, may mean that sufficiently prompt alerting is not achievable without unacceptable rates of nuisance alerting during safe flights.

Operation of the helicopter

As the AAIU report into the 1996 accident acknowledged, the owner made habitual use of his helicopter. His acquisition of an IFR-capable helicopter, and the employment of two professional pilots, both with Instrument Ratings, demonstrated a commitment to benefitting from the flexibility and efficiency which a private helicopter offers, and the earlier works at the departure helipad, clearing trees and fitting lights, also reflected a desire to maximise the utility of the helicopter. Although the operator's procedures and documentation met the necessary standards during the time the AOC was held, it seems that since the end of AOC flying, the style of operation had returned to the private realm, without, for example, an operations manual.

**Previous accident, Safety Recommendations, regulation, and oversight**

In its report on the previous accident involving the operator, the AAIU made a series of Safety Recommendations, several of which concerned additional oversight of private helicopter operations.

Similarities exist between the causal factors determined in that case and those around the loss of G-LBAL. The AAIU found that the primary cause of the accident to G-HAUG was *'loss of situational awareness'* on the part of the pilot flying, and it is apparent that the pilot or pilots of G-LBAL experienced a similar condition.

There are also similarities with the secondary causes identified by the AAIU including the use of a procedure not recognised for a civil helicopter pilot, which gave little margin for error, and in the course of which impact was inevitable by the time the pilots recognised that their trajectory was unsafe.

The AAIU report commented that:

> *'The flight used a navigation approach procedure that would not meet the standards required by the UK Authorities for public transport operations. However, this was not illegal because the flight was operated under private category rules.'*

With regard to G-LBAL, the departure would not have been permitted had it been from a licensed aerodrome. However, because it was from a private landing site, there was no requirement for a particular minimum visibility.

The AAIU report highlighted the difference between the majority of general aviation activity, concerning 'in the main, the operation of private pilots, largely in simple single-engined aircraft, with fairly basic instrumentation' and the operation then of the S-76 helicopter, which was, it stated, '*markedly different from these general aviation norms*'. The report explained that:

> *'The owner was not a pilot, and his prime requirement was that the operation should provide effective transportation in most weather conditions prevailing*

> *in the area. To achieve this he purchased a state-of-the-art aircraft and hired professional pilots to manage the operation. The evolving procedures generated by the pilots indicated a strong commitment to meeting the owner's requirements.'*

It also stated:

> *'The corporate environment of the operation of G-HAUG, particularly the type of flights flown, the use of such a sophisticated aircraft, the application of GPS to approaches in a very restricted area and the employment of professional pilots to manage the operation on behalf of an owner who was not a pilot, do not appear to be compatible with the norms of private category aviation, or with the spirit of the rules and regulations that apply to that category.'*

A similarity concerns the hazards and risk inherent in the particular manoeuvres being conducted at the time of the two accidents. The G-HAUG event occurred in IMC during execution:

> *'of a locally produced GPS-based approach procedure which gave little margin for error, and which was inadequate to alert the crew to terrain dangers.'*

while the G-LBAL event occurred during departure in inclement conditions, using a procedure not laid down in the flight manual or recognised as being compliant with the need to achieve Vmini before transition to instrument flight. Examination of the proposed vertical departure profile, into a dark foggy night with few (or, as the climb progressed, probably no) visual cues, should have identified that achieving Vmini by reference to the available visual cues was not certain. An AOC-holding organisation would have been required to consider this departure within its safety management system, and a good system might well have identified that the level of risk inherent was unsustainable.

These matters were addressed by the AAIU's recommendation (SR7 of 1998) that:

> '• *The UK CAA should consider the establishment of a special category for the operation of corporate aviation.'*

Although the UK CAA accepted this recommendation, no special category was established. CAP686 was issued after the G-HAUG accident, but provided guidance rather than regulation. Private operations of complex aircraft continue as before.

The same intent was also expressed in another recommendation (SR8 of 1998), which took account of the transition to regulation by the JAA:

> *'The JAA Joint Working Group for JAR OPS 2, which reviews operation standards for aircraft operation in the JAA States, including the UK and Ireland, should consider the establishment of a special category for the operation of corporate aviation, to encompass the operation of aircraft such as G-HAUG'*

The JAA (whose functions have largely been subsumed by the EASA) did not respond to this recommendation and no special category was established.

A further Safety Recommendation (SR10 of 1998) suggested that operators could act before regulations required them to do so:

> '• *The Irish Aviation Authority (IAA) and the UK CAA should bring to the attention of operators of corporate aircraft the safety benefits that would result from external vetting of their operations, pending the establishment of a suitable regulatory framework for corporate aviation activities.*
> *(SR 10 of 1998)'*

The UK CAA accepted this recommendation, but the operator of G-LBAL did not seek external vetting.

The CAA's paper 2007/03 *'Helicopter Flight in Degraded Visual Conditions'* described the circumstances of a number of accidents in the years up to 2004, and found that:

> *'Serious consideration must be given to the measures that need to be taken to reverse this trend, taking into account improvements to regulations, operating procedures and requirements or pilot training requirements.'*

It addressed visibility versus height, taking into account the available view over the nose of a helicopter, and noted that:

> *'Pilots should be better trained to make informed decisions on whether 'to fly or not' in marginal conditions.'*

Although the operator had a draft operations manual and safety management system, these appeared not to have progressed beyond the draft stage. Adoption of them might have brought about an accurate assessment of the risk inherent in the departure from Gillingham Hall in fog and better ways of evaluating the visibility at the time, the provision of procedures enabling the two pilots to benefit from potential synergy in multi-crew operations, and training in those procedures.

In conclusion, despite a previous fatal accident, a comprehensive investigation by the AAIU, the acceptance of safety recommendations by the CAA, and other work, including the CAA's paper 2007/03 and CAP686, the causes of the G-HAUG accident were almost replicated in another fatal accident by the same operator some years later.

The AAIB has referred previously to the pressures – real or perceived – on pilots of aircraft operated in the corporate environment. These pressures remain when an aircraft is operated privately, but the private operation is also less comprehensively regulated. In particular, in the absence of minimum visibility requirements for operations at private sites, pilots of helicopters operating privately have no absolute criteria to support a decision whether or not to depart. A combination of appropriate regulation, and techniques for mitigating these pressures, may be required to improve the safety of non-commercial complex helicopter operations.

**Safety action**

Although the recommendations intended to prevent a recurrence of the accident involving G-HAUG were broadly accepted, no action resulted. The EASA has published Part NCC, covering non-commercial complex aircraft operations. The UK will adopt Part NCC in 2016. The AAIB asked the CAA to comment on how its implementation might answer the recommendations made in the AAIU report. The CAA did not respond directly but stated that, following this investigation and in connection with previous work by the AAIB[8], it considered that:

> *'A broader and deeper review of IFR flying outside controlled airspace in general is advised.'*

Accordingly the CAA has proposed the following safety action:

> *'The CAA intends that a multi-disciplined review be initiated, potentially involving industry participation, to review the whole subject and produce recommendations and suggested courses of action. Target date for completion of the review is 01 October 2015.'*

Vmini

The investigation established that the definition of Vmini promulgated by the FAA does not reflect the practical meaning of the term. It does not take account of IFR operations including hovering and accelerating flight after lift-off, until Vmini is achieved, and decelerating flight below Vmini prior to landing. The definition was carried across into the AW139 flight manual.

There is an opportunity for the meaning of Vmini to be clarified to reflect more accurately its meaning, and so the following Safety Recommendation is made:

> **Safety Recommendation 2015-024**
>
> The Federal Aviation Authority should amend its definition of Vmini, to reflect the legitimacy of flight under instrument flight rules by reference to external visual cues at speeds below Vmini.

The EASA definition of Vmini lacks clarity and, like the FAA definition, does not convey the practical application of the term. Therefore the following Safety Recommendation is made:

> **Safety Recommendation 2015-025**
>
> The European Aviation Safety Agency should amend its definition of Vmini, to provide a clear definition that reflects the legitimacy of flight under instrument flight rules by reference to external visual cues at speeds below Vmini.

**Footnote**

[8] FACTOR F1/2015 responding to AAIB Safety Recommendation 2014-035 regarding the serious incident to G-WIWI.

**Conclusion**

The helicopter departed the private site in fog and at night. Operation from the site in such conditions was permissible under existing regulation. Departure from a licensed aerodrome in such conditions would not have been permitted.

Evidence suggests that the flight crew may have been subject to somatogravic illusion caused by the helicopter's flight path and the lack of external visual cues.

The absence of procedures for two pilot operation, the pilots' lack of formal training in such procedures, and the limited use of the automatic flight control system, may have contributed to the accident.

Opportunities to reduce the likelihood of such an event, presented by the report into the operator's previous fatal accident, appeared not to have been taken.

The UK will adopt new regulations involving non-commercial complex aircraft operations in 2016 and, following the accident to G-LBAL and other occurrences investigated by the AAIB involving helicopters, the CAA intends to complete a review the subject of IFR flying outside controlled airspace by 1 October 2015.

# AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | North American T-28A Trojan, N14113 |
| **No & Type of Engines:** | 1 Wright 1820-768 radial piston engine |
| **Year of Manufacture:** | 1951 (Serial no: 81-1) |
| **Date & Time (UTC):** | 30 April 2015 at 1111 hrs |
| **Location:** | Duxford Airfield, Cambridgeshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Nose landing gear failure, engine shock-loaded, propeller blade tips bent |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 70 years |
| **Commander's Flying Experience:** | 17,915 hours (of which 160 were on type)<br>Last 90 days - 2 hours<br>Last 28 days - 1 hour |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and additional inquiries made by the AAIB |

### Synopsis

The aircraft was on its takeoff run for a test flight after annual maintenance. At approximately 80 kt IAS the pilot became aware of a severe lateral vibration which was followed by failure of the nose landing gear (NLG). The aircraft came to stop on the runway in a nose-down attitude, resting on the remains of the nose gear strut. The failure was caused by the propagation of a crack in the NLG forging, emanating from a bolt hole in the anti-shimmy damper bracket.

### History of the flight

The aircraft was on its takeoff run for an air test after annual maintenance and, as it accelerated through 80 kt IAS, the pilot became aware of a pronounced and severe lateral vibration through the airframe. The pilot immediately closed the throttle and the nose of the aircraft simultaneously dropped as the nosewheel and yoke detached. The propeller struck the runway and stopped; the aircraft continued an estimated 150 yards before coming to a stop on the runway, resting on its main landing gear and the remains of the NLG strut. The pilot made the aircraft safe and exited without further incident. Figure 1 shows the nosewheel and yoke detaching during the takeoff run.

**Figure 1**

Nosewheel and yoke detachment during the takeoff run
(Picture courtesy of Mr Brian Marshall)

### Engineering findings

The failure occurred at the top of the NLG forging as a result of cracking emanating from a bolt hole which was one of three holding the anti-shimmy damper bracket in place. An examination of the NLG after the accident found evidence of previous crack propagation in the same area and the cracks had not been detected during routine or pre-flight visual inspections. There is no specific non-destructive test (NDT) schedule in place for this component so, to prevent recurrence, the maintenance organisation responsible for the aircraft is putting in place its own safety action to carry out an NDT on the NLG forging during future routine maintenance.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Auster J5F Aiglet Trainer, G-AMZT |
| **No & Type of Engines:** | 1 De Havilland Gipsy Major I piston engine |
| **Year of Manufacture:** | 1953 (Serial no: 3107) |
| **Date & Time (UTC):** | 18 June 2015 at 0930 hrs |
| **Location:** | Bolt Head Airfield, Devon |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - 1 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Damage to fuselage |
| **Commander's Licence:** | National Private Pilot's Licence |
| **Commander's Age:** | 78 years |
| **Commander's Flying Experience:** | 1,179 hours (of which 799 were on type)<br>Last 90 days - 17 hours<br>Last 28 days - 8 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The pilot made a straight-in approach to land on Runway 29 at Bolt Head Airfield which is a grass strip with no white runway designating markings. There was a strip of land cultivated with barley, approximately the same length and width as the runway, between the runway and the airfield boundary fence. The pilot mistook this strip of land for the runway. After touching down in the crop, the aircraft came to a stop in about 25 metres, before pitching over onto its back. The occupants, who were uninjured, exited the aircraft via the passenger's side window.

The pilot considered that it was possible, but unlikely, that the accident would have been avoided if he had joined overhead. However, he considered that white runway markings would have definitely aided in identifying the runway.

*This accident bears many similarities with another, nearly two weeks later, involving an Europa, G-TAGR, (also included in this Bulletin, see page 85) which had landed in the same barley crop after mistaking it for the reciprocal Runway 29.*

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Bolkow BO 207, G-EFTE |
| **No & Type of Engines:** | 1 Lycoming O-360-A1A piston engine |
| **Year of Manufacture:** | 1961 (Serial no: 218) |
| **Date & Time (UTC):** | 6 June 2015 at 13:30 hrs |
| **Location:** | Chichester (Goodwood) Airfield, West Sussex |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - 1 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Damage to propeller, spinner, cowling and engine shock-loaded |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 58 years |
| **Commander's Flying Experience:** | 825 hours (of which 100+ were on type)<br>Last 90 days - 7 hours<br>Last 28 days - 3 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB |

### Synopsis

As G-EFTE was about to taxi forwards, or while starting to move forward, the tail of the aircraft lifted up and the propeller struck the ground. Another aircraft, G-AXOJ, was nearby and its propwash may have affected G-EFTE but there were conflicting witness accounts on whether this occurred.

### G-EFTE - pilot's description of the accident

G-EFTE, a Bolkow BO 207 with a tailwheel configuration, was parked on the southern end of parking row 1 at Goodwood Airfield (Figure 1). After pre-flight checks the pilot requested taxi clearance and was told to taxi to the hold of Runway 24. The wind was from 250° at 15 kt. He taxied forwards, into wind, with the stick held full back and as he approached the southern end of parking row 2 he observed a Beagle Pup, registration G-AXOJ, approaching along the taxiway from his right. He stopped the aircraft at the southern end of parking row 3 and expected G-AXOJ to pass in front of him and turn left. However, G-AXOJ turned left through a gap of parked aircraft on row 3 to pass behind G-EFTE (Figure 1). The pilot of G-EFTE then lost sight of G-AXOJ and prepared to move forward but had to hold for another aircraft taxiing in front. As he was about to move forward again, or while starting to move, the tail of his aircraft lifted up and the propeller struck the ground.

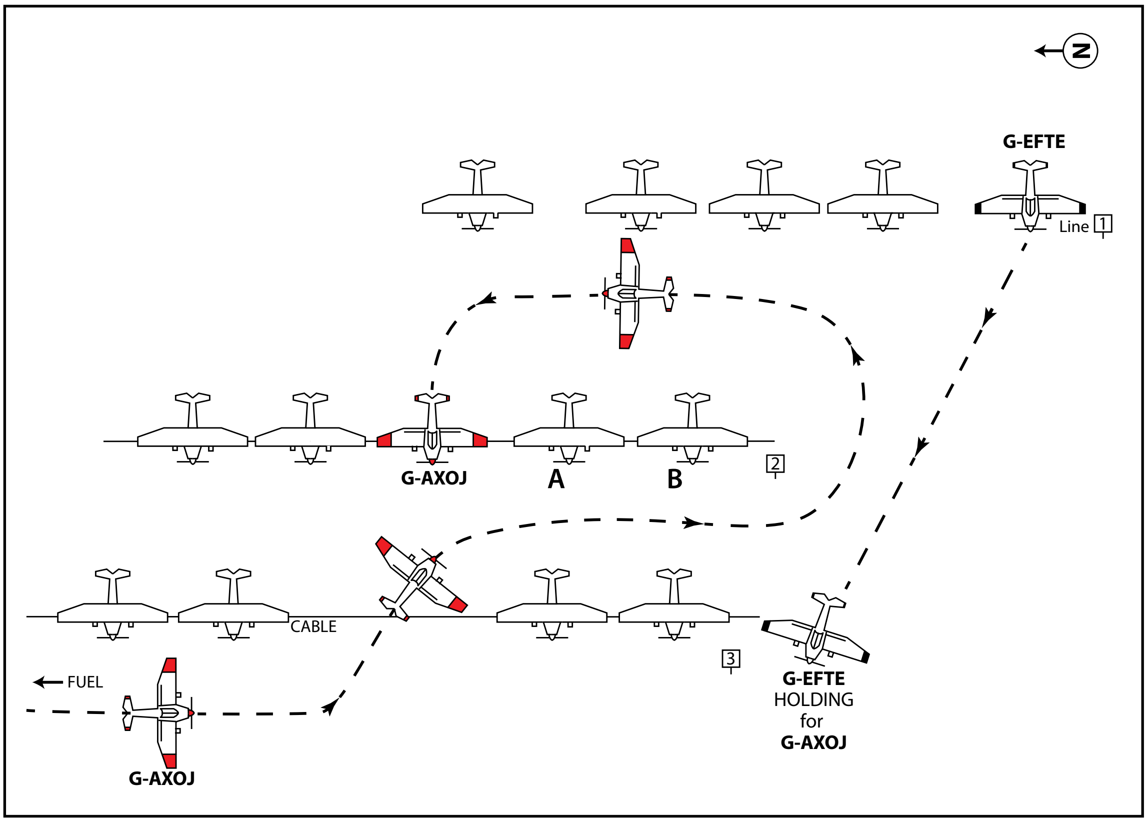


**Figure 1**

Sketch of the parking area and aircraft tracks (not to scale)

He shut down G-EFTE, checked that his passenger was safe and secure, and then called the Flight Information Service Officer (FISO) in the tower for assistance. The airfield's fire service attended the aircraft and pushed the tail down causing the tailwheel to touch down hard. Once the tail was down the pilot and his passenger exited in the normal manner. They carried out an inspection of the ground they had just taxied over and finding no holes or obstructions decided that the terrain had not been a contributing factor in this occurrence.

Following discussions with an eyewitness, the pilot came to the conclusion that the propwash from G-AXOJ had caused the tail of G-EFTE to lift in an uncontrollable manner.

### An eyewitness description of the accident

An eye witness to the event was a pilot conducting pre-flight checks while sitting in the left front seat of a Piper PA-28 parked on row 2 in position A or B as shown in Figure 1. She observed G-EFTE taxi in front of her aircraft and stop next to the row 3 sign. She then saw G-AXOJ taxi through a gap of parked aircraft on row 3 and taxi towards her in front of row 2. G-AXOJ then stopped in front of her aircraft and she believed the pilot was looking for somewhere to park. The aircraft then taxied behind G-EFTE and at some point "put on a fair bit of power", and as they did this the tail of G-EFTE began to lift into the air. She reported that the pilot of G-AXOJ did not appear to look at G-EFTE and taxied away to park. She took a photograph of G-EFTE resting on its propeller, before the fire service arrived (Figure 2).


**Figure 2**

Photograph of G-EFTE taken by the eyewitness in the parked Piper PA-28

**G-AXOJ - pilot's description of the accident**

G-AXOJ was a Beagle Pup that had arrived at Goodwood from Maypole. After refuelling, the pilot requested taxi instructions from the FISO and was told to give way to an aircraft passing left to right and then to proceed to parking row 2. He waited for the aircraft to pass and then taxied slowly as he reported that the grass was uneven and rutted, and that it was "very windy". He then saw G-EFTE waiting at the entrance to the parking area. He turned to pass between parked aircraft on row 3 and taxied along in front of row 2. He reported that when his aircraft was about 15 to 20 m away from G-EFTE, at his 3 o'clock position, his passenger in the right seat said "that aircraft has just tipped over". The pilot stopped, looked over to his right and saw that G-EFTE had nosed over. The FISO called for all aircraft to hold their position, so they waited in position and watched as the fire service attended the aircraft. His passenger described the aircraft as having tipped over "very slowly". After several minutes the pilot called the FISO to ask if they should shut down and were then told to proceed to parking which he did. The pilot stated that he was "100% convinced" that it was not his propwash that caused G-EFTE to tip over.

**The FISO's description of the accident**

The FISO, who was located in the control tower, recalled watching G-EFTE taxi up to the end of row 3 and he described seeing the tail "gently" lifting up. He said that G-AXOJ had stopped on the north side of G-EFTE and had not passed behind G-EFTE. After calling for the fire service to attend the scene he noticed that G-AXOJ was still stopped in the same position so he told him to continue taxiing to parking. He estimated that the nose of G-AXOJ was pointing south-east with G-EFTE at it's 2 o'clock position when the tail of G-EFTE lifted. The FISO could not explain why G-EFTE had tipped over, but he did not think it was caused by the propwash of G-AXOJ.

## Analysis

It was not possible, from the conflicting accounts, to determine the cause of G-EFTE tipping onto its propeller. However, regardless of the cause, the accident serves as a useful reminder of being careful when adding power while taxiing near other aircraft, especially near tailwheel aircraft or other 'taildragger' types.

## ACCIDENT

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Denney Kitfox, G-BSCH | |
| **No & Type of Engines:** | 1 Rotax 582 piston engine | |
| **Year of Manufacture:** | 1990 (Serial no: PFA 172-11621) | |
| **Date & Time (UTC):** | 23 June 2015 at 1845 hrs | |
| **Location:** | Private strip at Castle Bytham, Lincolnshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - 1 (Minor) | Passengers - N/A |
| **Nature of Damage:** | Damage to propeller, nose cone, windscreen and rudder, engine possibly shock-loaded | |
| **Commander's Licence:** | National Private Pilot's Licence | |
| **Commander's Age:** | 69 years | |
| **Commander's Flying Experience:** | 254 hours (of which 68 were on type)<br>Last 90 days - 0 hours<br>Last 28 days - 0 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

The pilot had not flown for three months and was keen to take advantage of good weather. He attempted to take off from his private, 310 m long, grass strip, with no wind indicated on the windsock. He continued past a visual marker which he used to check his rotation point because the aircraft had almost reached its takeoff speed. It became airborne but clipped a hedge on the western boundary of the strip and overturned in an adjacent tall crop. The pilot was able to escape unassisted but banged his head slightly as he vacated. He noted that he had recently lost weight and was glad that he had tightened his harness before flight.

The pilot stated that the grass along the strip was long and dry but he believed the cause of the accident was his over-enthusiasm to go flying that day. After the accident he lost confidence in his flying ability and decided that it was time for him to stop piloting aircraft.

**ACCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Europa, G-TAGR |
| **No & Type of Engines:** | 1 Rotax 912 ULS piston engine |
| **Year of Manufacture:** | 2004 (Serial no: PFA 247-13061) |
| **Date & Time (UTC):** | 1 July 2015 at 1120 hrs |
| **Location:** | Bolt Head Airfield, Devon |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Tail and rear fuselage cracked, left wing and aileron damage |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 73 years |
| **Commander's Flying Experience:** | 1,126 hours (of which 118 were on type)<br>Last 90 days - 32 hours<br>Last 28 days - 11 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

**Synopsis**

*This accident bears many similarities with another, nearly two weeks earlier, involving an Auster J5F Aiglet, G-AMZT, (also included in this Bulletin, see page 79) which had landed in the same barley crop after mistaking it for the reciprocal Runway 29.*

The pilot intended to land on grass Runway 11 at Bolt Head Airfield but mistakenly landed in a crop of barley to the right of it. He cites a lack of runway markings and the fact that the potentially deceptive nature of the airfield layout was not mentioned when he had telephoned the airfield operator earlier, as factors in the accident.

**History of the flight**

G-TAGR arrived, in loose formation with two others, from the north, intending to land on Runway 11. As the pilot turned right downwind, he looked at the airfield and saw a long strip of pale brown vegetation which he took to be the runway (Figure 1). He made his approach to this strip and only realised his mistake as he flared and the wheels sank into what was actually a crop of barley growing to the right of the grass runway. The aircraft slowed very rapidly, yawed through 180º and came to a halt in about 18 m.

The pilot believes the accident was caused by the complete absence of runway markings coupled with the fact that no mention was made of crops both sides of the runway when he telephoned to ask for permission to land. However, although this fact is correctly reflected in the Pooleys Flight Guide chart for Bolt Head, the airfield website has subsequently been updated to add the following caution:

> *'JULY 2015 - WARNING - THE STRIP OF CROPS TO THE SOUTH OF THE RUNWAY CAN BE DECEPTIVE AND CAN APPEAR TO BE RUNWAY - IT IS NOT , IT IS 3FT HIGH CROPS - INBOUND PILOTS MUST POSITIVELY IDENTIFY THE RUNWAY AND LAND ON THE MOWN GRASS PER OUR PLATE AND PHOTOS, NOT ON THE CROPS .'*


**Figure 1**

View looking along Runway 11 showing a barley crop growing along its southern edge, with more barley and a green corn field to the north. Pictures taken at different times of the year show that contrast and colours vary with ripeness of the crops.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Great Lakes Sports Trainer, G-GLST |
| **No & Type of Engines:** | 1 Warner Aircraft Corp Scarab 165 piston engine |
| **Year of Manufacture:** | 2010 (Serial no: PFA 321-13646) |
| **Date & Time (UTC):** | 7 June 2015 at 1515 hrs |
| **Location:** | Thruxton Aerodrome, Hampshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Damage to lower left wing and landing gear |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 51 years |
| **Commander's Flying Experience:** | 230 hours (of which 63 were on type)<br>Last 90 days - 7 hours<br>Last 28 days - 1 hour |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The pilot intended to land on a grass strip parallel to Runway 07 at Thruxton, having previously performed a touch-and-go. The approach to this runway crosses a hangar structure and the main tarmac apron before reaching the strip threshold. He was sideslipping the aircraft to the left when it "dropped a little more than expected" and the left wheel and wingtip contacted the roof of the hangar structure some 150 metres short of the threshold. The pilot continued to a normal landing, whereupon the damage to the hangar roof and the aircraft was discovered.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Murphy Rebel, G-DIKY |
| **No & Type of Engines:** | 1 Lycoming O-320-A2B piston engine |
| **Year of Manufacture:** | 2003 (Serial no: PFA 232-13182) |
| **Date & Time (UTC):** | 9 July 2015 at 1636 hrs |
| **Location:** | Stoke Golding Airfield, Leicestershire |
| **Type of Flight:** | Training |
| **Persons on Board:** | Crew - 2 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Left landing gear detached, right landing gear damaged, propeller destroyed and engine shock-loaded. Left wing tip fairing distorted, fuselage distorted below right door |
| **Commander's Licence:** | Airline Transport Pilot's Licence |
| **Commander's Age:** | 60 years |
| **Commander's Flying Experience:** | 18,480 hours (of which 12 were on type)<br>Last 90 days - 280 hours<br>Last 28 days - 55 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The accident occurred during the final landing following a day of flight training, during which the student had flown just under four hours. The commander was sitting in the right seat, with his student, who was flying the aircraft, in the left seat. The aircraft was positioned for a final approach to Runway 26 at Stoke Golding Airfield, and the approach was described by the commander as "well flown" until, at approximately 20 to 30 feet agl, the student flared the aircraft for landing. The commander called "too high, too high, go around"; however the student did not react and the aircraft stalled before striking the runway approximately 120 m beyond the Runway 26 threshold. The ground impact was sufficient to collapse the left landing gear leg, following which the aircraft settled onto its left wingtip, allowing the propeller to strike the ground. The aircraft swung to the left through approximately 150° and departed the runway, coming to rest two metres from a parked aircraft.

The commander assessed the cause of the accident to be the student's early landing flare, combined with the commander's verbal, rather than physical, intervention to prevent the subsequent heavy landing.

**SERIOUS INCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | 1) Pioneer 300, G-OPFA<br>2) Valenta Ray X, S037996 |
| **No & Type of Engines:** | 1) 1 Rotax 912 ULS piston engine<br>2) 1 Electric engine |
| **Year of Manufacture:** | 1) 2004 (Serial No: PFA 330-14298)<br>2) 2014 (Serial No: SO37996) |
| **Date & Time (UTC):** | 5 April 2015 at 1240 hrs |
| **Location:** | Upton-upon-Severn, Worcestershire |
| **Type of Flight:** | 1) Private<br>2) Private |
| **Persons on Board:** | 1) Crew - 1 Passengers -1<br>2) Crew - None Passengers - None |
| **Injuries:** | 1) Crew - None Passengers - None<br>2) Crew - N/A Passengers - N/A |
| **Nature of Damage:** | 1) 10 mm puncture in leading edge and minor surface paint damage to left wing<br>2) Destroyed |
| **Commander's Licence:** | 1) National Private Pilot's Licence<br>2) None |
| **Commander's Age:** | 1) 52 years<br>2) 59 years |
| **Commander's Flying Experience:** | 1) 1,069 hours (of which 472 were on type)<br>Last 90 days - 9 hours<br>Last 28 days - 3 hours<br><br>2) 3,000 hours (of which 3,000 were on type)<br>Last 90 days - 15 hours<br>Last 28 days - 6 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB |

**Synopsis**

While flying in uncontrolled airspace and in good visibility a remotely piloted model glider and a light aircraft collided at a height of approximately 630 ft. The glider sustained serious damage before crashing into a field. The aircraft sustained minor damage and landed uneventfully. There were no injuries.

**History of the flight**

The model glider pilot reported that he and others were flying remotely piloted gliders from their club's field at Fish Meadow, Upton-upon-Severn, Worcestershire. The field is about 35 ft amsl. There was little or no cloud and the wind was east-south-easterly at 5 to 10 kt.

The 1.8 kg glider had an electrically powered propeller to assist with launching, a wingspan of 3.8 m and was fitted with a height limiter that automatically removed the power to the motor at a pre-determined height above the launch site or after 30 seconds, whichever occurred first. During this flight the height limiter was set to 100 m. It also had on-board telemetry that allowed the pilot to monitor its height.

The glider was hand launched by the pilot at about 1230 hrs and climbed, under the power of its motor, to 100 m when the motor automatically cut; this was confirmed by the on-board telemetry. After about 10 min, as the glider was flying slowly in a thermal, its pilot heard the sound of a powered aircraft to his right flying from north to south. As the aircraft entered his peripheral vision he determined it was flying a course approximately along the River Severn "at a low level and travelling quite quickly." He was unable to take avoiding action before the glider and the powered aircraft collided while over the river.

The glider's left wing separated and drifted downwind while the rest of the glider fell into a field about 260 m south-west of the launch site. The last altitude observed by the glider pilot, as indicated by the glider's telemetry, just before the collision, was 190 m agl (630 ft agl).

The aircraft pilot reported that he was on a local flight from Gloucestershire Airport. Visibility was in excess of 10 km with a layer of grey cloud at various heights above him throughout the flight. The aircraft initially headed north from Tewkesbury between 900 and 1,500 ft amsl. As it approached Upton-upon-Severn, the pilot and his passenger noticed two model aircraft flying from a field to the east of the river, "well below them" as they flew round the perimeter of the field. The pilot then headed away from the area. A short time afterwards there was a "loud thud" as the aircraft struck what the pilot believed was a seagull, seeing a slim grey/white object pass over the left wing. He then noticed some damage to the upper skin of the left wing but the fabric did not appear to be punctured. He recalled the altimeter indicating about 900 ft amsl when he scanned the altimeter shortly after the impact.

After checking that the aircraft handled normally the pilot contacted Gloucester Approach and informed them that he was returning as his aircraft had suffered a substantial bird strike. The aircraft subsequently landed safely with the AFFRS in attendance. It had sustained a small hole, about 10 mm in diameter, in the top of the left wing's leading edge and surface damage to the wing fabric behind the hole.

**Pilots' comments**

The model glider pilot commented that it was not unusual for light aircraft activity to be seen in the vicinity of the club's flying field. He added that he limits his glider to 300 m (about 1,000 ft) agl. At this height his glider is able to be seen and controlled.

The aircraft pilot commented that he was aware of the presence of the model aircraft flying site and had seen activity there on previous occasions. However, before this accident he did not realise how big the models were or how high they were flown. He added that the grey cloud cover may have made it very difficult to see the model from the air.

## Model aircraft flying

The sport of model flying in the UK is governed by the British Model Flying Association (BMFA). There are around 850 BMFA affiliated clubs in the UK. Additionally, there are a number that are not affiliated, with a significant amount of activity that takes place away from clubs in areas such as public open spaces, private fields, and mountain and slope sites.

## Guidance document

Civil Aviation Publication (CAP) 658 – *'Model Aircraft: A Guide to Safe Flying'* states:

> *'A 'model aircraft' is defined as any 'Small Unmanned Aircraft (SUA)' (0-20 kg) used for sporting and recreational purposes...*
>
> ***Chapter 2 Legal Requirements***
>
> *4.2.1* ***Article 138 – Endangering safety of any person or property***
> *A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.'*
> *All model flying activity is controlled by this article of the ANO and it is important that the operator of any model aircraft should bear this in mind at all times.*
>
> *4.2.2* ***Article 166 – Small unmanned aircraft***
> *…*
> *(3) The person in charge of a small unmanned aircraft must maintain direct, unaided visual contact with the aircraft sufficient to monitor its flight path in relation to other aircraft, persons, vehicles, vessels and structures for the purpose of avoiding collisions.*
> *(4) The person in charge of a small unmanned aircraft which has a mass of* ***more than 7 kg*** *[AAIB bold] excluding its fuel but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight, must not fly the aircraft:*
> *(c) at a height of more than 400 feet above the surface….'*

There is no height limit for a SUA under 7 kg. However, the pilot must maintain sight of the aircraft for the purpose of control and separation.

## EU regulation 923/2012, Standardised European Rules of the Air (SERA)

SERA.5005 *Visual flight rules,* states:

> *'…*
> *(f) Except when necessary for take-off or landing, or except by permission from the competent authority, a VFR flight shall not be flown:*
>
> *(1) over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft;*

> (2) *elsewhere than as specified in (1), at a height less than 150 m (500 ft) above the ground or water, or 150 m (500 ft) above the highest obstacle within a radius of 150 m (500 ft) from the aircraft.'*

**Notice to Airmen (NOTAM)**

In an attempt to publicise the model flying site to other pilots the model glider pilot published a NOTAM on an independent website. However, as this website is not recognised by the CAA, it would only be visible to registered users of the website.

The CAA commented that if a request for a NOTAM was submitted to them the details would be checked to ascertain if an Article 166 Exemption was required. For such activities, the organiser/operator is to submit an application to them. NOTAM action is taken for all model aircraft activities where an Article 166 Exemption has been issued and any others above 400 ft agl. It added that the decision on whether or not to take NOTAM action would depend on the intensity of the activity and the location in relation to controlled airspace and other sites of aviation activity. In this event it would not have been taken.

**Discussion**

The mid-air collision occurred in Class G (uncontrolled) airspace at about 600 ft agl with visibility reported to be in excess of 10 km.

Although the model glider pilot saw the aircraft, as it approached from the north, he had insufficient time to take avoiding action. The aircraft pilot did see two other model gliders but did not see the see the accident glider before the collision. At the point of collision the aircraft may have flown below 1,000 ft whilst within 600 m of the town of Upton-upon-Seven.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Robinson R44 II Raven II, G-CDXX |
| **No & Type of Engines:** | 1 Lycoming IO-540-AE1A5 piston engine |
| **Year of Manufacture:** | 2005 (Serial no: 10624) |
| **Date & Time (UTC):** | 25 June 2015 at 1402 hrs |
| **Location:** | Leicester Airport |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - 1 (Minor) Passengers - N/A |
| **Nature of Damage:** | Tail cone bent, main rotor blades damaged and right skid snapped |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 24 years |
| **Commander's Flying Experience:** | 96 hours (of which 9 were on type)<br>Last 90 days - 9 hours<br>Last 28 days - 6 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

A record of the accident was captured by two CCTV cameras. The helicopter was parked on a concrete extension that adjoined an apron adjacent to the helicopter operator's hangar facility at Leicester Airport. The pilot was intending to make a local flight and having completed his pre-flight checks, gradually increased the rotor rpm to about 80%. From the CCTV it can be observed that at about this time, the helicopter rapidly yawed to the left and rotated through about 290° before tipping over onto its right side. The helicopter came to rest with a sufficient gap between the forward right door, which had opened as the helicopter struck the ground, and the concrete apron to enable the pilot to vacate the helicopter unaided. The pilot reported sustaining minor injuries.

A rapid yaw to the left could be induced if too much left pedal is applied at the point of governor engagement due to the effectiveness of the tail rotor.

**ACCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Dynamic WT9 UK Dynamic, G-SJPI |
| **No & Type of Engines:** | 1 Rotax 912ULS piston engine |
| **Year of Manufacture:** | 2008 (Serial no: DY281) |
| **Date & Time (UTC):** | 20 June 2015 at 1733 hrs |
| **Location:** | Airstrip near Bourne, Lincolnshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - 1 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Right main landing gear collapsed and right flap damaged |
| **Commander's Licence:** | National Private Pilot's Licence |
| **Commander's Age:** | 50 years |
| **Commander's Flying Experience:** | 420 hours (of which 70 were on type)<br>Last 90 days - 27 hours<br>Last 28 days - 10 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The pilot reported that the left wing contacted crops at the side of the runway at low speed during the landing roll. This caused the aircraft to swing to the left and the right main landing gear to collapse. The occupants were uninjured and able to vacate the aircraft unaided. The pilot assessed that he may have landed too far to the left of the runway centreline.

Operations from unlicensed aerodromes and private strips require special consideration; in this case crops were growing close to the edge of the runway. CAA Safety Sense Leaflet 12 - *Strip Sense*, notes that approximately one third of general aviation reportable accidents in the UK occur during takeoff or landing at unlicensed aerodromes. The leaflet contains useful safety information for pilots intending to operate from such locations.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | EV-97 Teameurostar UK Eurostar, G-CEZF |
| **No & Type of Engines:** | 1 Rotax 912-UL piston engine |
| **Year of Manufacture:** | 2007 (Serial no: 3205) |
| **Date & Time (UTC):** | 5 June 2015 at 1250 hrs |
| **Location:** | Broadmeadow Farm, Herefordshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Damage to nose and right main landing gear, right wing and propeller |
| **Commander's Licence:** | National Private Pilot's Licence |
| **Commander's Age:** | 58 years |
| **Commander's Flying Experience:** | 438 hours (of which 398 were on type)<br>Last 90 days - 11 hours<br>Last 28 days - 6 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The aircraft commenced its takeoff roll on Runway 28 in a southerly wind of about 10-15 kt. After a ground roll of about 100 metres, the aircraft suddenly veered to the left. The pilot was unable to correct the swing and the aircraft left the runway, coming to a halt some five metres into a field. The aircraft's nose and right main landing gear and its right wing and propeller were damaged.

The pilot considered that he applied insufficient control input to correct the swing caused by the gusting crosswind.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Rans S6-ES Coyote II, G-BYOU |
| **No & Type of Engines:** | 1 Rotax 582-48 piston engine |
| **Year of Manufacture:** | 1998 (Serial no: PFA 204-13460) |
| **Date & Time (UTC):** | 22 August 2014 at 1645 hrs |
| **Location:** | Mount Airey Airstrip, South Cave, East Yorkshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - 1 (Serious) Passengers - N/A |
| **Nature of Damage:** | Aircraft damaged beyond economic repair |
| **Commander's Licence:** | National Private Pilot's Licence |
| **Commander's Age:** | 55 years |
| **Commander's Flying Experience:** | 139 hours (of which 119 were on type)<br>Last 90 days - N/K<br>Last 28 days - N/K |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

During the pre-flight inspection the pilot checked the fuel quantity, which he reported as being 22 litres in the right tank and 15 litres in the left. The engine started without difficulty and the mag drops were reportedly satisfactory. Once the engine was warm, the pilot taxied the aircraft towards the runway and carried out the final checks, which were normal. He selected one stage of flap and full throttle for the takeoff on Runway 07. After rotation and becoming airborne, the pilot placed the aircraft in a steep climb, mindful of the wind from the right and a telephone mast on the left.

Shortly after takeoff the engine stopped and the aircraft stalled. It came to rest close to the far end of Runway 07, with the pilot having received serious injuries including a fractured spine, two broken ankles and internal injuries.

The cause of the engine failure was not determined with any certainty, but the pilot suspected fuel starvation.

**ACCIDENT**

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | Savannah VG Jabiru(1), G-CCSV | |
| **No & Type of Engines:** | 1 Jabiru 2200 piston engine | |
| **Year of Manufacture:** | 2004 (Serial no: BMAA/HB/362) | |
| **Date & Time (UTC):** | 18 June 2015 at 1600 hrs | |
| **Location:** | Inglenook Farm, Dover, Kent | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - 1 |
| **Injuries:** | Crew - None | Passengers - None |
| **Nature of Damage:** | Landing gear and wings damaged | |
| **Commander's Licence:** | Private Pilot's Licence | |
| **Commander's Age:** | 67 years | |
| **Commander's Flying Experience:** | 4,077 hours (of which 3,600 were on type)<br>Last 90 days - 45 hours<br>Last 28 days - 26 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot | |

Following an uneventful flight to renew a 'permit to fly', the aircraft was on final approach to Runway 33 at a height of approximately 100 ft agl when the engine stopped. The engine was restarted but stopped for a second time at approximately 40 ft. The pilot concentrated on landing but a sudden "lateral displacement" put the aircraft left of the runway centre line. She was unable to abandon the approach and may have over-corrected for the lateral disturbance with the result that the aircraft deviated to the right of the centreline and then to the left again with the wheels on the ground. It clipped a hedge and turned through 180° before coming to rest with the right wing and cockpit in the hedge. The pilot and passenger were uninjured and exited the aircraft using the left door.

The cause of the engine failure could not be established and the pilot is unable to explain the cause of the sudden lateral displacement.

**ACCIDENT**

| | |
|---|---|
| **Aircraft Type and Registration:** | Skyranger 912(2), G-JBUL |
| **No & Type of Engines:** | 1 Rotax 912-UL piston engine |
| **Year of Manufacture:** | 2005 (Serial no: BMAA/HB/440) |
| **Date & Time (UTC):** | 29 June 2015 at 1703 hrs |
| **Location:** | Old Park Farm Airfield, Port Talbot |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - None |
| **Injuries:** | Crew - None Passengers - N/A |
| **Nature of Damage:** | Damage to landing gear, wings, propeller, fuselage and windscreen |
| **Commander's Licence:** | National Private Pilot's Licence |
| **Commander's Age:** | 56 years |
| **Commander's Flying Experience:** | 306 hours (of which 182 were on type)<br>Last 90 days - 17 hours<br>Last 28 days - 8 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

The pilot reported that following an uneventful taxi and takeoff from Runway 18, the engine stopped at a height of approximately 1,000 feet agl. The pilot lowered the nose and trimmed for best glide but realised he would not be able to return to the runway and chose to land in an adjacent field. Having successfully cleared a high voltage powerline, he sideslipped the aircraft but the landing was heavy, resulting in significant damage. The pilot was uninjured and exited through the door, which had opened when the aircraft struck the ground. He reported that the engine had been ground run after the accident with no anomalies and the reason the engine had stopped was not determined.

## ACCIDENT

| | |
|---|---|
| **Aircraft Type and Registration:** | Skyranger Swift 912S(1), G-CFSW |
| **No & Type of Engines:** | 1 Rotax 912ULS piston engine |
| **Year of Manufacture:** | 2008 (Serial no: BMAA/HB/587) |
| **Date & Time (UTC):** | 2 July 2015 at 1800 hrs |
| **Location:** | Kemeys Commander Airfield, Monmouthshire |
| **Type of Flight:** | Private |
| **Persons on Board:** | Crew - 1 Passengers - 1 |
| **Injuries:** | Crew - None Passengers - None |
| **Nature of Damage:** | Damage to nosewheel assembly, propeller, left wing and main landing gear |
| **Commander's Licence:** | Private Pilot's Licence |
| **Commander's Age:** | 50 years |
| **Commander's Flying Experience:** | 241 hours (of which 9 were on type)<br>Last 90 days - 9 hours<br>Last 28 days - 9 hours |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot |

On returning to Kemeys Commander Airfield in Monmouthshire after a short local flight, the pilot made an approach to grass Runway 13. The runway surface was damp and the wind was from the south-east at 5 kt. The pilot estimated that he touched down between a third and a half of the way down the 500 m runway, bounced once and subsequently overran the end of the runway, over a rut and into a hedge. Both occupants, who were wearing full four-point harnesses, vacated the aircraft without difficulty. The pilot attributed the accident to his unfamiliarity on type coupled with an approach which he believed was flown too fast.

**ACCIDENT**

| | | |
|---|---|---|
| **Aircraft Type and Registration:** | X'air Falcon 133(1), G-CCSO | |
| **No & Type of Engines:** | 1 Verner 133M piston engine | |
| **Year of Manufacture:** | 2004 (Serial no: BMAA/HB/364) | |
| **Date & Time (UTC):** | 5 July 2015 at 1305 hrs | |
| **Location:** | Near Owston Ferry, North Lincolnshire | |
| **Type of Flight:** | Private | |
| **Persons on Board:** | Crew - 1 | Passengers - None |
| **Injuries:** | Crew - None | Passengers - N/A |
| **Nature of Damage:** | Substantial | |
| **Commander's Licence:** | National Private Pilot's Licence | |
| **Commander's Age:** | 49 years | |
| **Commander's Flying Experience:** | 87 hours (of which 37 were on type)<br>Last 90 days - 5 hours<br>Last 28 days - 4 hours | |
| **Information Source:** | Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB | |

The aircraft was flying to Sandtoft Airfield, Lincolnshire, at an altitude of 1,100 ft, when the engine started to run roughly on one cylinder, the oil pressure gauge registered zero and the engine then stopped. The pilot immediately selected a field, which contained a standing wheat crop, for a forced landing and, realising there would be a danger of the aircraft overturning on touchdown, decided to stall the aircraft in from a height of about 5 ft. The subsequent heavy landing caused considerable damage to the landing gear and fuselage.

After shutting down the aircraft, the pilot informed Sandtoft of his situation and vacated the aircraft normally. From the symptoms, he concluded that the crankshaft had snapped, although the engine had only accumulated some 40 hours since installation. The engine was one of the earlier, two-crankshaft bearing models which were superseded by a stronger, three bearing design.

# Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

**BULLETIN CORRECTION**

| | |
|---|---|
| **Date & Time (UTC):** | 20 August 2014 at 1834 hrs |
| **Location:** | Near Padbury, Buckinghamshire |
| **Information Source:** | AAIB Field Investigation |

**AAIB Bulletin No 4/2015, Page 63 refers**

This report stated that the pilot's headset enabled the pilot to accept incoming calls hands-free, but did not support either voice-activated dialling or dictated SMS text messaging.

Further inquiries have demonstrated that this model of headset **is** capable of supporting voice-activated dialling and dictated SMS text messaging hands-free when used in conjunction with the mobile phone the pilot was using.

This dictated SMS messaging function requires a data connection with a mobile phone network or Wi-Fi[1] network to operate. If the data connection is lost prior to completion and sending of a dictated SMS, the message is cancelled. It is not possible to interrupt a dictated message such that it can be completed later, or to use the function whilst a phone call is being made. Previously composed text cannot be copied to an SMS message using the hands-free function. Messages can also be dictated using the phone's microphone when a wireless headset is not connected.

The pilot had tried to make an outgoing call to a relative at 1831:03 hrs, but the call had failed to connect with the mobile network. This was followed at 1831:28 hrs by a 148-character SMS text message being sent from the pilot's phone to the same relative. A series of tests was carried out using the same model of headset and phone to determine if it was possible to send a dictated SMS within the available 25[2] seconds. When using the headset, a minimum of 46 seconds was required and without the headset, a minimum of 30[3] seconds was required. There was, therefore, insufficient time for the pilot to have dictated the message. This confirms that the message would have been composed and sent by physically accessing the phone.

This work corrects a detail in AAIB's factual reporting and does not change the analysis within the report.

**Footnote**

1 The message during the accident flight was sent over the mobile phone network.

2 The maximum amount of time between the failed call and the SMS being sent and is dependent on the phone having connected to the mobile network immediately after the failed call.

3 The time to send a dictated message is shorter when no headset is used as the dictation function does not read back the message before it can be sent.

# TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

6/2010 Grob G115E Tutor, G-BYUT and Grob G115E Tutor, G-BYVN near Porthcawl, South Wales on 11 February 2009.
Published November 2010.

7/2010 Aerospatiale (Eurocopter) AS 332L Super Puma, G-PUMI at Aberdeen Airport, Scotland on 13 October 2006.
Published November 2010.

8/2010 Cessna 402C, G-EYES and Rand KR-2, G-BOLZ near Coventry Airport on 17 August 2008.
Published December 2010.

1/2011 Eurocopter EC225 LP Super Puma, G-REDU near the Eastern Trough Area Project Central Production Facility Platform in the North Sea on 18 February 2009.
Published September 2011.

2/2011 Aerospatiale (Eurocopter) AS332 L2 Super Puma, G-REDL 11 nm NE of Peterhead, Scotland on 1 April 2009.
Published November 2011.

1/2014 Airbus A330-343, G-VSXY at London Gatwick Airport on 16 April 2012.
Published February 2014.

2/2014 Eurocopter EC225 LP Super Puma G-REDW, 34 nm east of Aberdeen, Scotland on 10 May 2012 and G-CHCN, 32 nm south-west of Sumburgh, Shetland Islands on 22 October 2012
Published June 2014.

3/2014 Agusta A109E, G-CRST Near Vauxhall Bridge, Central London on 16 January 2013.
Published September 2014.

1/2015 Airbus A319-131, G-EUOE London Heathrow Airport on 24 May 2013.
Published July 2015.

2/2015 Boeing B787-8, ET-AOP London Heathrow Airport on 12 July 2013.
Published August 2015.

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# GLOSSARY OF ABBREVIATIONS

| | |
|---|---|
| aal | above airfield level |
| ACAS | Airborne Collision Avoidance System |
| ACARS | Automatic Communications And Reporting System |
| ADF | Automatic Direction Finding equipment |
| AFIS(O) | Aerodrome Flight Information Service (Officer) |
| agl | above ground level |
| AIC | Aeronautical Information Circular |
| amsl | above mean sea level |
| AOM | Aerodrome Operating Minima |
| APU | Auxiliary Power Unit |
| ASI | airspeed indicator |
| ATC(C)(O) | Air Traffic Control (Centre)( Officer) |
| ATIS | Automatic Terminal Information System |
| ATPL | Airline Transport Pilot's Licence |
| BMAA | British Microlight Aircraft Association |
| BGA | British Gliding Association |
| BBAC | British Balloon and Airship Club |
| BHPA | British Hang Gliding & Paragliding Association |
| CAA | Civil Aviation Authority |
| CAVOK | Ceiling And Visibility OK (for VFR flight) |
| CAS | calibrated airspeed |
| cc | cubic centimetres |
| CG | Centre of Gravity |
| cm | centimetre(s) |
| CPL | Commercial Pilot's Licence |
| °C,F,M,T | Celsius, Fahrenheit, magnetic, true |
| CVR | Cockpit Voice Recorder |
| DFDR | Digital Flight Data Recorder |
| DME | Distance Measuring Equipment |
| EAS | equivalent airspeed |
| EASA | European Aviation Safety Agency |
| ECAM | Electronic Centralised Aircraft Monitoring |
| EGPWS | Enhanced GPWS |
| EGT | Exhaust Gas Temperature |
| EICAS | Engine Indication and Crew Alerting System |
| EPR | Engine Pressure Ratio |
| ETA | Estimated Time of Arrival |
| ETD | Estimated Time of Departure |
| FAA | Federal Aviation Administration (USA) |
| FIR | Flight Information Region |
| FL | Flight Level |
| ft | feet |
| ft/min | feet per minute |
| g | acceleration due to Earth's gravity |
| GPS | Global Positioning System |
| GPWS | Ground Proximity Warning System |
| hrs | hours (clock time as in 1200 hrs) |
| HP | high pressure |
| hPa | hectopascal (equivalent unit to mb) |
| IAS | indicated airspeed |
| IFR | Instrument Flight Rules |
| ILS | Instrument Landing System |
| IMC | Instrument Meteorological Conditions |
| IP | Intermediate Pressure |
| IR | Instrument Rating |
| ISA | International Standard Atmosphere |
| kg | kilogram(s) |
| KCAS | knots calibrated airspeed |
| KIAS | knots indicated airspeed |
| KTAS | knots true airspeed |
| km | kilometre(s) |
| kt | knot(s) |
| lb | pound(s) |
| LP | low pressure |
| LAA | Light Aircraft Association |
| LDA | Landing Distance Available |
| LPC | Licence Proficiency Check |
| m | metre(s) |
| mb | millibar(s) |
| MDA | Minimum Descent Altitude |
| METAR | a timed aerodrome meteorological report |
| min | minutes |
| mm | millimetre(s) |
| mph | miles per hour |
| MTWA | Maximum Total Weight Authorised |
| N | Newtons |
| $N_R$ | Main rotor rotation speed (rotorcraft) |
| $N_g$ | Gas generator rotation speed (rotorcraft) |
| $N_1$ | engine fan or LP compressor speed |
| NDB | Non-Directional radio Beacon |
| nm | nautical mile(s) |
| NOTAM | Notice to Airmen |
| OAT | Outside Air Temperature |
| OPC | Operator Proficiency Check |
| PAPI | Precision Approach Path Indicator |
| PF | Pilot Flying |
| PIC | Pilot in Command |
| PNF | Pilot Not Flying |
| POH | Pilot's Operating Handbook |
| PPL | Private Pilot's Licence |
| psi | pounds per square inch |
| QFE | altimeter pressure setting to indicate height above aerodrome |
| QNH | altimeter pressure setting to indicate elevation amsl |
| RA | Resolution Advisory |
| RFFS | Rescue and Fire Fighting Service |
| rpm | revolutions per minute |
| RTF | radiotelephony |
| RVR | Runway Visual Range |
| SAR | Search and Rescue |
| SB | Service Bulletin |
| SSR | Secondary Surveillance Radar |
| TA | Traffic Advisory |
| TAF | Terminal Aerodrome Forecast |
| TAS | true airspeed |
| TAWS | Terrain Awareness and Warning System |
| TCAS | Traffic Collision Avoidance System |
| TGT | Turbine Gas Temperature |
| TODA | Takeoff Distance Available |
| UHF | Ultra High Frequency |
| USG | US gallons |
| UTC | Co-ordinated Universal Time (GMT) |
| V | Volt(s) |
| $V_1$ | Takeoff decision speed |
| $V_2$ | Takeoff safety speed |
| $V_R$ | Rotation speed |
| $V_{REF}$ | Reference airspeed (approach) |
| $V_{NE}$ | Never Exceed airspeed |
| VASI | Visual Approach Slope Indicator |
| VFR | Visual Flight Rules |
| VHF | Very High Frequency |
| VMC | Visual Meteorological Conditions |
| VOR | VHF Omnidirectional radio Range |

AAIB
Air Accidents Investigation Branch