



Air Accident Investigation Unit Ireland

FORMAL REPORT

ACCIDENT

**Cessna 208B, G-KNYS
Near Clonbullogue, Co. Offaly**

13 May 2018



**An Roinn Iompair
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport**

FINAL REPORT

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable and contributory causes.

In accordance with the provisions of Annex 13¹ to the Convention on International Civil Aviation, Regulation (EU) No 996/2010² and Statutory Instrument No. 460 of 2009³, safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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¹ **Annex 13:** International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.

² **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.

³ **Statutory Instrument (SI) No. 460 of 2009:** Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.



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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents, on 13 May 2018, appointed John Owens as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Report.

| | | |
|---|---|------------------------|
| Aircraft Type and Registration: | Cessna 208B Grand Caravan, G-KNYS | |
| No. and Type of Engines: | 1 x Pratt and Whitney Canada (PWC) PT6A-114A | |
| Aircraft Serial Number: | 208B1146 | |
| Year of Manufacture: | 2005 | |
| Date and Time (UTC)⁴: | 13 May 2018 @ 13.38 hrs approximately | |
| Location: | 3.5 nautical miles (NM) west of Clonbullogue Village, Co. Offaly | |
| Type of Operation: | Specialised Operations – Parachuting | |
| Persons on Board: | Crew – 1 | Passengers – 1 |
| Injuries: | Crew – 1 (Fatal) | Passengers – 1 (Fatal) |
| Nature of Damage: | Aircraft destroyed | |
| Commander's Licence: | Commercial Pilot Licence (CPL) Aeroplane (A), issued by the Civil Aviation Authority (CAA) of the United Kingdom (UK) | |
| Commander's Age: | 47 years | |
| Commander's Flying Experience: | 2,157 hours (estimated) Total on type undetermined | |
| Notification Source: | Dublin Air Traffic Control (ATC) | |
| Information Source: | AAIU Field Investigation | |

⁴ **UTC:** Co-ordinated Universal Time. Unless otherwise stated, all timings in this report are quoted in UTC; to obtain local time add one hour.

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SYNOPSIS

The Cessna 208B aircraft took off from Runway 27 at Clonbullogue Airfield (EICL), Co. Offaly at approximately 13.14 hrs. On board were the Pilot and a Passenger (a child), who were seated in the cockpit, and 16 skydivers, who occupied the main cabin. The skydivers jumped from the aircraft, as planned, when the aircraft was overhead EICL at an altitude of approximately 13,000 feet. When the aircraft was returning to the airfield, the Pilot advised by radio that he was on 'left base' (the flight leg which precedes the approach leg and which is normally approximately perpendicular to the extended centreline of the runway). No further radio transmissions were received. A short while later, it was established that the aircraft had impacted nose-down into a forested peat bog at Ballaghassan, Co. Offaly, approximately 2.5 nautical miles (4.6 kilometres) to the north-west of EICL. The aircraft was destroyed. There was no fire. The Pilot and Passenger were fatally injured.

The Investigation determined that the probable cause of the accident was a loss of control in a steeply banked left-hand turn, leading to a rapid loss of altitude. Four Safety Recommendations are made as a result of this Investigation.

NOTIFICATION AND RESPONSE

The AAIU on-call duty Inspector was notified of the accident by Dublin ATC at approximately 14.15 hrs. Three Inspectors of Air Accidents deployed to the accident site to commence an Investigation. Following an extensive excavation operation by the emergency services and local personnel to recover the two fatally injured occupants, and an initial examination of the aircraft wreckage by the AAIU, the site was secured overnight by An Garda Síochána. Three Inspectors of Air Accidents returned early the following morning to further examine the wreckage and the site, before the wreckage was recovered and transported under escort to the AAIU's facility at Gormanston, Co. Meath.

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1. FACTUAL INFORMATION

1.1 History of the Flight

The Cessna 208B aircraft (**Photo No. 1**) took off from Runway (RWY) 27 at EICL at approximately 13.14 hrs. The occupants on board were the Pilot, who was seated in the left-hand cockpit seat, a Passenger (a child), who was seated in the right-hand cockpit seat, and 16 skydivers, who occupied two bench seats in the main cabin.

The aircraft was owned by a UK-based parachute-aircraft leasing company and flown by a UK-based Pilot. At the time of the accident, it was operating the locally based Club's (hereafter referred to as the Club) fifth parachuting flight that day. It had been operating each weekend at the airfield since 21 April 2018 (a total of four weekends). Shortly after take-off, at 13.15:44 hrs, the Pilot advised Dublin ATC that the aircraft was passing 1,500 feet (ft) and requested climb clearance to FL130⁵. According to one of the Club members who was operating the radio at the airfield, when the aircraft was overhead the drop zone⁶, the Pilot advised that the drop would occur in two minutes. The radio operator said that following a check to ensure that the drop zone was clear, permission for the drop was given and the 16 skydivers exited the aircraft.

⁵ **FL130:** Flight Level 130, a three-digit representation of aircraft altitude (13,000 ft in this case) referenced to standard pressure (1013.25 hPa).

⁶ **Drop zone:** The area above and around a location where a skydiver freefalls and expects to land.



At 13.34:26 hrs, the Pilot reported to Dublin ATC that the drop was complete and the aircraft was in the descent. The aircraft was at an altitude of approximately 10,700 ft at that time. The radio operator at EICL said that the Pilot subsequently transmitted to advise that the aircraft was on 'left base'. The aircraft's earlier flights that day had landed on RWY 09 – the reciprocal of the take-off runway. Therefore, left base would have been to the north-west of the airfield. No further transmissions were received from the aircraft, and when it did not arrive as expected, the radio operator attempted to establish radio contact, but was unsuccessful.

At approximately 13.54 hrs, the Marine Rescue Co-ordination Centre (MRCC) in Dublin contacted EICL to advise that an alert signal was being received from an aircraft's Emergency Locator Transmitter (ELT) close to the airfield. Another aircraft, which was based at the airfield, was used to conduct a search for the missing aircraft. A land-based search was also initiated and Dublin ATC was informed of the situation. A short time later, the accident site was located approximately 2.5 NM (4.6 km) to the north-west of the airfield and approximately 1 NM (1.85 km) from the south-eastern perimeter of a wind farm. The aircraft was found to have been destroyed. The Pilot and Passenger were fatally injured. There was no fire.



Photo No. 1: G-KNYS - Cessna 208B Grand Caravan (*David Reeves*)

1.1.1 Witness Information

1.1.1.1 Witnesses located close to Accident Site

The Investigation interviewed three witnesses who were located close to the accident site at the time of the accident. Two witnesses (Witness No. 1 and Witness No. 2) were situated approximately 750 metres (m) to the south of the accident site (**Figure No. 1**). Witness No. 1 described hearing the aircraft pass overhead, before seeing it flying 'sideways' and that it was 'low down'. Witness No. 2 noted that a wing was 'sticking up'. Witness No. 1 indicated that the aircraft was on its left side and that it was travelling approximately northwards at the time (i.e. towards the area of the accident site). Witness No. 1 said that he and Witness No. 2 looked away momentarily and when they looked back, the aircraft was gone. He said that as he moved away from where they were standing, he met another person (Witness No. 3) who said that 'the plane's gone down'. Witness No. 2 then assisted Witness No. 3 with contacting the emergency services.

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Witness No. 3 had been walking in a northwards direction, approximately 250 m to the east and 200 m further north of Witnesses No. 1 and No. 2. He said that he heard the sound of an aircraft engine, looked up and saw the aircraft coming '*straight down*', nose first, before it disappeared behind a line of trees located to his north-west. This was followed by what the witness described as the sound of an impact. He estimated the time from when he first saw the aircraft to when it impacted was three seconds.



Figure No. 1: Location of witnesses relative to the accident site (*Google Earth*)

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1.1.1.2 Skydivers on Board at Departure

The Investigation interviewed the 16 skydivers who had been on board the aircraft when it departed from EICL on the accident flight. Several of the skydivers were wearing helmet cameras (**Section 1.11.7**). All of the skydivers jumped regularly at the Club and some had jumped earlier that day.

The skydivers were asked whether or not they had seen the aircraft after they exited it. Some skydivers saw it briefly, but most did not notice it. The skydivers were also asked to recall any interactions they had with the Pilot. Some had not interacted with him, so could not comment. Nearly all of those who commented had positive impressions of the Pilot. In relation to flying technique, one of the 16 skydivers said that the Pilot performed '*sharp turns as opposed to smooth turns more than once*'.

1.1.1.3 Accommodation Provider

The Pilot ordinarily lived in the UK and when operating at the Club stayed at a local guest house. In accident investigation, it is necessary to examine the pre-flight activity of a pilot to establish if the nature of such activities had a bearing on the rest and wellbeing of the individual. In this regard, the Investigation interviewed the owner of the guest house where the Pilot stayed the night before the accident.



The owner stated that the Pilot arrived at around 20.00 hrs, before going back out for something to eat and returned a short while later. The owner said that the Pilot watched TV and went to bed at approximately 21.30 hrs, was up the next morning at 07.45 hrs, had breakfast and left for the parachute Club. The owner described the Pilot as ‘very gentlemanly, very friendly’ and said that he was ‘absolutely perfect’ leaving the house that morning.

Note: All times in **Section 1.1.1.3** are local time.

1.1.1.4 Pilot who Witnessed Aircraft Descent on the Previous Day

A pilot who had experience on the aircraft type was at EICL on the day before the accident and observed the aircraft descending on that day. He said that the aircraft descended in what appeared to be a ‘very severely pitched down’ attitude. The witness said that it then ‘pulled up’ and went into a ‘tight bank ninety degrees and he did several of these, flipped it from one side to the other side’. He considered the manoeuvres to be ‘aerobatic’ in nature and thought that they may have been carried out to ‘bleed airspeed’ [in preparation for landing].

1.1.1.5 Club-based Personnel

Interview details with Club-based personnel are contained in **Section 1.17.7**.

1.2 Injuries to Persons

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The Pilot and Passenger sustained fatal injuries (**Table No. 1**).

| Injuries | Crew | Passengers | Others |
|-------------|------|------------|--------|
| Fatal | 1 | 1 | 0 |
| Serious | 0 | 0 | 0 |
| Minor /None | 0 | 0 | |

Table No. 1: Injuries to Persons

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

The aircraft impacted into a forested peat bog, approximately 2.5 NM (4.6 km) to the north-west of the departure airfield and approximately 1 NM (1.85 km) from the south-eastern perimeter of a wind farm. The impact was such that the front section of the aircraft, forward of the main wheels, was submerged below the surface of the bog. There was significant fuel contamination in evidence at the site. The accident site was compact and only trees immediately adjacent to the aircraft wreckage were damaged.

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1.5 Personnel Information

1.5.1 Pilot

1.5.1.1 General

The Pilot, a male aged 47 years, was seated in the left-hand cockpit seat at the time of the accident. He held a CPL (A), which was initially issued by the UK CAA on 1 April 2010. The licence contained four ratings: Instrument, Cessna SET (Single-Engine Turbine), MEP (Multi-Engine Piston) (land), and SEP (Single-Engine Piston) (land). The Pilot's Cessna SET rating was revalidated on 4 February 2017, following the completion of a rating test conducted by a CAA-approved Flight Examiner on that day. The rating was valid until 28 February 2019.

The Pilot's Class 1 Medical Certificate was issued by a UK-based Aeromedical Examiner (AME) on 11 May 2018. The Pilot's previous Class 1 Medical Certificate had an expiry date of 20 March 2018. The Pilot's Class 2 Medical Certificate had an expiry date of 20 March 2019.

1.5.1.2 Flying Experience

The last entry in the Pilot's logbook was made on 26 February 2018, resulting in a total time recorded in the logbook of 2,122.7 hours. The first entry in this particular logbook, which was the Pilot's fourth logbook, was made on 20 May 2017. The Pilot recorded 455.2 hours in this logbook, 453 of which were on the Cessna 208B type.

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The Pilot usually flew on some week-days at a skydiving centre located in the UK. The Investigation sought details from this organisation regarding the Pilot's recent flying hours. The organisation advised that the Pilot flew for two hours at the UK-based skydiving centre in the week leading up to the accident. Records indicate that the Pilot flew up to 18 flights per day while at EICL. These flights were recorded in the aircraft's technical logbook as being between 15 and 25 minutes long. The Pilot's flying experience as outlined in **Table No. 2** was estimated based on his logbook entries and the records available from the UK-based skydiving centre where the Pilot usually flew, and also the aircraft's technical logbook records found at the accident site.

| | |
|--------------------------|---------------------------------|
| Total all types: | 2,157.4 hours |
| Total on type: | 487.7 hours (since 20 May 2017) |
| Total on type P1: | 487.7 hours (since 20 May 2017) |
| Last 90 days: | 46.7 hours (all on type) |
| Last 28 days: | 34.7 hours (all on type) |
| Last 24 hours: | 3.4 hours (all on type) |

Table No. 2: Pilot's flying experience (estimated)



1.5.1.3 Additional Information

Following the occurrence, the Investigation was contacted by a number of individuals who expressed concern about the Pilot's medical fitness. The Investigation reviewed the Pilot's medical records and noted that in July 2015, the Pilot's licence was suspended due to concerns regarding the Pilot's psychological welfare (the medical records indicate that at that time, he had not flown since December 2014). Following medical intervention, a satisfactory review was carried out by a UK CAA-appointed specialist in June 2016. Subsequent to this, a Class 1 medical certificate was issued by a UK AME on 1 July 2016. A further follow-up review was carried out by the UK CAA-appointed specialist in November 2016 and again in July 2017, when it was noted that further such reviews were not considered necessary. The Pilot's most recent medical examination was conducted by a UK AME on 4 May 2018, which included a satisfactory review. The Pilot's Class 1 medical certificate was reissued on 11 May 2018, without restrictions.

1.5.2 Passenger

The Passenger, a child aged seven years, was seated in the right-hand cockpit seat at the time of the accident. The Passenger was travelling on the aircraft with his parents' permission. His parents, one of whom was a skydiver at the Club, were not on board the aircraft on the accident flight. The Passenger had been on board the aircraft on previous flights. A video recorded by one of the skydivers on the day prior to the accident shows the Passenger briefly holding the control column yoke under the supervision of the Pilot.

1.6 Aircraft Information

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1.6.1 General

The aircraft, a Cessna 208B (Grand Caravan), high-wing, 12.7 metres (m) long, all-metal aircraft, was manufactured in 2005. The aircraft had a United States (US) registration prior to 6 December 2017. Two cockpit seats were fitted and the aircraft could be operated from either side of the cockpit.

The aircraft type is equipped with roll spoilers fitted to the upper surface of the wing, inboard of each aileron. The spoilers move in conjunction with the ailerons. Trailing edge flaps are fitted, which can be selected to any position from 'UP' to 'FULL' (0 to 30°) by a selector lever in the cockpit pedestal. The lever has intermediate positions of '10°' and '20°'. A scale and pointer on the left side of the selector lever provides a flap position indication. A vane-type stall warning unit is fitted in the leading edge of the aircraft's left-hand wing. According to the Pilot's Operating Handbook (POH) for the aircraft, the vane '*senses the change in airflow over the wing [due to an impending stall], and operates the stall warning horn [in the cockpit] at airspeeds between 5 and 10 knots above the stall in all configurations*'.

The fuel system on the aircraft type consists of a fuel tank in each wing; each tank can be filled through a cap in its respective wing. A fuel tank selector panel, which contains a selector knob for each tank, is located in the overhead panel in the cockpit. The POH states that '*normal fuel management is with both fuel tank selectors in the ON position*'. It is not possible to selectively transfer fuel from one tank to the other. The POH also states that the '*Maximum fuel unbalance in flight is 200 lbs*'.

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If, during an engine start, one wing tank selector is in the OFF position, a red warning light labelled FUEL SELECT OFF illuminates on the annunciator panel located in the main instrument panel, and an aural alert is generated. The light and aural alert are also activated if either the left or right fuel tank selector valves are closed and the fuel remaining in the tank being used drops below 25 US gallons, or if both fuel tank selector valves are closed. If the FUEL SEL WARN Circuit Breaker (CB) is open (popped/pulled), the FUEL SELECT OFF annunciator will illuminate even with both fuel tank selectors ON, to warn that the fuel selector warning system is no longer active. This CB is fitted with a collar to protect it from being pulled. The collar is removable. The annunciator panel also contains amber *LEFT FUEL LOW* and *RIGHT FUEL LOW* caution lights, which illuminate if the fuel quantity in the respective fuel tank is 25 US gallons or less (each fuel tank can hold 167 US gallons approximately). According to the POH, a red warning light is a '*HAZARDOUS CONDITION*', which '*Requires Immediate Corrective Action*'. An Amber light is a '*CAUTIONARY CONDITION*', which '*May require Immediate Corrective Action*'.

The subject aircraft was modified to facilitate parachute operations. Records indicate that the modification was performed in September 2012. The modification included the installation of two longitudinal benches secured to the floor of the passenger cabin and the removal of the aircraft's normal cargo doors, located on the left-hand side of the aft fuselage. A roll-up door was fitted in place of these doors (visible in **Photo No. 1**). The '*CARGO DOORS REMOVED KIT*' supplement in the aircraft's POH states that '*with cargo door removed, the maximum airspeed must not exceed 155 KIAS*⁷'. The modification included the installation of an external step for skydivers to stand on when exiting the aircraft and external and internal grab handles. A wind deflector was also fitted.

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The aircraft was equipped with a transponder, which identified the aircraft's registration and altitude to ATC. The subject aircraft was also equipped with an oxygen system, which consisted of a storage cylinder located in the aft section of the aircraft and oxygen outlets fitted above the cockpit seats. The aircraft owner advised the Investigation that the oxygen system was not in use on the aircraft. The regulatory requirements regarding the use of supplementary oxygen are outlined in **Section 1.17.2.4**.

The maximum take-off weight of the aircraft was 8,750 pounds (lbs) (3,969 kilograms (kg)). Records indicate that the aircraft was last weighed on 4 December 2017. The associated weighing report recorded that the aircraft's '*Basic Weight*⁸ was 4,798 lbs. The parachute Club's manifest system indicated that the total weight of the 16 skydivers (including equipment) was approximately 3,150 lbs. The combined weight of the Pilot and Passenger was estimated to be approximately 290 lbs. The aircraft's technical logbook recovered at the accident site recorded a fuel uplift of 200 litres (for the accident flight) and a total fuel on board of 500 lbs. The Investigation estimated the aircraft's take-off weight as 8,738 lbs. The POH indicates that the take-off speed for a normal (i.e. not a short field) take-off at the maximum take-off weight is 83 KIAS. Logbook entries indicated that 100 lbs of fuel was being consumed on each flight.

⁷ **KIAS:** Knots Indicated Airspeed – Speed shown on the Airspeed Indicator and expressed in knots.

⁸ **Basic Weight:** The '*Basic Weight*' includes unusable fuel and certain specified installed aircraft equipment.



The last entry in the aircraft's logbook was made on 22 April 2018 and recorded that the aircraft had flown for a total time of 4,640.2 hours and had operated 6,298 flights. Using the technical logbook records provided by the aircraft owners and those recovered at the accident site, the Investigation estimated the total operational time of the aircraft from manufacture until the accident to be 4,670 hours. The total number of flights operated by the aircraft was estimated to be 6,379.

1.6.2 Airworthiness Certification

The aircraft's Certificate of Airworthiness was issued by the UK CAA on 12 December 2017. The Airworthiness Review Certificate was also issued by the CAA on the same date and was valid until 11 December 2018.

1.6.3 Maintenance History

Maintenance records indicate that several maintenance tasks, including an annual maintenance inspection, were certified on 12 December 2017. An operational check of the aircraft's stall warning system was performed during this maintenance visit. A calibration check of the aircraft's two airspeed indicators was also performed at this time. A total aircraft operating hours of 4,613.7 was recorded on this date. A defect was recorded in the technical logbook on 17 February 2018, as follows: '*sunvisor pilot side u/s [unserviceable]*'. There was no record of this being repaired. A video recording taken by a skydiver who was on board the aircraft the day before the accident appears to show that the left-hand sunvisor was missing on that flight. The requirements regarding a Minimum Equipment List (MEL) and the dispatch of an aircraft with a technical defect are outlined in **Section 1.17.2.5**.

1.6.4 Operating Limitations

The POH for the aircraft was not carried on board during the accident flight and was provided to the Investigation by the Club. The information regarding the aircraft's '*airspeed limitations*' and the aircraft's '*stall speeds*' was extracted from the POH and is reproduced in **Table No. 3**, **Table No. 4**, and **Table No. 5**.

| | Speed | KIAS | Remarks |
|-----------------|--|--|--|
| V _{MO} | Maximum Operating Speed: | 175 (the ' <i>CARGO DOORS REMOVED KIT</i> ' supplement in the POH limits the maximum airspeed to 155 KIAS) | Do not exceed this speed in any operation. |
| V _A | Manoeuvring Speed ⁹ : 8,750 Pounds 7,500 Pounds 6,250 Pounds 5,000 Pounds | 148 137 125 112 | Do not make full or abrupt control movements above this speed. |

⁹ **V_A (Manoeuvring Speed):** According to the POH, this is the maximum speed at which full or abrupt control movements may be used without overstressing the airframe.

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| | Speed | KIAS | Remarks |
|-----------------|-----------------|------|--|
| V _{FE} | Maximum Flap | | |
| | Extended Speed: | | |
| | 0° - 10° Flaps | 175 | Do not exceed these speeds with the given flap settings. |
| | 10° - 20° Flaps | 150 | |
| | 20° - 30° Flaps | 125 | |

Table No. 3: Airspeed Limitations

| Flap Setting | Angle of Bank | | | | | | | |
|--------------|---------------|--------------------|------|------|------|------|------|------|
| | 0° | | 30° | | 45° | | 60° | |
| | KIAS | KCAS ¹⁰ | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS |
| Up | 63 | 78 | 68 | 84 | 75 | 93 | 89 | 110 |
| 10° | 58 | 69 | 62 | 74 | 69 | 82 | 82 | 98 |
| 20° | 53 | 63 | 57 | 68 | 63 | 75 | 75 | 89 |
| 30° | 48 | 60 | 52 | 64 | 57 | 71 | 68 | 85 |

Table No. 4: Stall Speeds 8,750 lbs, most rearward centre of gravity

| Flap Setting | Angle of Bank | | | | | | | |
|--------------|---------------|------|------|------|------|------|------|------|
| | 0° | | 30° | | 45° | | 60° | |
| | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS | KIAS | KCAS |
| Up | 63 | 78 | 68 | 84 | 75 | 93 | 89 | 110 |
| 10° | 60 | 70 | 64 | 75 | 71 | 83 | 85 | 99 |
| 20° | 54 | 64 | 58 | 69 | 64 | 76 | 76 | 91 |
| 30° | 50 | 61 | 54 | 66 | 59 | 73 | 71 | 86 |

Table No. 5: Stall Speeds 8,750 lbs, most forward centre of gravity

The POH also lists the '*SPEEDS FOR NORMAL OPERATION*' (landing weight 8,500 lbs). The speed for a '*Normal Approach, Flaps Up*' is '*100-115 KIAS*'. For a '*Normal Approach, Flaps 30°*', the speed is '*75-85 KIAS*'. The landing checklist, as contained in the POH, lists the airspeed required for landing as '*75-85 KIAS*' (flaps '*FULL DOWN*', i.e. 30°).

The '*Maneuver Limits*' are also contained in the POH. This section states:

'This airplane is certificated in the normal category. The normal category is applicable to aircraft intended for non-aerobatic operations. These include any maneuvers incidental to normal flying, stalls (except whip stalls), lazy eights, chandelles, and turns in which the angle of bank is not more than 60°.'

1.6.5 Engine Details

The aircraft was fitted with a PT6A-114A gas turbine engine, manufactured by Pratt & Whitney Canada (PWC). Further details of the engine type are contained in **Appendix A**.

¹⁰ **KCAS:** Knots Calibrated Air Speed – indicated airspeed corrected for instrument and position error.



Records indicate that the engine was overhauled at an FAA-approved Repair Station in December 2008. Its total operating hours and cycles at the time of overhaul were 3,488.4 and 3,330, respectively. The last entry in the engine logbook was made on 22 April 2018 and recorded that the engine had operated for a total time of 5,711.3 hours and 6,451 cycles since new, and 2,222.9 hours and 3,121 cycles since overhaul. Using the additional records obtained, as outlined earlier, the Investigation estimated the approximate totals as 5,741.1 hours and 6,532 cycles since new and 2,252.7 hours and 3,202 cycles since overhaul.

1.6.6 Propeller Details

A three-bladed aluminium alloy, variable pitch propeller was installed. Records indicate that the propeller was overhauled by a UK CAA-approved Maintenance/Repair Organisation (MRO) and was released to service from overhaul on 30 November 2017. Its installation on G-KNYS was certified on 12 December 2017. The last entry in the propeller logbook was made on 22 April 2018 and recorded on that date that the propeller had operated for a total time of 26.5 hours since overhaul. Using the additional records obtained, as outlined earlier, the Investigation estimated the propeller's total operational time since overhaul as approximately 56.3 hours.

The engine and propeller are controlled by four control levers mounted on the pedestal in the cockpit, three of which are used during normal engine operation: the fuel lever, the propeller lever, and the power lever. A fourth lever – the emergency power lever – is only for use in the event of a malfunction of the engine's fuel control unit and allows the pilot to manually modulate engine power. Torque is the primary parameter used to set engine power for take-off and cruise operation for specified propeller speeds.

1.7 Meteorological Information

Met Éireann, the Irish meteorological service, was asked to provide details of the weather conditions prevailing in the Clonbullogue area between 12.00 hrs and 15.00 hrs on the day of the accident. Details from the report received are reproduced in **Table No. 6**.

| | |
|--|--|
| Meteorological Situation: | A weak ridge of High Pressure was drifting away eastwards as a frontal system approached the country from the west. Weather conditions at the site of the incident were quite benign with generally shallow cumuloform ¹¹ cloud, light to moderate breezes and only a small risk of isolated light showers of rain. |
| Surface Wind: Wind at 2,000 ft: | Circa 230-240° at 5-10 knots (kts). Circa 230° at 10-15 kts. |
| Visibility: | 10+ km. |
| Weather: | Nil, apart from a risk of very isolated light showers in the general vicinity. |

¹¹ **Cumuloform:** 'Fluffy' detached clouds. They show vertical motion or thermal uplift of air taking place in the atmosphere and are usually dense in appearance with sharp outlines.

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| | |
|---------------------------------------|--|
| Cloud: | SCT/BKN ¹² CuSc [cumulus-stratocumulus] with bases ranging 2500-5000 ft. |
| Surface Temperature/Dew Point: | 13/06 degrees Celsius, becoming 15/06 degrees Celsius over the course of the period 1200-1500 UTC. |
| Mean Sea Level (MSL) Pressure: | 1015 hectopascals (hPa). |
| Freezing Level: | 5,000 ft. |

Table No. 6: Weather conditions in the Clonbullogue area at the time of the occurrence

Solar data from the date and time of the accident indicates that the sun was positioned to the south-west of the accident site.

1.8 Aids to Navigation

Several of the skydivers were wearing helmet cameras which video-recorded their jumps on the accident flight. A skydiver's video recorded during the accident flight shows a portable satellite navigation unit located above the cockpit instrument panel in front of the Pilot. Such a unit was not found at the accident site or in subsequent examination of the aircraft wreckage (**Section 1.11.3**).

1.9 Communications

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Shortly after take-off, at 13.15:44 hrs, the Pilot advised Dublin ATC that the aircraft was passing 1,500 ft and requested climb clearance to FL130, which was approved. At 13.34:26 hrs, the Pilot reported to Dublin ATC that the drop was complete and the aircraft was in the descent. The last radio transmission received from the Pilot was to advise the radio operator at EICL that the aircraft was on '*left base*'. No '*MAYDAY*' call was heard.

1.10 Aerodrome Information

The aircraft took-off from Clonbullogue Airfield (EICL), which is situated in Co. Offaly in the Irish midlands. The airfield has one grass runway – RWY 09/27. According to the IAA's Aeronautical Information Publication (AIP)¹³, the runway is 770 m long, and has an elevation of 240 ft.

1.11 Flight Recorders

The aircraft was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR), nor was it required to be. Commission Regulation (EU) 965/2012, as amended by Commission Implementing Regulation (EU) 2019/1387, requires the installation of a '*lightweight flight recorder*' on turbine-engined aircraft with a maximum take-off weight of 2,250 kg or more that are first issued an individual Certificate of Airworthiness on or after 5 September 2022 (Section SPO.IDE.A.146 of Commission Regulation (EU) 965/2012 refers). There is no requirement for the retro-fitting of such recorders on older aircraft.

¹² **SCT/BKN:** Scattered/Broken.

¹³ AIP Ireland EICL AD 2-2 10 Oct 2019.



1.11.1 Aircraft Data Acquisition System

1.11.1.1 General

The aircraft was fitted with an Aircraft Data Acquisition System 'ADAS+', which was manufactured by the Engine Manufacturer's parent company. According to the Engine Manufacturer, the ADAS unit provides '*an integrated aircraft data source and analysis tool for operators, maintenance personnel and fleet owners*'. The unit also contains a '*built in flight data recorder to assist in accident/incident investigations*', although it is not certified as crash-survivable. The ADAS system includes the unit itself and several transducers¹⁴, some of which utilise sensors from other systems on the aircraft, including the aircraft's pitot-static sensors and engine parameter sensors. The data was recorded every 0.489 seconds (2.045 Hz).

The Engine Manufacturer stated that following the installation of the ADAS system, certain parameters require calibration to ensure that the ADAS unit is recording the same values as are displayed by the aircraft's instrumentation. In the case of engine torque, according to the Engine Manufacturer, it may be necessary during the calibration process to introduce a negative offset at indicated torque values of zero, to ensure that the ADAS unit is as accurate as possible at mid to high torque levels. The Engine Manufacturer advised that below 70%-75% Ng (engine rotational speed) fuel flow may not be recorded.

The ADAS unit from the accident aircraft was found at the site when the front section of the aircraft was lifted from the bog. It was damaged, but intact (**Photo No. 2**), and was shipped to the Engine Manufacturer's Norwood facility in the USA on 15 May 2018 with the assistance of the National Transportation Safety Board (NTSB). It was examined in the presence of a Federal Aviation Administration (FAA) representative, acting on behalf of the NTSB.

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Photo No. 2: ADAS unit recovered from the wreckage

1.11.1.2 ADAS Parameters

Following extensive preparatory work by the Engine Manufacturer, the unit was successfully downloaded on 23 May 2018 and the data was provided to the Investigation in a spreadsheet. **Table No. 7** lists the 21 parameters that the recovered unit was capable of recording and those that were actually recorded:

¹⁴ **Transducer:** A device that converts variations in physical quantity, such as pressure, into an electrical signal.

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| Parameter | Note |
|--|---|
| Time Value | This value appears to be the total recording time in seconds, which, in the case of this unit, was recorded in 0.489 second increments. The final value recorded was 946704417.5. |
| Time Actual | This recorded a date of 01/01/2000 and a time of day every 0.489 seconds. The time of day was not aligned with UTC. The parameters listed in the rows below were recorded at a frequency of 2.045 Hz (every 0.489 seconds). |
| Engine ITT (Inter Turbine Temperature) (°C) | Recorded. |
| OAT (Outside Air Temperature) (°C) | Recorded. |
| AC Hour Meter | Not recorded. |
| Engine Torque (Foot Pounds – ft lbs) | Recorded. |
| Static Pressure (Inches of Mercury – inHg) | Recorded. |
| Engine Ng (Engine Rotational Speed) (%) | Recorded. |
| Engine Np (Propeller Rotational Speed) (rpm) | Recorded. |
| Engine Wf (Fuel Flow) (Pounds per Hour – lbs/hr) | Recorded. |
| Airspeed (Knots – Kts) | Recorded (tolerance $\pm 5\%$). |
| Altitude (Feet) | Recorded. The Engine Manufacturer advised that values are referenced to the International Standard Atmosphere (ISA), in which the sea level reference is 29.92 inches of mercury (1013.25 millibars/hPa) and the temperature reference is 59 degrees Fahrenheit (15 degrees Celsius). |
| Aircraft Bus Voltage | Approximately 27.6 volts recorded throughout. |
| Internal Battery Voltage | Approximately 0.5 volts recorded throughout. |
| Internal Board Temp | Recorded. |
| Configuration ID | Discrete value of '7' recorded. |
| Run/Maint | Discrete value of '1' recorded. |
| Trend Switch | Discrete value of '1' recorded. |
| AC EPL | Discrete value of '1' recorded. |
| Eng P/S | Discrete value of '1' recorded. |
| Engine Bleed | Discrete value of '0' recorded. |

Table No. 7: ADAS Parameters



1.11.1.3 Overview of Information Obtained

The ADAS unit contained data recorded over a period of 29 minutes approximately. This included the entire accident flight and approximately the final 28 seconds of the previous flight. The first recorded '*Time Actual*' from the accident flight was 00:00:10.78 when the Ng increased above zero. Approximately two and a half minutes later, the airspeed also increased above zero. The recorded altitude from the end of the previous flight until the aircraft took-off on the accident flight fluctuated between -36 ft and 32 ft, approximately. During the take-off roll (airspeed above zero) the recorded altitude fluctuated between -36 ft and 4.5 ft.

The data indicates that the aircraft became airborne on the accident flight at a '*Time Actual*' of 00:03:04.20 and at an airspeed of approximately 77 kts. The fuel flow at this stage was 437.6 lbs/hr. The engine torque was 1,795.5 ft lbs. An extract of the ADAS data is reproduced in tabular form in **Figure No. 2**, with the first row of airborne data highlighted in blue. The row timings increment in 0.489 second intervals.

| | A | B | C | D | E | F | G | H | I |
|-----|-------------------------|-------------|-----------------------|--------------------|------------------|--------------------|---------------------------|-------------------|------------------|
| 1 | Time Actual | Time Value | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Engine Torque (ft lbs) | Airspeed (kts) | Altitude (ft) |
| 606 | '01/01/2000 00:03:02.73 | 946702982.7 | 437.064 | 698.292 | 95.614 | 1897.572 | 1783.071 | 74.542 | -16.219 |
| 607 | '01/01/2000 00:03:03.22 | 946702983.2 | 436.81 | 698.103 | 95.591 | 1897.7321 | 1785.84 | 75.886 | 6.372 |
| 608 | '01/01/2000 00:03:03.71 | 946702983.7 | 438.056 | 698.292 | 95.599 | 1895.301 | 1794.838 | 76.423 | 0.724 |
| 609 | '01/01/2000 00:03:04.20 | 946702984.2 | 437.602 | 698.103 | 95.606 | 1891.5959 | 1795.53 | 77.498 | 23.315 |
| 610 | '01/01/2000 00:03:04.68 | 946702984.7 | 436.835 | 698.482 | 95.583 | 1890.951 | 1793.454 | 77.767 | 17.667 |
| 611 | '01/01/2000 00:03:05.17 | 946702985.2 | 435.494 | 698.465 | 95.575 | 1892.074 | 1790.512 | 78.036 | 38.375 |
| 612 | '01/01/2000 00:03:05.66 | 946702985.7 | 435.654 | 698.103 | 95.591 | 1894.176 | 1781.514 | 78.304 | 34.61 |
| 613 | '01/01/2000 00:03:06.15 | 946702986.2 | 436.643 | 698.137 | 95.599 | 1894.5 | 1779.437 | 78.842 | 59.084 |

Figure No. 2: ADAS data extract (first row of airborne data highlighted)

The engine and propeller parameters (fuel flow (Wf), Inter-Turbine Temperature (ITT) engine speed (Ng), torque, propeller speed (Np)), and the aircraft's altitude and airspeed from take-off until the end of the recording, with reference to the ADAS '*Time Actual*' are shown in graphical form in **Figure No. 3**.

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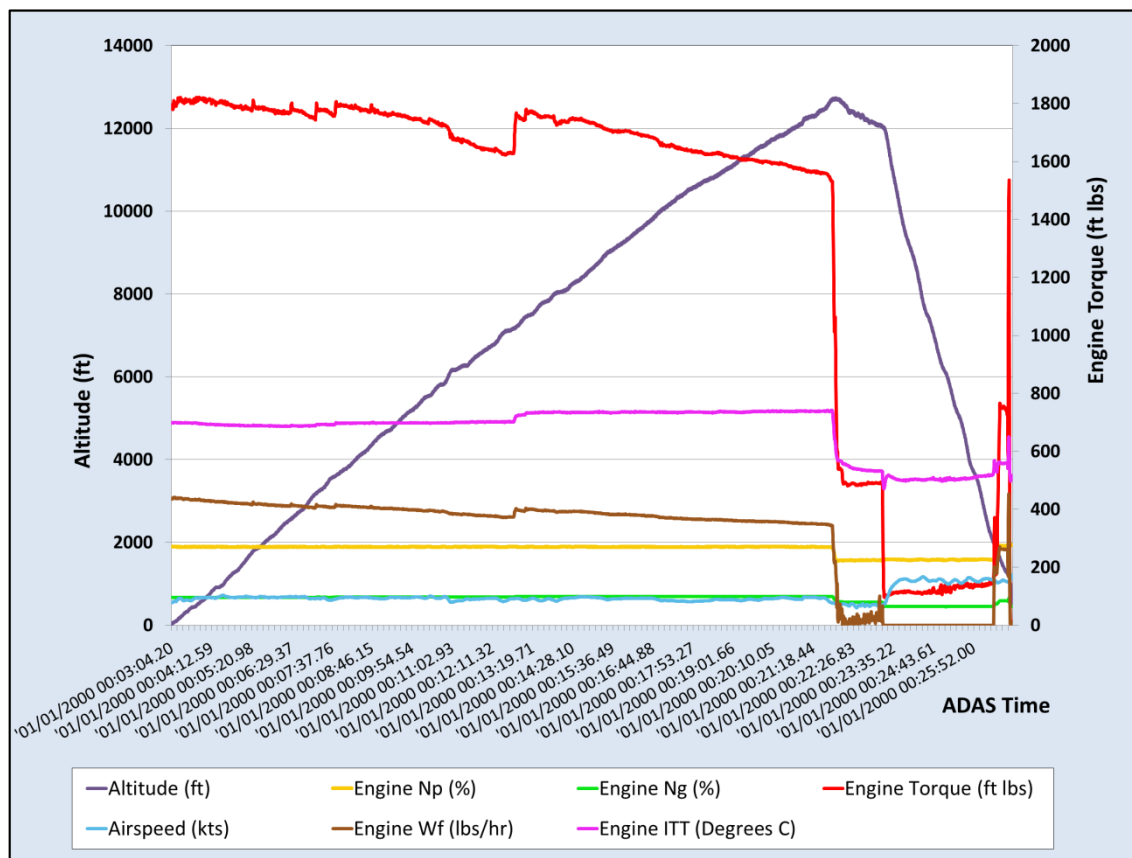


Figure No. 3: ADAS data extract from take-off until end of recording

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Later in the flight, at a 'Time Actual' of 00:21:51.65, when the aircraft was at a recorded altitude of 12,725 ft (as indicated by the ADAS data), the fuel flow and associated engine parameters started to reduce. The Ng at this stage was 97.5%. The maximum altitude recorded by the ADAS unit was 12,736 ft at a 'Time Actual' of 00:21:56.54, although several values close to this value were recorded around this time. The aircraft's altitude only decreased by approximately 725 ft over the next one minute and 21 seconds. The 'Time Actual' was 00:23:17.14 at that stage. The recorded altitude was 12,007 ft, the airspeed was approximately 70 kts, and the Ng was 74.9%. The data indicates that the recorded fuel flow then reduced to zero (the Engine Manufacturer advised that below 70%-75% Ng, fuel flow may not be recorded). The associated engine parameters then reduced further and the rate of descent increased. The recorded airspeed also increased, reaching 166 kts at approximately 7,900 ft (column highlighted in blue in **Figure No. 4**).

| | A | B | C | D | E | F | G | H | I |
|------|-------------------------|-------------|--------------------|-----------------|---------------|-----------------|------------------------|----------------|---------------|
| | Time Actual | Time Value | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Engine Torque (ft lbs) | Airspeed (kts) | Altitude (ft) |
| 1 | | | | | | | | | |
| 3228 | '01/01/2000 00:24:23.58 | 946704263.6 | 0 | 501.558 | 64.109 | 1587.127 | 107.911 | 165.485 | 7909.7261 |
| 3229 | '01/01/2000 00:24:24.07 | 946704264.1 | 0 | 502.432 | 64.12 | 1588.7159 | 107.565 | 166.361 | 7902.5298 |
| 3230 | '01/01/2000 00:24:24.55 | 946704264.6 | 0 | 501.304 | 64.13 | 1588.944 | 108.085 | 166.236 | 7842.5679 |
| 3231 | '01/01/2000 00:24:25.04 | 946704265 | 0 | 501.338 | 64.137 | 1587.244 | 109.642 | 166.986 | 7837.772 |
| 3232 | '01/01/2000 00:24:25.53 | 946704265.5 | 0 | 502.279 | 64.155 | 1585.207 | 111.026 | 166.611 | 7778.126 |
| 3233 | '01/01/2000 00:24:26.02 | 946704266 | 0 | 500.604 | 64.18 | 1582.4969 | 112.584 | 166.736 | 7780.4878 |
| 3234 | '01/01/2000 00:24:26.51 | 946704266.5 | 0 | 501.042 | 64.187 | 1579.802 | 113.449 | 166.111 | 7728.4941 |
| 3235 | '01/01/2000 00:24:27.00 | 946704267 | 0 | 501.32 | 64.187 | 1576.103 | 111.892 | 165.986 | 7733.2212 |
| 3236 | '01/01/2000 00:24:27.48 | 946704267.5 | 0 | 501.336 | 64.162 | 1575.88 | 112.93 | 164.985 | 7683.5879 |
| 3237 | '01/01/2000 00:24:27.97 | 946704268 | 0 | 500.58 | 64.123 | 1575.88 | 114.488 | 164.61 | 7685.9521 |

Figure No. 4: Extract of ADAS parameters at approximately 7,900 ft (airspeed highlighted)



The ADAS data indicated that the Ng remained at approximately 65% throughout this part of the descent. The engine's ITT, which would also give an indication of fuel flow and hence the position of the power lever in the cockpit, remained at approximately 500°C (compared to approximately 700° C at take-off) throughout this part of the descent. The torque values recorded ranged from 96 ft lbs to 152 ft lbs. When the recorded altitude reached 1985.7 ft, the fuel flow, having been at zero throughout the descent, increased (row highlighted in blue in **Figure No. 5**). Approximately 2.5 seconds later, the propeller speed (Np) started to increase from the speed it had been throughout the descent (approximately 1,600 rpm), and two seconds later had increased to over 1,900 rpm (row highlighted in purple in **Figure No. 5**). The ADAS unit recorded for a further 27 seconds approximately.

| | A | B | C | D | E | F | G | H | I |
|------|-------------------------|-------------|--------------------|-----------------|---------------|-----------------|------------------------|----------------|---------------|
| 1 | Time Actual | Time Value | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Engine Torque (ft/lbs) | Airspeed (kts) | Altitude (ft) |
| 3478 | '01/01/2000 00:26:25.70 | 946704385.7 | 0 | 528.666 | 65.139 | 1578.342 | 169.173 | 153.557 | 1981.731 |
| 3479 | '01/01/2000 00:26:26.19 | 946704386.2 | 153.873 | 549.784 | 66.822 | 1587.272 | 206.033 | 153.42 | 1985.717 |
| 3480 | '01/01/2000 00:26:26.68 | 946704386.7 | 201.056 | 566.533 | 68.79 | 1594.3051 | 298.444 | 152.738 | 1953.827 |
| 3481 | '01/01/2000 00:26:27.17 | 946704387.2 | 200.248 | 568.711 | 71.663 | 1591.124 | 352.09 | 152.738 | 1955.819 |
| 3482 | '01/01/2000 00:26:27.66 | 946704387.7 | 190.148 | 560.465 | 72.684 | 1584.202 | 370.953 | 152.328 | 1919.944 |
| 3483 | '01/01/2000 00:26:28.14 | 946704388.1 | 179.622 | 550.939 | 72.772 | 1587.728 | 339.457 | 152.601 | 1919.944 |
| 3484 | '01/01/2000 00:26:28.63 | 946704388.6 | 179.937 | 544.001 | 72.582 | 1629.964 | 264.525 | 152.055 | 1882.075 |
| 3485 | '01/01/2000 00:26:29.12 | 946704389.1 | 181.121 | 541.499 | 72.501 | 1721.113 | 246.354 | 152.192 | 1884.069 |
| 3486 | '01/01/2000 00:26:29.61 | 946704389.6 | 180.723 | 535.005 | 72.488 | 1762.442 | 220.916 | 151.237 | 1848.193 |
| 3487 | '01/01/2000 00:26:30.10 | 946704390.1 | 180.298 | 533.452 | 72.546 | 1861.072 | 173.326 | 150.691 | 1846.2 |
| 3488 | '01/01/2000 00:26:30.59 | 946704390.6 | 178.899 | 531.536 | 72.596 | 1922.29 | 198.419 | 149.189 | 1810.324 |

Figure No. 5: Extract of ADAS parameters showing fuel flow and Np increase

The recorded fuel flow at 1,500 ft (row highlighted in blue in **Figure No. 6**) was 262 lbs/hr ('Time Actual' of 00:26:39.38, and approximately 18 seconds before the end of the recording). The ITT had increased to 557°C and the Ng had increased to 84%. The torque recorded at this stage was 750 ft lbs. The airspeed was recorded as approximately 153 kts.

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| | A | B | C | D | E | F | G | H | I |
|------|-------------------------|-------------|--------------------|-----------------|---------------|-----------------|------------------------|----------------|---------------|
| 1 | Time Actual | Time Value | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Engine Torque (ft lbs) | Airspeed (kts) | Altitude (ft) |
| 3503 | '01/01/2000 00:26:37.91 | 946704397.9 | 262.627 | 558.472 | 83.996 | 1914.0649 | 749.94 | 151.1 | 1571.042 |
| 3504 | '01/01/2000 00:26:38.40 | 946704398.4 | 262.376 | 558.513 | 83.996 | 1917.365 | 748.21 | 151.237 | 1535.584 |
| 3505 | '01/01/2000 00:26:38.89 | 946704398.9 | 262.259 | 558.714 | 84.026 | 1920.347 | 750.633 | 152.328 | 1533.614 |
| 3506 | '01/01/2000 00:26:39.38 | 946704399.4 | 262.304 | 557.947 | 84.026 | 1920.016 | 750.979 | 152.874 | 1500.127 |
| 3507 | '01/01/2000 00:26:39.87 | 946704399.9 | 262.074 | 558.51 | 84.008 | 1920.51 | 747.518 | 154.103 | 1498.157 |
| 3508 | '01/01/2000 00:26:40.36 | 946704400.4 | 262.235 | 558.081 | 84.002 | 1918.035 | 752.363 | 154.785 | 1468.609 |

Figure No. 6: Extract of ADAS parameters at approximately 1,500 ft

Approximately 11 seconds later (highlighted in amber in **Figure No. 7**, which includes an extract of the final 11 seconds of recorded data), at a 'Time Actual' of 00:26:50.62, which was approximately seven seconds before the end of the recording, the Ng had reduced to 81.7% and the torque had reduced to 573 ft lbs. The altitude, as recorded by the ADAS unit, was 1,221 ft at this stage. The airspeed recorded was 149 kts. Approximately 1.5 seconds later (highlighted in purple in **Figure No. 7**), the recorded altitude was 1,161 ft. The Ng had increased to 93.8% and the torque had increased to 1,535 ft lbs. The fuel flow increased to 452 lbs/hr during the period, before starting to reduce. The airspeed recorded was 150 kts.

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Approximately two seconds later (highlighted in pink in **Figure No. 7**), at the commencement of the final 3.5 seconds approximately of the recording, the Ng had reduced to 71.9%, while the torque had reduced to 53 ft lbs. The recorded altitude at this stage was 1,028 ft. The airspeed recorded was 155 kts. During the subsequent 3.5 seconds approximately, the Ng reduced to 65% approximately, the torque values became negative and the Np increased. The recorded airspeed also increased to 174 kts. The final 'Time Actual' recorded was 00:26:57.45 (coinciding with 'Time Value' of 946704417.45). This was approximately 23 minutes and 54 seconds after take-off. The final altitude recorded was 529 ft approximately.

The data from the ADAS unit indicates that, on the accident flight, G-KNYS operated between 10,000 ft and 13,000 ft for a period of less than seven minutes and never exceeded 13,000 ft (this is relevant to the requirements regarding the use of supplemental oxygen – see **Section 1.17.2.4** and **Section 2.8.3**).

| | A | B | C | D | E | F | G | H | I |
|------|-------------------------|-------------|--------------------|-----------------|---------------|-----------------|------------------------|----------------|---------------|
| 1 | Time Actual | Time Value | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Engine Torque (ft lbs) | Airspeed (kts) | Altitude (ft) |
| 3520 | '01/01/2000 00:26:46.22 | 946704406.2 | 261.292 | 559.296 | 83.99 | 1914.557 | 743.538 | 152.192 | 1299.6331 |
| 3521 | '01/01/2000 00:26:46.71 | 946704406.7 | 261.178 | 558.946 | 84.008 | 1915.877 | 743.538 | 151.646 | 1305.474 |
| 3522 | '01/01/2000 00:26:47.20 | 946704407.2 | 260.79 | 559.642 | 83.996 | 1916.868 | 740.423 | 150.554 | 1284.0551 |
| 3523 | '01/01/2000 00:26:47.68 | 946704407.7 | 260.721 | 560.053 | 83.978 | 1917.6949 | 739.384 | 150.281 | 1287.95 |
| 3524 | '01/01/2000 00:26:48.17 | 946704408.2 | 260.698 | 560.169 | 83.978 | 1913.417 | 741.807 | 150.145 | 1264.583 |
| 3525 | '01/01/2000 00:26:48.66 | 946704408.7 | 261.018 | 560.019 | 83.966 | 1915.9041 | 731.078 | 150.281 | 1272.371 |
| 3526 | '01/01/2000 00:26:49.15 | 946704409.2 | 260.676 | 560.19 | 83.96 | 1922.34 | 723.117 | 149.735 | 1243.163 |
| 3527 | '01/01/2000 00:26:49.64 | 946704409.6 | 253.148 | 560.279 | 83.924 | 1921.673 | 727.444 | 149.735 | 1247.059 |
| 3528 | '01/01/2000 00:26:50.13 | 946704410.1 | 217.018 | 541.276 | 82.999 | 1912.168 | 597.653 | 149.326 | 1221.745 |
| 3529 | '01/01/2000 00:26:50.62 | 946704410.6 | 169.452 | 573.702 | 81.75 | 1923.629 | 573.945 | 149.189 | 1221.745 |
| 3530 | '01/01/2000 00:26:51.10 | 946704411.1 | 367.657 | 625.148 | 84.687 | 1930.364 | 1082.204 | 148.78 | 1190.59 |
| 3531 | '01/01/2000 00:26:51.59 | 946704411.6 | 452.262 | 650.188 | 91.788 | 1929.134 | 1475.208 | 149.735 | 1194.484 |
| 3532 | '01/01/2000 00:26:52.08 | 946704412.1 | 401.01 | 645.073 | 93.823 | 1925.574 | 1535.604 | 150.008 | 1161.382 |
| 3533 | '01/01/2000 00:26:52.57 | 946704412.6 | 372.488 | 601.136 | 89.517 | 1892.062 | 1146.58 | 151.1 | 1153.593 |
| 3534 | '01/01/2000 00:26:53.06 | 946704413.1 | 168.26 | 561.827 | 83.748 | 1901.231 | 463.364 | 152.738 | 1114.649 |
| 3535 | '01/01/2000 00:26:53.55 | 946704413.6 | 147.803 | 529.965 | 76.252 | 1921.866 | 241.855 | 154.376 | 1093.23 |
| 3536 | '01/01/2000 00:26:54.03 | 946704414 | 6.188 | 505.403 | 71.925 | 1919.53 | 53.4 | 155.331 | 1028.973 |
| 3537 | '01/01/2000 00:26:54.52 | 946704414.5 | 2.997 | 496.258 | 67.225 | 1934.759 | -2.669 | 157.924 | 991.976 |
| 3538 | '01/01/2000 00:26:55.01 | 946704415 | 5.993 | 498.884 | 65.823 | 1941.9871 | -6.995 | 159.732 | 916.389 |
| 3539 | '01/01/2000 00:26:55.50 | 946704415.5 | 2.997 | 503.198 | 65.192 | 1940.457 | -0.073 | 161.858 | 864.411 |
| 3540 | '01/01/2000 00:26:55.99 | 946704416 | 0 | 508.141 | 65.075 | 1937.75 | -0.765 | 164.36 | 775.856 |
| 3541 | '01/01/2000 00:26:56.48 | 946704416.5 | 8.504 | 512.325 | 65.039 | 1942.854 | -5.092 | 167.612 | 714.252 |
| 3542 | '01/01/2000 00:26:56.97 | 946704417 | 9.857 | 515.86 | 65.09 | 1946.58 | 2.176 | 170.613 | 610.296 |
| 3543 | '01/01/2000 00:26:57.45 | 946704417.5 | 2.706 | 517.063 | 65.191 | 1936.095 | 12.213 | 174.246 | 529.808 |

Figure No. 7: ADAS data extract (final 11 seconds approximately)



An extract of the parameters recorded during the descent phase of flight is shown in graphical form in **Figure No. 8**.

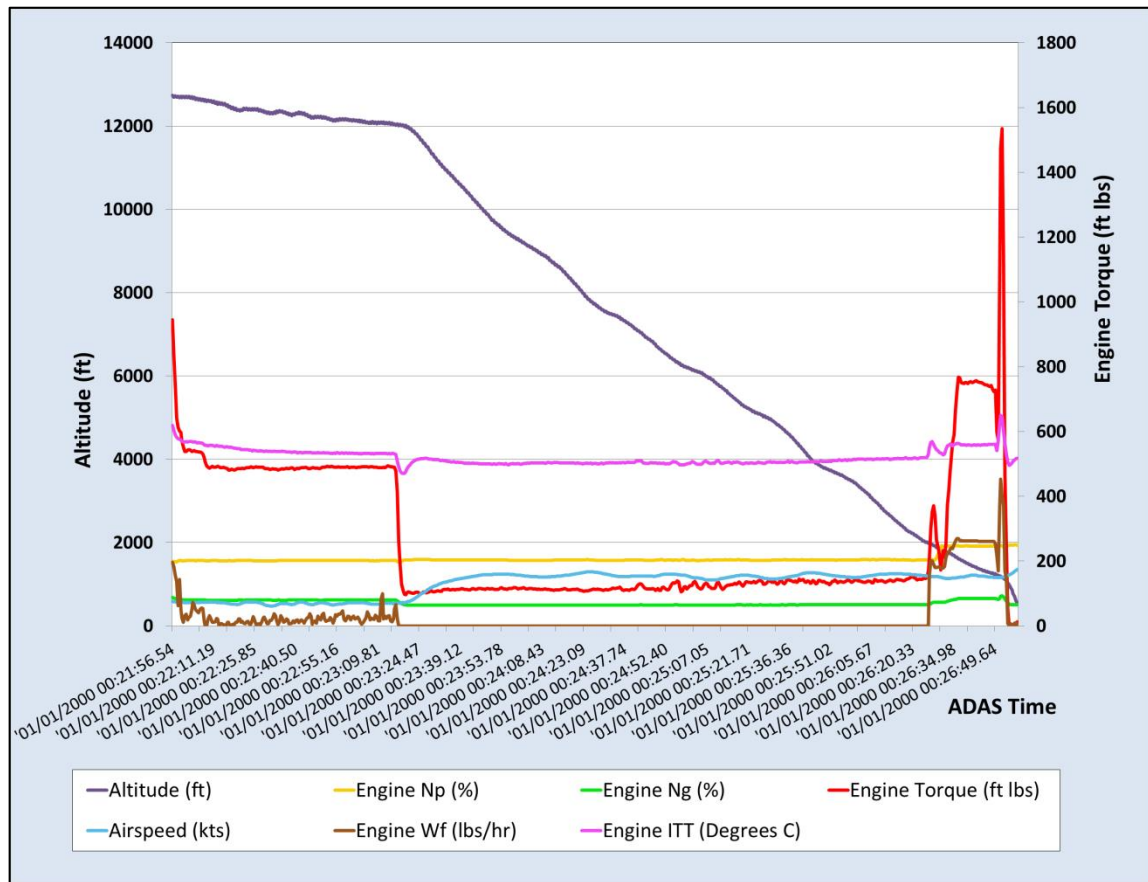


Figure No. 8: ADAS data extract from descent phase until end of recording

1.11.2 Aircraft Avionics

The Aircraft Manufacturer advised that [apart from the ADAS] none of the avionic units fitted to the aircraft recorded flight data.

1.11.3 Portable Satellite Navigation System

The Investigation noted that one of the skydivers' videos recorded during the accident flight shows a portable GPS navigation unit installed above the cockpit instrument panel in front of the Pilot. Such devices are usually capable of recording an aircraft's flight path. However, recordings may occasionally be unavailable, either due to device settings or accident-related damage. Extensive excavation using a mechanical digger was required to facilitate the recovery of the aircraft wreckage at the accident site. This resulted in the removal of a large volume of peaty soil. The existence of a GPS navigation unit was not known at this time. However, all removed soil was 'graded' by the digger, visually examined, and where necessary, searched by hand for aircraft debris during back-filling of the excavated hole. A GPS navigation unit (or part thereof) was not found at the accident site or in subsequent detailed examination of the entire aircraft wreckage at the AAU's examination facility, which included manually sifting through the substantial quantity of soil that was present in the recovered wreckage.

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1.11.4 ATC Radar

Several ground-based radar heads are located throughout the country and provide primary and secondary radar data for ATC purposes. Primary radar functions by transmitting a radio signal and analysing the reflection from an object such as an aircraft, to establish the aircraft's range and bearing from the radar antenna. Secondary radar interrogates an aircraft's transponder to identify the aircraft and determine its altitude referenced to ISA¹⁵.

The information from several radar heads is automatically combined and processed by ATC systems before being displayed on the controller's screen. At altitudes up to 5,000 ft, the altitude is adjusted for the air pressure on the day (QNH) before being displayed. At altitudes above 5,000 ft, the altitude is referenced to 1013.2 hPa. The data is refreshed every five seconds approximately. Radar tracks are such that when a valid signal is no longer received, the data will show a calculated '*coasted track*' for a number of seconds, indicating the predicted position of the aircraft, prior to the aircraft track no longer being displayed.

ATC provided the Investigation with the combined radar data for the accident flight; this had been adjusted by ATC tracker software for the air pressure on the day. Due to the location of the aircraft relative to the radar heads, the aircraft was only detected above a certain altitude. The data obtained included the aircraft's position, heading, ground speed, altitude and vertical speed and was used by the Investigation to plot the path of the accident flight from when the aircraft was first detected by radar until it was last detected.

The flight path of the accident flight, as extracted from the combined radar data, is shown by the white line in **Figure No. 9**. ATC Radar first detected the aircraft just after 13.15 hrs, as it climbed to the north-west after take-off from EICL. The combined radar data indicates that the aircraft was at approximately 1,275 ft at this stage. The data indicates that the aircraft performed a series of turns while climbing until it reached overhead EICL, where it performed an orbital turn to the right while continuing to climb. The combined radar data indicates that the maximum altitude reached was 12,975 ft at time 13:32:37, when the aircraft was approximately 0.15 NM (0.28 km) north of the threshold of RWY 27 at EICL.

The combined radar data indicates that the aircraft then passed overhead the runway in a south-westerly direction, descending by only 50 ft over the next 15 seconds. According to the data, the aircraft continued to slowly descend (600 ft per minute approximately) when travelling to the south-west. At time 13:34:12, when the aircraft was at an altitude of 12,125 ft approximately, it commenced a descending right-hand turn. This continued for around one minute, until the aircraft was on a northerly heading at an altitude of approximately 7,675 ft, which it reached at time 13:35:17; the descent rate based on the radar data was 4,107 feet per minute (ft/min) in that period.

The aircraft maintained a northerly heading for approximately 3.4 NM (1 minute and 15 seconds), while descending to an altitude of approximately 4,125 ft (as recorded by radar), which it reached at time 13:36:32. The aircraft then performed a left-hand turn, taking it over the wind farm, while it continued to descend, before taking up a straight south-easterly track at time 13:37:07, back in the general direction of EICL. The aircraft's altitude at this stage was approximately 2,225 ft.

¹⁵ **ISA (International Standard Atmosphere):** Sea level pressure/temperature of 1013.2 hectopascals (29.92 inches of mercury) and 15°C (59°F).



The last valid (non-coasted) radar return was received at time 13:37:32, when the aircraft was approximately 2.3 NM (4.26 km) to the north-west of the threshold of RWY 09 at EICL. According to the radar data, the aircraft's parameters at that stage were:

- Altitude (corrected by ATC software for the air pressure on the day): 1,350 ft
- Ground speed: 160.1 kts (ATC radar data indicates that this had been increasing over the previous 20 seconds; the Investigation calculated its average value during the 20 second period, based on the radar indicated values, as 150 kts)
- Heading: 119 degrees magnetic
- Descent rate: 2,125 ft/min

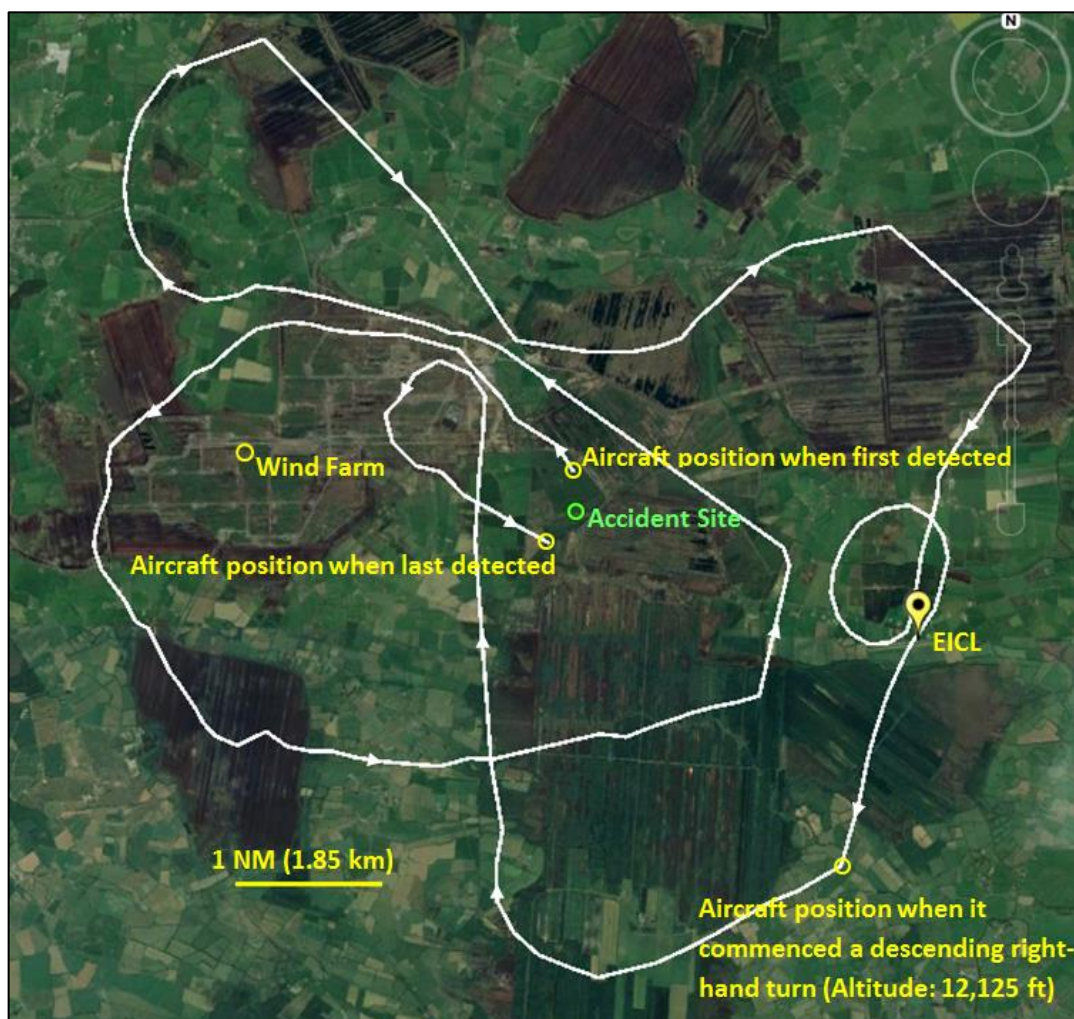


Figure No. 9: Aircraft track extracted from radar data (adapted from *Google Earth*)

ATC also provided (in spreadsheet format) the altitude data acquired solely from a Dublin-based radar head. This altitude data was recorded at four second intervals and had not been corrected for the air pressure on the day. The maximum altitude recorded by the Dublin-based radar head was 12,900 ft. The Investigation adjusted this altitude data, which was recorded in 100 ft increments¹⁶, for the air pressure on the day and compared it to the altitude data obtained from the ADAS unit (**Section 2.5.2**).

¹⁶ This increment is a function of the aircraft's transponder.

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1.11.5 Open-Source Aircraft Tracking

Open-source aircraft tracking data was available for the accident flight. However, it provided no further useful information than that provided by the ATC data.

1.11.6 Pilot's Mobile Phone

Certain mobile phone applications (Apps) designed for use by aircraft pilots, have the ability to log flight data. Such data can be useful from an accident investigation perspective.

The Pilot's mobile phone was recovered at the accident site. Due to the extent of the damage sustained by the phone as a result of the accident, the Investigation requested the assistance of the UK Air Accidents Investigation Branch (AAIB). Because of the nature of the damage, the UK AAIB sent the phone to a UK-based data recovery specialist. The data recovery specialist repaired the phone's motherboard and operating system. However, no data could be obtained from the device.

1.11.7 Skydivers' Cameras

Several of the skydivers were wearing helmet cameras which video-recorded their jumps. One of the videos was recorded by a skydiver who was one of the last to exit the aircraft. The video, which is of approximately five minutes duration, shows the skydiver's entire jump, including the exit from the aircraft, freefall, piloting of the canopy (parachute) and landing.

As the skydiver descended from the south, along a line approximately perpendicular to the runway, the skydiver's camera mainly pointed towards the landing zone at EICL. Approximately three minutes and 48 seconds after the skydiver exited the aircraft, which was approximately 30 seconds before the skydiver landed, the camera briefly pointed towards the north-west. At this time, the video recorded what appeared to be the aircraft for less than one second, as it descended into a line of trees in the distance at a location consistent with the accident location. The skydiver only became aware of this content some days after the accident and immediately contacted the Investigation. A still image extracted from this video is shown in **Figure No. 10**.

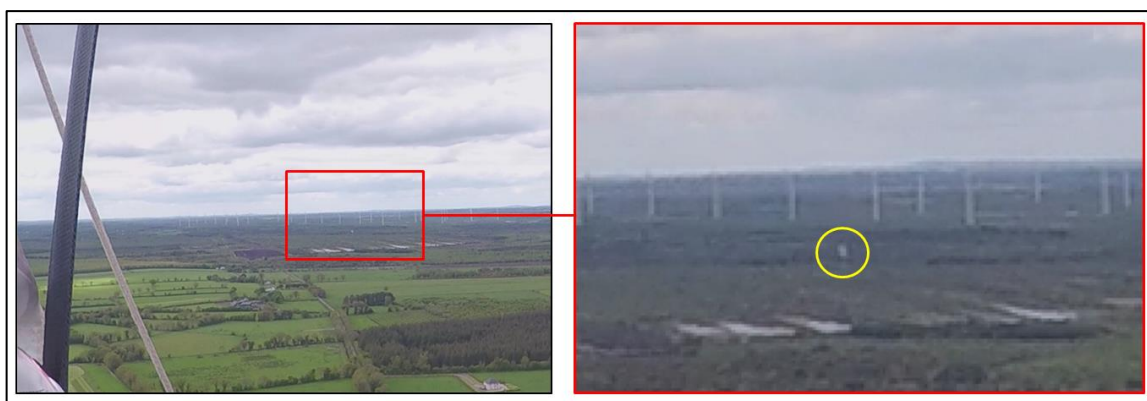


Figure No. 10: Still image (left) as extracted from Skydiver's video. The right-hand image was zoomed from this still image with what appears to be the aircraft circled in yellow



In the two minutes before this, the same video intermittently shows two other skydivers descending with their parachutes deployed. One of these was further to the north-west at approximately the same altitude; the other was approaching the landing zone from the east, at a lower altitude.

The videos recorded by the other skydivers show the aircraft as the skydivers were about to jump and also in the moments after they jumped. The videos also show that the Pilot was wearing sunglasses. The aircraft's trailing edge flaps can be seen in a partially extended configuration. The videos indicate that all flight control surfaces were present and that the aircraft was flying normally at that time.

One of the skydivers' videos from the day before the accident showed the cockpit-mounted annunciator panel with what was established to be the red *FUEL SELECT OFF* warning light illuminated and the amber *LEFT FUEL LOW* caution light illuminating briefly (left image in **Figure No. 11**). The video also shows the overhead fuel tank selector panel with the left-hand fuel tank selected to the *OFF* position (right image in **Figure No. 11**). Neither the annunciator panel nor the fuel selector panel were visible in the videos from the accident flight.

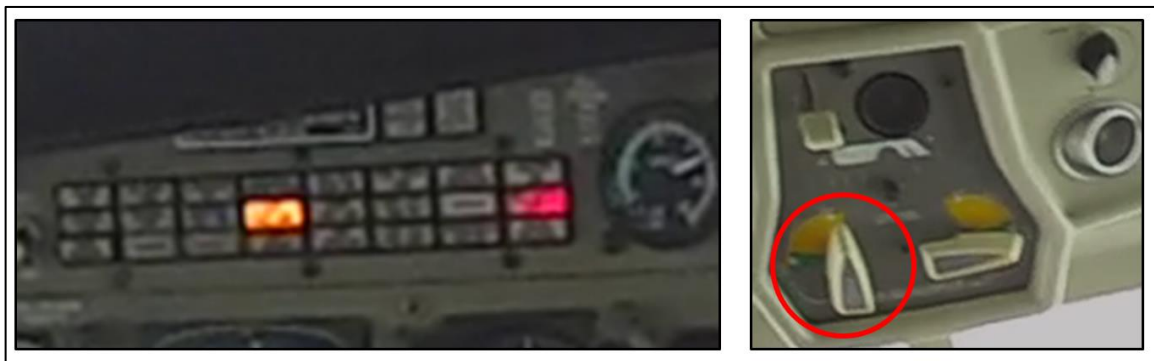


Figure No. 11: Annunciator panel and fuel selector panel in flight on the day before the accident. Left tank selector OFF (circled)

Photographs provided by a skydiver that were taken on board the aircraft on other flights at the Club showed the fuel selector panel and the annunciator panel. One photograph showed both fuel tanks selected to ON and the *LEFT FUEL LOW* caution light illuminated. Another photograph showed the left fuel tank selected to OFF and the *LEFT FUEL LOW*, *RIGHT FUEL LOW* and *FUEL SELECT OFF* lights illuminated.

Post-accident examination of the annunciator panel and the fuel selector panel is described in **Section 1.12.3.3**.

1.11.8 Closed Circuit Television Recordings

The Investigation obtained CCTV recordings from security systems installed at a wind farm and at a construction training facility, both located to the north-west of the accident site. There was no recording of the accident aircraft in the videos obtained from the construction training facility's CCTV system, which was configured for security monitoring of the facility and its associated buildings.

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The CCTV system at the wind farm was similarly configured; however, two of the system's (fixed) cameras, which were pointing approximately to the south-east of the wind farm, showed the aircraft in flight. One of these cameras was located at the maintenance and administration buildings within the wind farm complex, and was pointing towards another building. The upper image in **Figure No. 12** shows the field of view of this camera, the upper third of which is of the sky. The lower image in the figure shows the upper left-hand section of the camera's field of view in greater magnification. The aircraft (circled in red) was visible in this section for approximately five seconds, travelling diagonally from the upper edge of the field of view towards its left-hand edge. The video did not contain sufficient detail to permit further analysis. **Note:** It was subsequently established that the camera system's clock was not displaying the correct time.

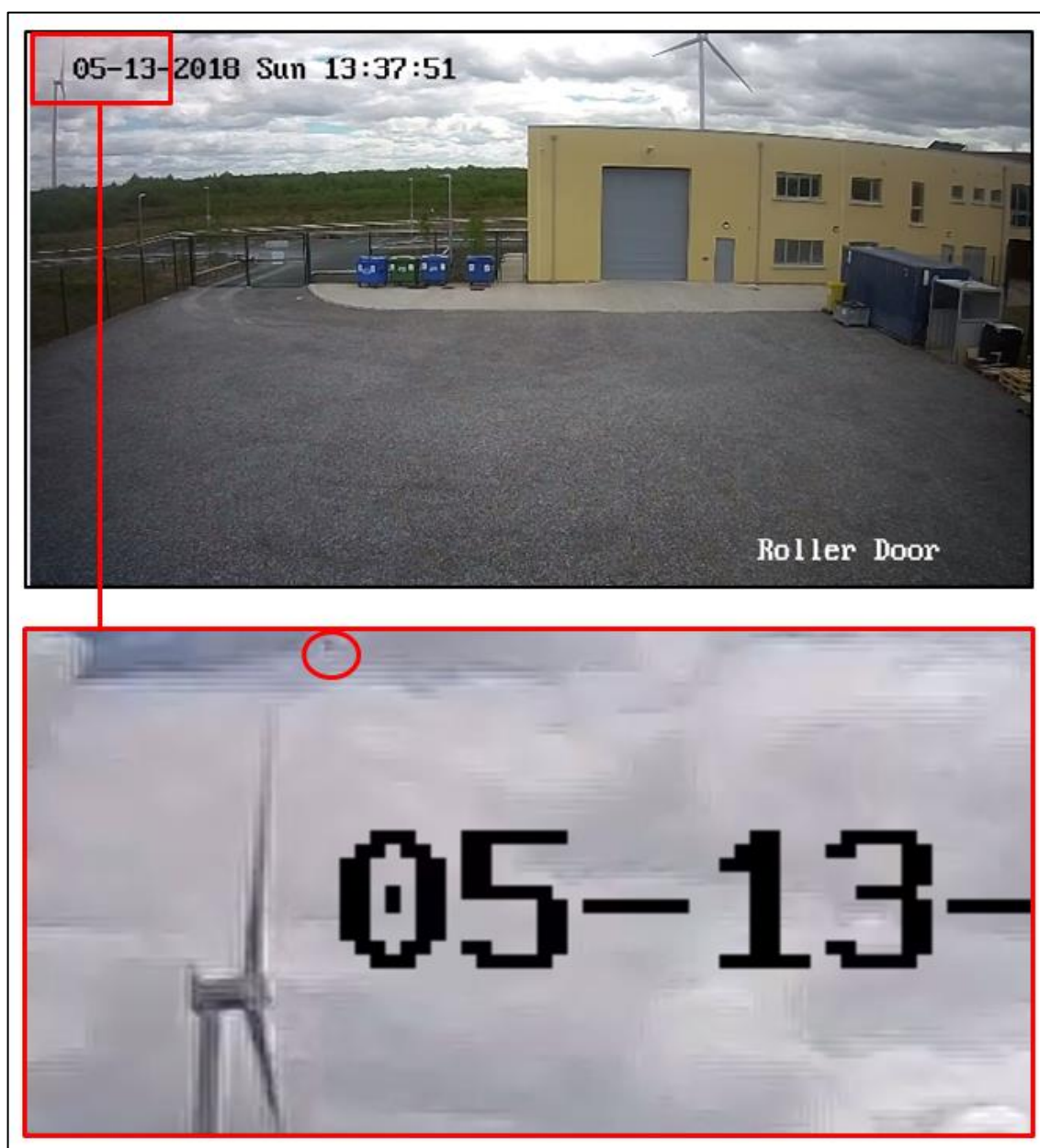


Figure No. 12: Field of view of camera located within wind farm complex (upper image). The lower image shows upper left-hand corner magnified, with the aircraft circled in red



The other camera which recorded the aircraft was mounted on a security hut located just outside the wind farm complex. This camera was approximately 0.7 NM (1.3 km) to the north-east of the camera located within the complex and approximately 1.2 NM (2.2 km) north-west of the accident site. The upper image in **Figure No. 13** shows the field of view of this camera. The sky is visible in the upper right-hand corner; the lower image shows this section in greater magnification, just as the aircraft entered the camera's field of view. The aircraft (circled in red) was visible in this section for approximately 11 seconds. During the first 7.5 seconds approximately, the aircraft can be seen flying towards the upper edge of the field of view, following what appears to be a normal trajectory. In the final 3.5 seconds approximately, the aircraft can be seen rapidly losing altitude and travelling towards a line of trees in what appears to be a near-vertical (nose-down) attitude.



Figure No. 13: Field of view of camera located on security hut (upper image). The lower image shows upper right-hand corner magnified, with aircraft circled in red

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The upper image in **Figure No. 14** was also extracted from the CCTV recording and shows the aircraft (circled in red) just before it rapidly lost altitude. The lower image in the figure shows the aircraft before it disappeared below the line of trees in what appeared to be a near-vertical (nose-down) attitude. However, at this stage, there appears to be some degree of motion back in the direction from where the aircraft had been travelling in the earlier part of the recording. Also at this stage, one of the aircraft's wings appears to be lower than the other. This CCTV recording was subsequently analysed with the assistance of the NTSB (**Section 1.16**).



Figure No. 14: Aircraft (circled in red) just before it rapidly lost altitude (upper image). The lower image shows the aircraft in what appeared to be a near-vertical descent

1.12 Wreckage and Impact Information

1.12.1 Initial Observations

The aircraft impacted into a forested peat bog, approximately 2.5 NM (4.6 km) to the north-west of the departure airfield.



The accident site was compact. Only trees immediately adjacent to the aircraft wreckage were damaged. The compact nature of the site is apparent in video recorded from above the accident site by an Irish Coast Guard Search and Rescue helicopter, which was responding to the accident. A still image extracted from this video is shown in **Figure No. 15**. The accident site's height above sea level was approximately 230 ft.



Figure No. 15: Still image extracted from video recorded by a responding Search and Rescue helicopter. Accident site circled (*Irish Coast Guard*)

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The impact was such that the entire front section of the aircraft, forward of the main wheels, was submerged below the surface of the bog (**Photo No. 3** and **Photo No. 4**). On the aircraft type, this section is approximately 4.8 m in length. The aft fuselage, wings and tail section were above ground. The wreckage above ground was lying towards its left-hand side and generally angled back towards the north-east. The lower (underside) surface of the fuselage, on which the fixed main landing gear was mounted, was pointing towards the north-west (310° magnetic approximately). This was towards the CCTV camera located at the wind farm security hut (**Section 1.11.8**).



Photo No. 3 and Photo No. 4: Aircraft as found at accident site

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All flight control surfaces were present. The aircraft's wings were almost fully detached at the wing roots; the right-hand wing had broken forwards¹⁷, with the wing tip pointing towards 235° magnetic. The right-hand wing had sustained substantial compressive damage to its forward section, along its entire length.

The left wing was lying rearwards, with the wing tip pointing towards 060° magnetic. The outer section of the wing's leading edge was wedged against the trunk of a tree. This tree, the top of which was missing, was leaning towards the main wreckage. The forward section of the wing sustained substantial compressive damage along its entire length. The damage was greater than that sustained by the right wing and was more severe towards the outer section of the wing. Due to the damage sustained to both wings, it was not possible to positively establish the position of the trailing edge flaps at the accident site. However, the observed position of the flaps' guide rollers in their tracks indicated some level of extension.

The rear section of the aircraft had broken upwards with respect to the fuselage. This section was almost inverted, but remained loosely attached to the forward section of the aircraft. The lower section of the leading edge of the vertical stabiliser was wedged against a tree. The stabiliser and the rudder were destroyed due to the impact and the tree was partially uprooted; the roots of the tree were in contact with the upper surface of the inboard section of the left-hand horizontal stabiliser. The inboard upper surface of the right-hand elevator was also in contact with this tree; the trailing edge of the elevator was distorted by the contact. The outer section of the left-hand horizontal stabiliser had sustained substantial impact damage. The upper surface of the trailing edge of the left-hand elevator, at its outboard section, was in firm contact with the trunk of another tree. The right-hand elevator was deflected downwards more than the left-hand elevator. The trailing edges of the elevator trim tabs were protruding just above the neutral position.

Due to the extent of the damage to the aircraft, it was not possible to verify the continuity of the flight controls from the cockpit section to the wings. The cables in the tail section running towards the rudder and elevator were inspected and were found to be intact.

The tip of an aluminium alloy propeller blade was found on the forest floor, several metres away from the main wreckage.

1.12.2 Recovery Operations

Due to the force of the impact, the entire front section of the aircraft, including the cockpit was below the surface of the bog. This resulted in a level of urgency at the accident site and emergency service personnel initially used shovels to excavate the surrounding soil in an attempt to gain access to the cockpit section and locate the two occupants. With local assistance, this was followed by the use of a mechanical excavator and then by a much larger soft-ground-specific excavator, which required several trees to be felled to permit its access. The two occupants were found within the cockpit section of the aircraft, when it was lifted from the bog at approximately 21.00 hrs, following extensive excavation.

¹⁷ The direction of all damage is referenced to the normal orientation of the aircraft.



The engine and the propeller were also recovered from the excavated area. Part of the propeller's reduction gearbox had fractured from the engine and remained attached to the propeller hub. There were two blades attached to the hub. One of these blades was bent forwards; the other was torn, twisted and bent rearwards (**Photo No. 5**).

The third propeller blade was not located immediately; however, following further significant excavation of the site after the aircraft had been extracted, the remaining propeller blade was found. The tip of this blade was missing; the tip found earlier was identified to be from this particular blade. All recovered wreckage was transported under escort to the AAIU's facility in Gormanston on the day following the accident for detailed examination.



Photo No. 5: Propeller as initially recovered (third blade subsequently recovered)

1.12.3 Aircraft Examination

1.12.3.1 General

Detailed wreckage examination was performed at the AAIU's wreckage examination facility with the assistance of the Aircraft Manufacturer and the UK AAIB. All flight control surfaces were found to be attached. Due to the extent of the damage, continuity of the flight control cables could not be established. The elevator cables were found attached to the forward bell-crank (lever assembly) under the cabin floor and to the aft bell-crank in the tail section. The rod from the aft bell-crank to the elevator torque tubes was intact. The rudder cables were found attached to the rudder bell-crank connected to the base of the rudder. The left and right aileron cables were found attached to the bell-cranks located close to the ailerons. The aileron cables were found to be broken at the wing roots, where the wings had partially separated from the fuselage. The left flap cable remained attached in the wing. The right flap cables were separated at the inboard and outboard bell-cranks.

The flap actuator was found to be extended by approximately 40 millimetres (mm) (**Photo No. 6**). According to data provided by the Manufacturer, this equates to a flap setting of approximately 20°.

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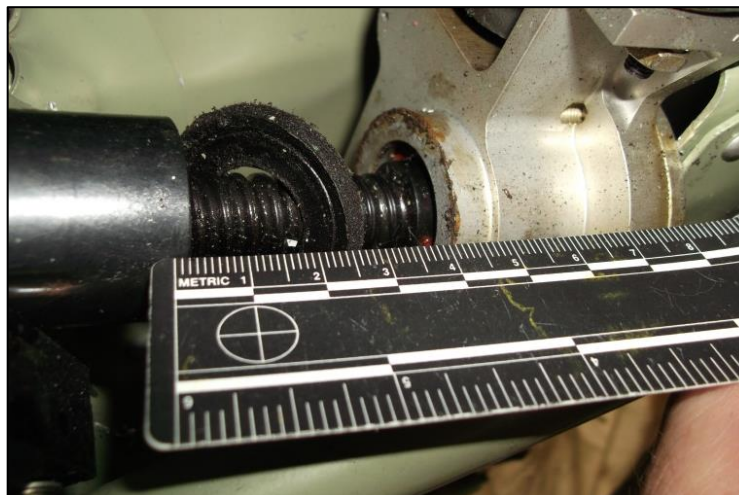


Photo No. 6: Measured extension of flap actuator

1.12.3.2 Elevator Torque Tube

On the aircraft type, the elevator cables from the cockpit are connected to an elevator actuation lever in the aircraft's tail section. This lever actuates the elevators in unison through two inter-connected torque tubes. Each torque tube, which is approximately 180 mm long and 63 mm in diameter, is riveted on one end to an input flange by six 'AD rivets'¹⁸ (diameter 5/32 of an inch) and to the elevator at the other end by further rivets. The input flanges are secured to the actuation lever by three bolts.

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The maintenance inspection requirements for the area are highlighted in a Special Airworthiness Information Bulletin (CE-17-25) published by the FAA on 25 August 2017, which is also available on the EASA website as a Safety Information Bulletin. The Bulletin was published to highlight the potential for corrosion on elevator torque tubes on certain Cessna aircraft and draws attention to the applicable maintenance inspections. The Bulletin states that the following maintenance manual inspection task is applicable to the 208/208B aircraft types (task no. 27-30-00-720, manual revision 33, dated 15 May 2017):

'Examine the elevator hinges, hinge bolts, hinge bearings, torque tube, horn, attach fittings, and bonding jumper for corrosion, cracks, signs of damage, wear, unserviceable fasteners, security, and correct safetying¹⁹'.

The task is to be performed every 600 hours or 24 months. The Maintenance records indicate that task no. 27-30-00-720 was last performed on the aircraft in February 2017. Maintenance Manual Revision 31 was extant at that time and included the examination criteria outlined above.

¹⁸ **AD Rivet:** A rivet made from 2117 aluminium alloy.

¹⁹ **Safetying:** The action of making something (especially aircraft parts) safe or secure.



When the aircraft was examined at the accident site, it was observed that the right-hand elevator was deflected downwards more than the left-hand elevator. When the recovered wreckage was examined further at the AAIU's facility in Gormanston, it was found that each elevator could be moved independently of the other. There was no restriction in their movement; however, on further inspection, it was noted that all rivets securing the right-hand elevator torque tube to the actuation assembly had sheared. The sheared rivets were not loose and no cracks, corrosion, or other defects with the torque tube were evident.

The Investigation removed the right-hand elevator to permit further examination (**Photo No. 7**). The torque tube was removed from the elevator and sent to a metallurgist for detailed analysis.

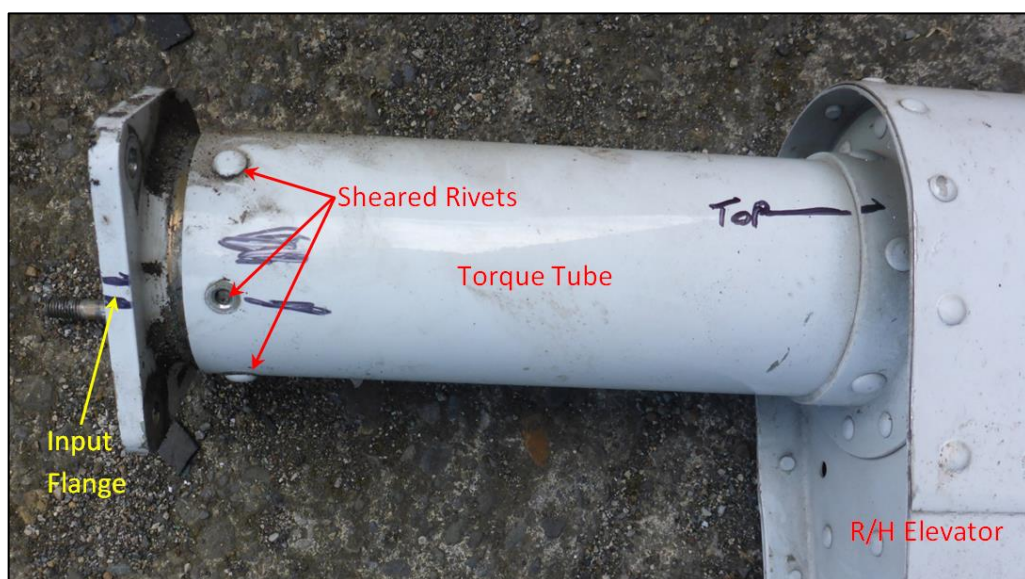


Photo No. 7: R/H Elevator Torque Tube (with elevator removed from aircraft)

Following his analysis, the metallurgist reported the following:

'The appearance of the fracture surfaces [of the rivets] was consistent with instantaneous failure in shear', and that 'there was no evidence of fatigue crack growth'.

The metallurgical examination identified that *'there were both circumferential and axial [force] components to the loading, which caused [the] failure'*. The metallurgist also noted that during the failure, the rivets had been pushed to one side of their corresponding holes. This, coupled with markings on the fracture surfaces, enabled the direction of movement of the input flange, relative to the rivets, to be determined. This is indicated by the yellow arrows in **Figure No. 16**, which shows four views of the input flange. The direction corresponds to the right-hand elevator being moved by external loads in a downward direction relative to a stationary torque tube/left-hand elevator or a torque tube/left-hand elevator exerting an upward input to a stationary or downward-moving right-hand elevator.

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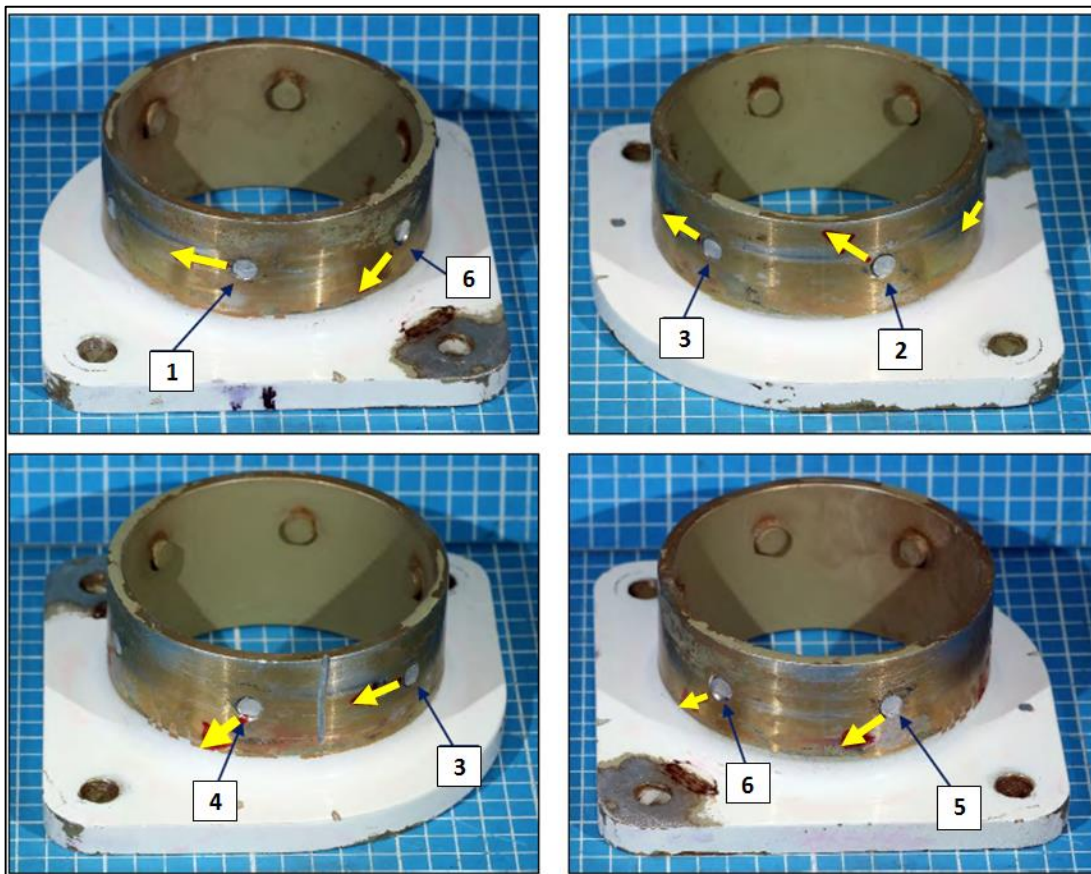


Figure No. 16: Four views of the input flange (with the torque tube removed). Yellow arrows indicate direction of movement of the input flange relative to the rivets (numbered 1-6)

Sheared elevator torque tube rivets were previously observed by the NTSB during their examination of another Cessna 208B aircraft following an accident that occurred in the US in 2014 (NTSB Accident Number ANC14FA022). The probable cause of that accident was deemed to be '[...] *delayed remedial action and initiation of a recovery procedure after a simulated pitch trim excursion, which resulted in a loss of airplane control*'. The wreckage examination noted that '*the left elevator torque tube separated from the center fitting along the rivet line*', that '*all of the examined fractures had a dull, grainy appearance consistent with overload failure*' and that '*there was no evidence of pre-existing corrosion or cracking [...]*'.

1.12.3.3 Fuel Selector Panel, Annunciator Panel and Circuit Breaker Panel

A significant quantity of fuel was present at the accident site. The aircraft's overhead fuel selector panel was destroyed in the accident and the positions of each fuel tank selector could not be determined. The annunciator panel was not visible in the skydivers' videos from the accident flight. During subsequent examination, the Investigation removed the two bulbs from the annunciator panel's *FUEL SELECT OFF* warning light in an attempt to determine whether or not the warning light was on at the time of the accident.

If an impact occurs when a bulb is in a lit state, its (hot) filament may stretch and fail, whereas, if an impact occurs when a bulb in an unlit state, its (cold) filament may remain intact or may shatter or break in an un-stretched condition.



Due to the extent of the damage to the annunciator panel, only one of the bulbs from the *FUEL SELECT OFF* warning light could be examined. The filament in this bulb appeared to have been in an unlit state at the time of impact, as indicated by shattered, un-stretched filament coils.

The Investigation also examined the bulbs in the *LEFT FUEL LOW* and *RIGHT FUEL LOW* caution lights (**Figure No. 17**). The bulbs in *LEFT FUEL LOW* light also appeared to have failed in an unlit state as indicated by broken, un-stretched filament coils. Due to impact damage, the glass was broken in each of the two bulbs from the *RIGHT FUEL LOW* light. The filament from one of the bulbs was missing; however, the filament from the other bulb appeared to have been illuminated at the time of impact, as indicated by the stretched filament coils.

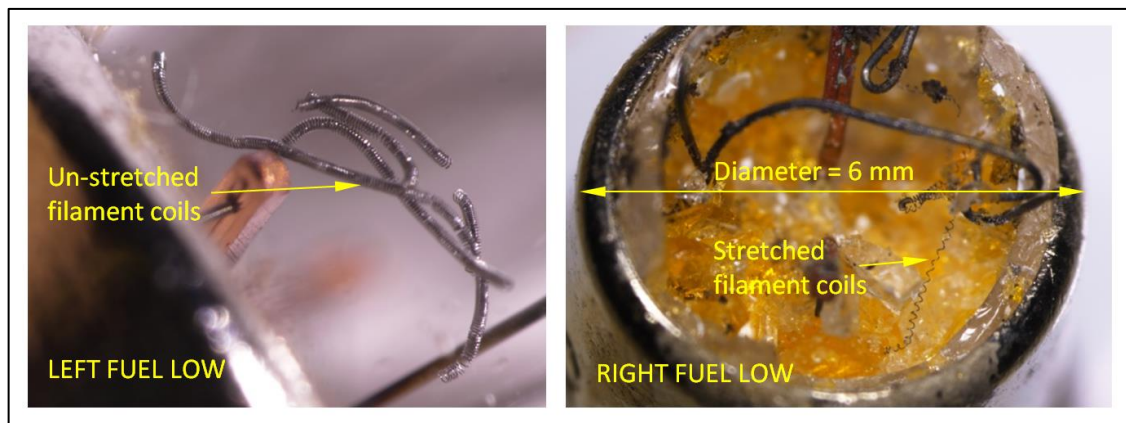


Figure No. 17: Bulbs from *LEFT FUEL LOW* and *RIGHT FUEL LOW* caution lights

The Investigation also examined the aircraft's CB panel; the *FUEL SEL WARN* CB was found to be in the open (popped/pulled) position.

1.12.4 Engine Examination

The engine was disassembled and examined at the AAU's wreckage examination facility with the assistance of the Engine Manufacturer.

Impact damage was visible on all external surfaces of the gas generator and exhaust casings. There was no evidence of magnetic metallic debris bridging the probes of the accessory gearbox chip detector. The power control and reversing linkage on the Fuel Control Unit (FCU) was bent from impact; however, it was still capable of partial movement. The emergency power lever was also fractured from impact. The oil filter was found to be clean, as was the residual oil within the filter housing. The engine was not capable of rotation. The front housing of the propeller reduction gearbox was fractured and the second stage of reduction gears had separated from the engine.

Large amounts of organic debris (soil/peat) were found within the engine's compressor inlet (**Photo No. 8**). When the debris was removed, evidence of rubbing was found on the first-stage compressor blades, the tips of which were curled in a direction opposite to the direction of rotation. All blades were present.

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Photo No. 8: Engine compressor inlet

Organic debris was also found within the engine's combustion section and was present on the fuel nozzles.

The compressor turbine shroud exhibited rubbing damage on its full circumference. Rubbing damage was also present on the compressor turbine guide vane ring. All blades were present on the compressor turbine, but exhibited rubbing damage from contact with the turbine shroud.

All of the blades on the power turbine were fractured (**Photo No. 9**). The fractured surfaces exhibited features consistent with overload. Several of the blades were bent in a direction opposite to the direction of rotation (**Photo No. 10**). The edges of the blades exhibited rubbing damage from contact with the power turbine vane ring. The contact also resulted in the blades being displaced in their mounting hub, in a downstream direction.



Photo No. 9: Fractured power turbine blades (*Engine Manufacturer*)



Photo No. 10: Blade bending in a direction opposite that of rotation (*Engine Manufacturer*)

The power turbine shroud exhibited rubbing damage from contact with the power turbine blades. All vanes on the power turbine guide vane ring were damaged as a result of contact with the power turbine blades. Fragments of the power turbine blades and blade tips were found within the exhaust case. The blade tips exhibited rubbing from contact with the power turbine shroud. The upstream side of the power turbine disc exhibited circular rubbing damage from contact with the power turbine shaft housing.



The following points are extracts from the Engine Manufacturer's 'Summary of Findings':

- *'The [propeller] reduction gearbox housing was fractured resulting in complete separation of the 2nd stage gears and propeller from the rest of the engine.*
- *Impact damage caused deformation of the exhaust duct resulting in axial displacement of the Power Turbine (PT) disk and shaft [...].*
- *Access to the compressor revealed rubbing of the 1st stage blades causing curling of the blade tips in the opposite direction of rotation.*
- *The Compressor Turbine (CT) blades showed rubbing of the tips against the shroud. The disk and blade fixings exhibited rubbing from contact with the CT and PT vanes [...].*
- *The PT blades were fractured at various locations within the airfoils. Many remaining airfoils exhibited bending in the opposite direction of rotation. The fracture surfaces showed features characteristic of overload and many blade fragments were recovered from the exhaust. Blade tip fragments displayed rubbing from contact with the blade shroud. The disk faces [...] and centre hub all exhibited circular rubbing from contact with adjacent static components.*
- *There was no evidence of pre-impact damage noted on the examined component of both gearboxes as well as main line bearings'.*

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The Engine Manufacturer concluded by stating:

'Rotational signatures found on the compressor, compressor turbine, power turbine and adjacent static components are indicative that the engine was rotating at impact, likely in a low to mid power range. There was no evidence of pre-impact anomalies observed on the examined engine components'.

1.12.5 Propeller Examination

The propeller sustained substantial damage during impact. The AAIU shipped it to the Propeller Manufacturer's facility in the USA for disassembly and examination. Representatives from the FAA oversaw the work on behalf of the NTSB and the AAIU. The following are extracts from the conclusions of the Propeller Manufacturer's report:

- *'No indications of any type of propeller failure or malfunction prior to impact were found.*
- *The propeller has indications consistent with a mid-level amount of rotational energy absorption (rotation at impact likely with some engine power) during the impact sequence. Exact engine power levels were not determined.*

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- *The propeller has several indications of operating at or near the pickup²⁰/flight idle angle (approximately 15 degrees measured at the blade's 30" radial station) at impact. No impact signature markings or component positions were found that indicate blades at feather or reverse position at impact. This concluded propeller blade angle is consistent with indicated power levels'.*

The Propeller Manufacturer's report noted that the conclusions were based on observations including the following:

- *'The propeller fragments have sudden-failure type damage that is typically associated with impact forces and gross part deflections. The investigation found no evidence of any type of fatigue failure or pre-impact issue.*
- *The propeller hub fragments and blade butts have witness marks from contact with blade counterweight and pitch change component hardware during the accident sequence. The position of these marks indicates an approximate propeller blade angle of flight idle/pickup.*
- *The propeller blade bending, twisting, paint scuffing, leading edge impacts, and overall propeller assembly damage is typical of that associated with mid-level rotational energy absorption (rotation with likely some engine power) at impact'.*

1.13 Medical and Pathological Information

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The Pilot and the Passenger were fatally injured.

1.13.1 The Pilot

The Pilot was found within the cockpit section of the aircraft. He was secured to the left-hand cockpit seat by a five-point restraint harness and was removed from the seat by the emergency services.

Post-mortem examination was performed at the Midlands Regional Hospital at Tullamore, Co. Offaly on 14 May 2018. Multiple fractures were noted, including those to the upper and lower limbs. The autopsy report stated that samples of blood and urine were forwarded to the State Laboratory for toxicological examination and that ethanol (alcohol) and drugs were 'Not detected'. The report noted that there was 'no evidence of acute infarction²¹ or fibrosis' of the heart and that 'coronary arteries were normal'. The pathologist deemed the cause of death to be due to 'massive generalised trauma [...]'.

1.13.2 The Passenger

The Passenger was found within the cockpit section of the aircraft, secured to the right-hand cockpit seat by a five-point restraint harness. The Passenger was removed from the seat by the emergency services.

²⁰ **Pickup:** Automatically controlled minimum blade angle stops.

²¹ **Infarction:** Obstruction of the blood supply to an organ or region of tissue.



Post-mortem examination was performed at the Midlands Regional Hospital on 14 May 2018. The associated report noted multiple fractures had occurred, including fractures to the upper and lower limbs. The pathologist deemed the cause of death to be due to '*massive generalised trauma* [...]'.

1.14 Fire

There was no fire.

1.15 Survival Aspects

When the cockpit section was lifted from the bog, the Pilot and Passenger were found secured to the cockpit seats by their five-point restraint harnesses. However, due to the severity of the impact and the extent of the damage to the aircraft, the accident was not survivable.

1.16 Tests and Research

1.16.1 Video Analysis performed by the National Transportation Safety Board

In an attempt to determine the aircraft's trajectory, altitude, speed and orientation in the moments leading up to the accident, the Investigation requested the NTSB (representing the State of Manufacture of the aircraft) to conduct analysis of the video recording captured by the CCTV camera located at the security hut situated just outside the wind farm complex. To prevent bias, the NTSB conducted this analysis without using data from the ADAS unit (Section 1.11.1) or from ATC radar (Section 1.11.4).

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This camera's lens captured a wide field of view, which included the security hut itself and objects such as fences and roadways close to it, in addition to the sky in the distance (**Figure No. 18**). However, the wide angle lens resulted in severe '*barrel distortion*²²' that caused the fences and the edges of the security hut to appear curved. The distortion was greatest near the corners of the image; the aircraft was visible in the top right corner of the image. The distortion was removed mathematically before proceeding with further analysis.



Figure No. 18: Still image extracted from CCTV video from security hut camera

²² **Barrel distortion:** A defect in an image in which vertical or horizontal straight lines appear as convex curves.

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The recorded video had a resolution of 2,688 x 1,520 pixels and an effective frame rate of eight frames per second (the rate at which new images appeared in the video frames). To permit analysis of the video, a calibrated mathematical model of the camera optics was required, which necessitated a survey of the camera's location to obtain the dimensions and relative position of objects in the camera's near field of view. To ensure that this information was as accurate as possible, the Investigation commissioned an architectural firm to conduct a detailed site survey.

The site survey measured locations such as road markings, fence posts and security huts relative to the camera. The associated analysis report stated that these references were used in an iterative camera calibration process that resulted in estimates of the camera orientation angles and its horizontal field of view angle. A mathematical model of the camera with the calibrated camera parameters was then used, within a computer program, to project a virtual wireframe model of the airplane onto frames from the video. The virtual wireframe model was moved and rotated, within the program, until it optimally matched the image of the aircraft in the video frames. Once an optimal match was achieved, the location and orientation of the virtual wireframe model was the most accurate estimate of the location and orientation of the accident airplane. The accuracy of this estimation process was limited by the fact that the image of the airplane in video frames was small, consisting only of several dark pixels. Because of clouds, the aircraft's nose, tail and both wingtips were only visible in a small number of frames.

41 The report stated that there was a $\pm 10\%$ uncertainty on the estimated distance from the camera to the aircraft and also a $\pm 10\%$ uncertainty on the estimated heading and bank angle. The NTSB analysed the 11 seconds (approximately) of the recording that showed the aircraft, and identified six key frames for further analysis. The first 7.5 seconds (approximately) show the aircraft following what appears to be a normal trajectory. The analysis time was set to zero when the aircraft first became visible (dashed yellow line in **Figure No. 19**). The first frame analysed was recorded at time 3.3 seconds and before the wings of the aircraft became discernible. The direction from the camera at this point is shown in **Figure No. 19** by the blue line marked 'A'. The last analysed frame was recorded at time 10.8 seconds, when the aircraft was descending in what appeared to be a nose-down attitude just before it disappeared into a line of trees. The direction from the camera at this point is shown in **Figure No. 19** by the blue line marked 'B'.

The ends of the lines are coloured red to indicate the $\pm 10\%$ uncertainty range of the distances involved. The location of the accident site is indicated by a red star between the two red lines. According to the analysis, estimation of the angle of lines A and B was based on video frames after barrel distortion correction and had an estimated accuracy of $\pm 1^\circ$.

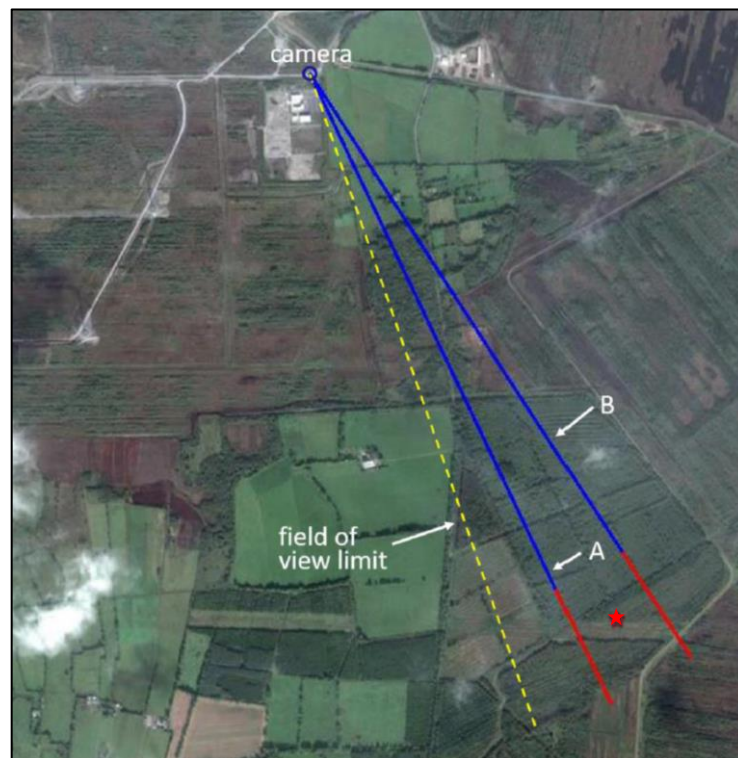


Figure No. 19: Satellite view showing directions from camera at time 3.3 seconds (Line A) and at time 10.8 seconds (Line B). Red star indicates the location of the accident site (NTSB)

The video frames that were of interest were those in which the aircraft's nose, tail and wingtips were discernible and when the aircraft had not yet started to descend in what appeared to be a near-vertical, nose-down attitude. The analysis noted that there were four such reasonably spaced frames, recorded at times 3.9, 4.6, 5.6 and 6.8 seconds. The analysis estimated the ground speed of the aircraft between times 3.9 seconds and 6.8 seconds as 73.5 metres per second (m/s) or 143 kts. The aircraft's altitude was estimated to be 1,398 ft Above Mean Sea Level (AMSL) at time 3.9 seconds and 1,217 ft at time 6.8 seconds, indicating a descent rate of approximately 3,745 ft/min in that time period.

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At time 6.8 seconds, the aircraft's height above the ground was estimated to be 987 ft. Between time 6.8 seconds and time 10.8 seconds, the aircraft was '*rapidly descending*' and its horizontal speed component was relatively small. According to the analysis, when it was last clearly seen in the video, '*descending almost nose down*' its ground speed component seems to indicate motion towards Line A, '*which could explain the crash site location being between lines A and B*'. The analysis stated that due to the $\pm 1\%$ uncertainty of the angles of Lines A and B, it is possible that Lines A and B could be rotated clockwise by one degree, which would bring Line B closer to the accident location.

The estimated heading of the aircraft was $040^\circ \pm 5^\circ$ between time 3.9 and 6.8 seconds. The estimated bank angle in this period was either $50^\circ \pm 5^\circ$ right wing down, which the analysis stated was the small angle camera-optics-based estimate, or $-130^\circ \pm 5^\circ$ (i.e. a large left wing down bank angle), which is the large angle estimate derived from the images. The analysis noted that '*based on the optical analysis alone, it cannot be determined which bank angle estimate is more "correct"*'. The analysis stated that the pitch angle of the aircraft was difficult to determine, but was estimated to be between 15° and 25° nose down.

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1.16.2 Aerodynamic Considerations

1.16.2.1 The Generation of Lift

When an aerofoil (e.g. an aircraft wing) moves through the air, it is subjected to aerodynamic forces (**Figure No. 20**). Airflow over and under the wing is represented by the black lines in the figure. The aerofoil's shape causes the velocity of the airflow above the aerofoil to increase and the air pressure to reduce. The resulting pressure differential between the upper and lower surfaces of the aerofoil produces lift. The aerofoil's chord line runs from the aerofoil's leading edge to its trailing edge. The angle between the chord line and the airstream is known as the angle of attack (AoA). Changing the AoA will change the amount of lift generated.

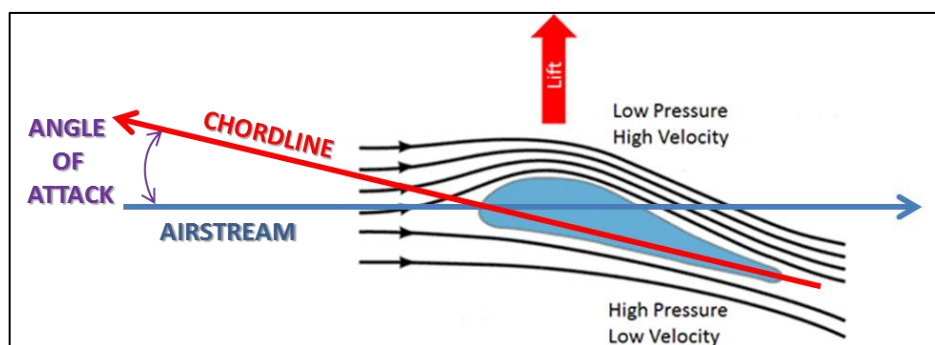


Figure No. 20: An aerofoil in an airstream (Adapted from Woodbank)

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As the AoA increases, the pressure differential between the aerofoil's upper and lower surfaces becomes greater and lift increases. However, beyond a certain angle, known as the 'critical AoA' (**Figure No. 21**), the airflow, having been attached to the upper surface of the wing, separates and becomes turbulent. The aerofoil at this point is considered to be in a stalled condition. A stall causes a sudden loss of lift. The 'critical AoA' is fixed and is not affected by an aircraft's speed or weight.

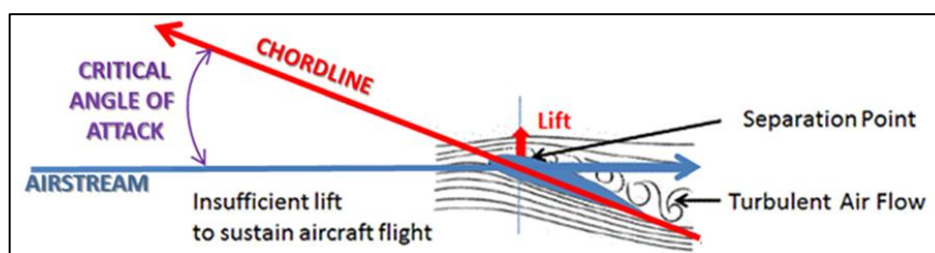


Figure No. 21: An aerofoil in an airstream at its critical AoA (Adapted from Woodbank)

1.16.2.2 Banked turns

An aircraft can be rolled (banked) through the use of the ailerons. For example, to roll the aircraft to the left, the pilot's inputs cause the left aileron to move up and the right aileron to move down. The camber²³ of the (right-hand) wing at the down-going aileron is increased, as is the angle of the effective chord line (**Figure No. 22**). This increases the angle of attack in the area of the aileron, and the wing's lift increases.

²³ **Camber:** In this case, it refers to the convexity of curvature of the aerofoil from its leading to its trailing edge.
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Conversely, the upward deflection of the left aileron decreases the camber and effective chord line of the left wing at the aileron, resulting in decreased lift on the left wing. Thus, the increased lift on the right wing and the decreased lift on the left wing cause the aircraft to roll to the left.

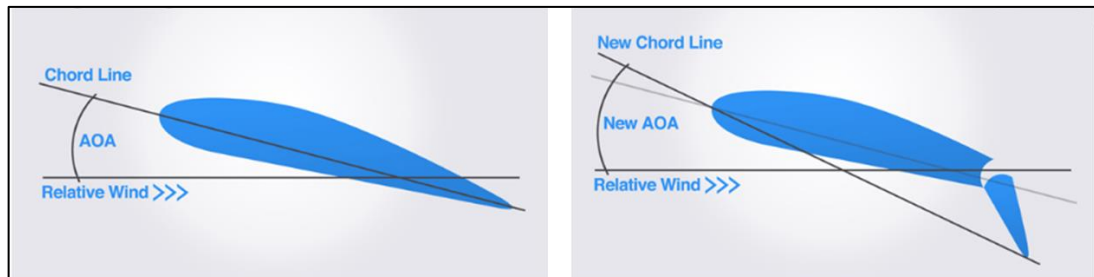


Figure No. 22: The effect of lowering an aileron on an aerofoil's AoA (*boldmethod*)

The up-going wing's increase in lift results in a corresponding increase in drag on that wing. This tends to yaw the aircraft in a direction opposite to the intended turn, making the turn uncoordinated. Therefore, to keep the turn coordinated, rudder is applied in the direction of the turn.

A skidding turn²⁴ will occur if the rudder application is such that the aircraft yaws excessively in the direction of the turn. The excessive yaw will tend to cause the aircraft to roll further and will tend to rotate the nose of the aircraft towards the ground. The yaw will also cause the outside wing to experience a faster airflow than the inside wing. To counteract the increasing bank angle, instinctively, a pilot may apply opposite aileron. This will cause the aircraft to be in an uncoordinated, cross-controlled situation in which, in a left-hand turn, left rudder and right aileron are applied. The application of opposite aileron will increase the angle of attack on the inside wing. According to the FAA's Airplane Flying Handbook (FAA-H-8083-3B), *'Should a stall be encountered with these inputs, the airplane may rapidly enter a spin'*.

Sustaining altitude during a steep turn (bank angle exceeding 45°) requires significant back pressure on the elevator because the inclination (angle) of the lift vector decreases the vertical component of lift (**Figure No. 23**). An increase in engine power would also be required to compensate for the reduction in lift and the overall increase in drag.

²⁴ **Skidding turn:** In a skidding turn, an aircraft's tail tends to skid towards the outside of the turn.

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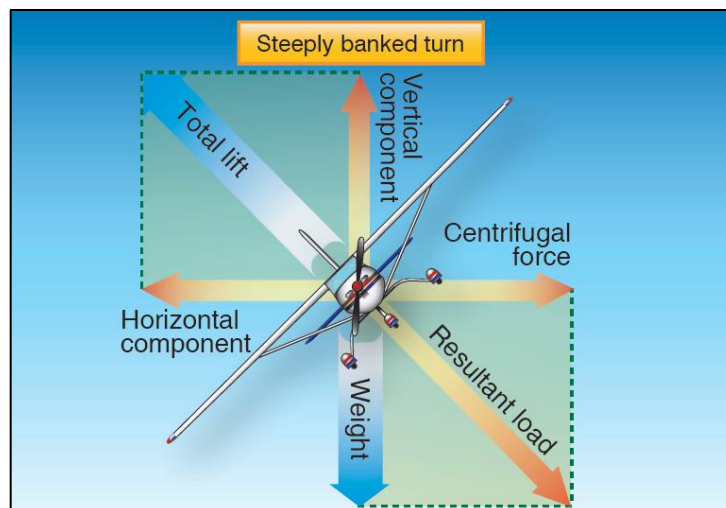


Figure No. 23: Effect on vertical component of lift during steeply banked turns (FAA)

1.16.2.3 The Effect of Wing Loading on Stall Speed

For level flight, lift must be equal to weight. For stable level flight the load factor is one (1), i.e. 1G (acceleration due to gravity). However, in a banked turn, the load factor increases due to the acceleration towards the centre of the turn (centripetal acceleration). In effect, the aircraft experiences greater 'weight', perpendicular to its wings, which increases the wing loading. This increased loading requires more lift to keep an aircraft from losing altitude than would be the required during wings-level flight; the pilot achieves this by pulling back on the control column to increase the angle of attack. This causes the aircraft to be closer to stalling than it would be for wings-level flight, i.e. the aircraft will stall at a higher speed (the accelerated stall speed) than if it was flying wings level. The aircraft's stall speed increases in proportion to the square root of the load factor.

The load factor is obtained from the formula: $\frac{1}{\cos(\text{bank angle})}$

Table No. 8 shows how the load factor and the stall speed rapidly increase above a bank angle of 60° (in co-ordinated turns).

| Bank Angle | Load Factor | Accelerated Stall Speed Factor | Flap 'Up' Stall Speed (KIAS) |
|------------|-------------|--------------------------------|------------------------------|
| 0° | 1 | 1 | 63 (POH) |
| 30° | 1.15 | 1.07 | 68 (POH) |
| 45° | 1.41 | 1.19 | 75 (POH) |
| 60° | 2 | 1.41 | 89 (POH) |
| 75.5° | 4 | 2 | 126 (calculated) |
| 80° | 5.7 | 2.29 | 144 (calculated) |

Table No. 8: The effect of bank angle on load factor and stall speed



1.16.2.4 Descending Turn

In descending turns, the inside wing travels down a steeper descent path than the outside wing and therefore has a greater angle of attack than the outside wing.

1.16.2.5 Under-The-Bottom Stall

In his book, *'Emergency Maneuver Training'*, the author (Rich Stowell) states the following:

'Under-the-bottom'²⁵ stalls are accelerated stalls [stalls occurring at higher speeds than the normal 1G stall speed]. The basic configuration involves turning flight in which the inside wing stalls first. The airplane might then yaw and roll sharply into a steeper bank (possibly even inverted) as the nose pitches forward. This stall behaviour is often encountered in descending turns, in skidding turns, and in steep, level turns. Uncorrected, these stalls can quickly transition into a spin whose direction is the same as the initial turn direction (called an under-the-bottom spin).

[...]

Skidding with rudder also induces yaw and roll components in the direction of the turn. The inside wing operates at a higher angle of attack as a result; hence, it tends to stall first. Applying opposite aileron to counter the yaw-induced roll could instigate aggressive tip stall behaviour even sooner by further increasing the local angle of attack on the inside wing'.

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1.16.2.6 Spin Dynamics

In his book *'The light Airplane Pilot's Guide to Stall/Spin Awareness'*, the author (Rich Stowell) states that: *'Two ingredients must be present for an airplane to spin: stall and yaw'.*

In the *'Airplane Flying Handbook (FAA-H-8083-3B)'*, the FAA state that *'A stall that occurs while the airplane is in a slipping²⁶ or skidding turn can result in a spin entry and rotation in the direction of rudder application'* and that the incipient phase (from the time the airplane stalls and starts rotating until the spin has fully developed) *'lasts about 4 to 6 seconds in light aircraft'.*

The first action in attempting to recover from a spin, as contained in the aircraft's POH and in other publications, is to retard the engine power lever to idle.

²⁵ When banking, bottom rudder is rudder application on the same side as the lowered wing.

²⁶ **Slipping turn:** In a slipping turn, the aircraft banks too much for the rate of the turn and the nose of the aircraft tends to yaw towards the outside of the turn.

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1.16.3 Propeller Torque Reaction

The accident aircraft's propeller rotated clockwise (viewed from the cockpit). On aircraft with a clockwise-rotating propeller, a sudden increase in engine power will result in a torque reaction which will cause a tendency of the aircraft to roll and yaw to the left.

During its investigation of an accident involving another Cessna 208B²⁷, which occurred in 2007, the AAIU commissioned a flight test to assess the effect of torque reaction when engine power is increased suddenly. The test was as follows: *'Reduce to V_{sw} ²⁸ – [minus] 5 kts and apply full power maintaining aileron or rudder position without change'*. The following result was recorded: *'Bank 30° to the left initially and then increasing, yaw 20° left, initial bank was followed by a nose drop, descent and then stall buffet as g loading increased'*.

1.16.4 Approach Height Considerations

An aircraft's final approach to landing is usually performed at an angle of 3° to the runway. This equates to a decrease of approximately 300 feet of altitude per NM of horizontal distance travelled (altitude decrease = $\tan(3^\circ) \times \text{horizontal distance travelled}$).

1.17 Organisational and Management Information

1.17.1 Introduction

The aircraft was owned by a UK-based parachute-aircraft leasing company and was provided to the EICL-based Club on 21 April 2018.

This Investigation is a Safety Investigation, and in that context, this Section of the Report reviews the legislation and guidance material regarding parachute operations, including the carriage of passengers and the leasing arrangements for the aircraft and the employment of the Pilot.

1.17.2 Applicable European Legislation

1.17.2.1 General

Within EASA Member States, aircraft operations for the purpose of transporting a skydiver or parachutist are subject to the requirements of Commission Regulation (EU) No 965/2012. Such operations are classified as either commercial specialised operations (Part-SPO) (subject to the requirements of Annex VIII of 965/2012) or non-commercial specialised operations with other than complex motor-powered aircraft (Part-NCO) (subject to the requirements of Annex VII of 965/2012).

Annex III of Commission Regulation (EU) No 965/2012 (*Organisation Requirements for Air Operations – Part-ORO*) as amended by Commission Regulation (EU) No 379/2014, came into force in Ireland on 24 August 2016. According to '*ORO.GEN.005 Scope*' of the Regulation (965/2012 as amended by 379/2014), it is applicable to the following operations:

²⁷ AAIU Report 2009-003, published 20 January 2009.

²⁸ V_{sw} : Stall warning speed.



- '(a) commercial air transport operations (CAT);*
- (b) commercial specialised operations [Part-SPO];*
- (c) non-commercial operations with complex motor-powered aircraft²⁹ [Part-NCC];*
- (d) non-commercial specialised operations with complex motor-powered aircraft [Part-SPO]'*.

Annex VIII '*Specialised Operations – Part-SPO*' was introduced by Commission Regulation (EU) No 379/2014 (amending Commission Regulation (EU) No 965/2012) and was later amended by Commission Regulation (EU) 2015/140. Section '*SPO.GEN.005 Scope*' states the following:

- '(a) This Annex applies to any specialised operation where the aircraft is used for specialised activities such as agriculture, construction, photography, surveying, observation and patrol, aerial advertisement.*
- (b) Notwithstanding (a), non-commercial specialised operations with other-than complex motor-powered aircraft shall comply with Annex VII (Part-NCO).*
- (c) Notwithstanding point (a), the following operations with other-than complex motor-powered aircraft may be conducted in accordance with Annex VII (Part-NCO):*

[...]

- (2) parachute dropping, sailplane towing or aerobatic flights performed either by a training organisation having its principal place of business in a Member State and approved in accordance with Regulation (EU) No 1178/2011 [Aircrew Regulation], or by an organisation created with the aim of promoting aerial sport or leisure aviation, on the condition that the aircraft is operated by the organisation on the basis of ownership or dry lease, that the flight does not generate profits distributed outside of the organisation, and that whenever non-members of the organisation are involved, such flights represent only a marginal activity of the organisation'.*

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The responsibilities of operators are contained in Section *ORO.GEN.110* of Commission Regulation (EU) No 965/2012. This section, which, according to *ORO.GEN.005 Scope*, is applicable to Part-SPO operators, states the following:

- '(a) The operator is responsible for the operation of the aircraft in accordance with Annex IV to Regulation (EC) No 216/2008³⁰, as applicable, the relevant requirements of this Annex and its air operator certificate (AOC) or specialised operation authorisation (SPO authorisation) or declaration*

²⁹ **Complex Motor Powered aircraft:** (i) An aeroplane with a maximum certificated take-off mass exceeding 5,700 kg, or certificated for a maximum passenger seating configuration of more than nineteen, or certificated for operation with a minimum crew of at least two pilots, or equipped with (a) turbojet engine(s) or more than one turboprop engine, or (ii) a helicopter certificated: for a maximum take-off mass exceeding 3,175 kg, or for a maximum passenger seating configuration of more than nine, or for operation with a minimum crew of at least two pilots, or (iii) a tilt rotor aircraft (ref EASA).

³⁰ Also known as the '*Basic Regulation*'. This has been replaced by Regulation (EU) 2018/1139.

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- (b) *Every flight shall be conducted in accordance with the provisions of the operations manual.*
- (c) *The operator shall establish and maintain a system for exercising operational control over any flight operated under the terms of its certificate, SPO authorisation, or declaration.*
- (d) *The operator shall ensure that its aircraft are equipped and its crews are qualified as required for the area and type of operation.*
- (e) *The operator shall ensure that all personnel assigned to, or directly involved in, ground and flight operations are properly instructed, have demonstrated their abilities in their particular duties and are aware of their responsibilities and the relationship of such duties to the operation as a whole’.*

Personnel requirements are contained in Section ORO.GEN.210 of Commission Regulation (EU) 965/2012. This section states the following:

[...]

- (c) *The operator shall have sufficient qualified personnel for the planned tasks and activities to be performed in accordance with the applicable requirements’.*

In accordance with Commission Regulation (EU) No 965/2012 ‘ORO.DEC.100 Declaration’, operators shall provide the competent authority with all relevant information prior to commencing operations and notify the competent authority without delay of any changes to its declaration. According to ‘SPO.GEN.100 Competent Authority’, the Competent Authority is the ‘*authority designated by the Member State in which the operator has its principal place of business or is residing*’.

The IAA advised the Investigation that the Club submitted an [initial] declaration for SPO operations on 22 September 2016, followed by further declarations that amended the initial declaration (e.g. including the removal of aircraft resulting in periods of inactivity). The Club submitted a declaration to the IAA on 3 May 2018, which included details of the accident aircraft and indicated it was being operated under Part-SPO and that the Club was the ‘operator’ of the aircraft. The leasing arrangements in relation to the accident aircraft are described in **Section 1.17.5**.

The Competent Authority’s responsibilities regarding oversight are contained in Section ‘ARO.GEN.300 Oversight’ of Commission Regulation (EU) No 965/2012 (as amended). This section states the following:

- (a) *The competent authority shall verify:*

[...]

- (2) *continued compliance with the applicable requirements of organisations it has certified, specialised operations it has authorised and **organisations from whom it received a declaration** [emphasis added];*
- (3) *continued compliance with the applicable requirements of non-commercial operators of other-than complex motor-powered aircraft; [...].’.*



The Competent Authority's responsibilities regarding declarations received from organisations are contained in Section 'ARO.GEN.345 Declaration – organisations'. This section states the following:

- '(a) Upon receiving a declaration from an organisation carrying out or intending to carry out activities for which a declaration is required, the competent authority shall verify that the declaration contains all the information required by Part-ORO and shall acknowledge receipt of the declaration to the organisation.*
- '(b) If the declaration does not contain the required information, or contains information that indicates non-compliance with applicable requirements, the competent authority shall notify the organisation about the non-compliance and request further information. If deemed necessary the competent authority shall carry out an inspection of the organisation. If the non-compliance is confirmed, the competent authority shall take action as defined in ARO.GEN.350'.*

Section ARO.GEN.305 Oversight programme contains the requirements for the Competent Authority's oversight programme. ARO.GEN.305 (d) deals with the oversight of declared organisations. The Acceptable Means of Compliance for this section states the following:

'The oversight programme should be developed on a yearly basis. All operators should be considered for inclusion into the programme not later than 12 months after the date of the first declaration received. At least one inspection should be performed within each 48-month cycle starting with the date of the first declaration received'.

The IAA advised the Investigation that the Club did not have a continuous period of SPO operation since its initial declaration. The IAA stated that the Club's initial SPO declaration and subsequent SPO change declarations were reviewed and acknowledged as required by the Regulation, and that an inspection was carried out on 17 May 2019. The Club informed the Investigation that it had several meetings with the IAA in relation to its initial SPO declaration and that the IAA advised the Club on various matters prior to and since the initial declaration.

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1.17.2.2 Pilot Licensing

Commission Regulation (EU) No 1178/2011 (laying down technical requirements and administrative procedures related to civil aviation aircrew) states that *'the privileges of the holder of a PPL(A) are to act without remuneration as PIC [Pilot-in-Command] or co-pilot on aeroplanes or TMGs [Touring Motor Glider] engaged in non-commercial operations'*. Therefore, once a pilot receives remuneration, a CPL is required.

1.17.2.3 Carriage of another Person in the Flight Compartment

Paragraphs 3, 4 and 5 of Article 5 of Commission Regulation (EU) No 965/2012 were added by Commission Regulation (EU) No 800/2013 (amending Commission Regulation (EU) No 965/2012). These paragraphs were replaced by Commission Regulation (EU) No 379/2014 (amending Commission Regulation (EU) No 965/2012). Commission Regulation (EU) No 379/2014 also introduced two new paragraphs (6 and 7) to Article 5 of Commission Regulation (EU) No 965/2012. Commission Regulation (EU) No 2015/140 (amending Commission Regulation (EU) No 965/2012) amended Article 5, Paragraph 7; this paragraph states:

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*'Flights taking place immediately before, during or immediately after specialised operations and directly connected to those operations shall be operated in accordance with paragraphs 3, 4 and 6, as applicable. **Except for crew members, persons other than those indispensable to the mission shall not be carried on board**' [Emphasis added].*

The Investigation asked EASA if Article 5, Paragraph 7 referred to Part-NCO as well as Part-SPO. EASA advised that it *'applies to all specialised operations, regardless of whether operated under Part-NCO or Part-SPO [...]*

1.17.2.4 Supplemental Oxygen Requirements

The aircraft was equipped with a supplemental oxygen system that was not in use. The applicable requirements regarding supplemental oxygen are contained in SPO.OP.195, which states the following:

'The operator shall ensure that task specialists and crew members use supplemental oxygen continuously whenever the cabin altitude exceeds 10 000 ft for a period of more than 30 minutes and whenever the cabin altitude exceeds 13 000 ft, unless otherwise approved by the competent authority and in accordance with SOPs'.

Similar requirements are contained in NCO.OP.190 and NCC [Non-Commercial Operations with Complex Motor-Powered Aircraft].OP.210.

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1.17.2.5 Minimum Equipment List Requirements

A Minimum Equipment List (MEL) derived from the Aircraft Manufacturer's Master Minimum Equipment List (MMEL), and approved by the state of the Operator, is required for commercial operations (Article 30 of Commission Regulation (EU) 2018/1139 and Section ORO.MLR.105 of Commission Regulation (EU) 965/2012). An MEL is not required for non-commercial operations (Section NCO.GEN.155 of Commission Regulation (EU) 965/2012). However, in such cases, in accordance with NCO.IDE.A.105 *'a flight shall not be commenced when any of the aeroplane instruments, items of equipment or functions required for the intended flight are inoperative or missing [...]*'. There was no MEL for the aircraft. As outlined in **Section 1.6.3**, the sun-visor on the accident aircraft was reported as unserviceable on 17 February 2018. The Manufacturer's MMEL permits flight with the sun-visor inoperative or missing for up to 10 days only.

1.17.3 IAA Guidance Material regarding Parachute Operations

The IAA is responsible for the management of Irish controlled airspace, the safety regulation of Irish civil aviation and the oversight of civil aviation security in Ireland. The IAA published three Operations Advisory Memorandums (OAMs) in relation to parachute operations: OAM 03, *'(EU) Air Operations Task Specialists Requirements in Commercial and Non-Commercial Aircraft Operations in support of Parachute Dropping'* (dated 8 September 2017); OAM 04, *'Notice to Operators and Pilots of Aircraft flown in support of Parachute Dropping'*, (dated 11 August 2017); and OAM 05, *'Information for Persons engaged in Parachute Jumping in Ireland'* (dated 11 August 2017). OAM 05 states the following:



'[...] Parachute centres in Ireland conducting flights in support of parachute dropping for commercial purposes available to members of the public are required to declare their aircraft operational capabilities to the Irish Aviation Authority (IAA) and may only use pilots holding a Commercial Pilot Licence [...]

The OAMs point to the regulations applicable to parachuting and skydiving operations. However, they do not specifically highlight that the carriage of persons on aircraft being used for such operations, other than those indispensable to the mission, is prohibited.

1.17.4 UK Guidance Material regarding Parachute Operations

The aircraft was UK-registered and the Pilot was UK-based. Therefore, the Investigation reviewed guidance material published by the UK Civil Aviation Authority (CAA). Civil Aviation Publication (CAP) 660, *'Parachuting'* (fourth edition incorporating amendment 2008/01) was published in July 2008. According to the CAA's website, the status of CAP 660 is *'Reference Only'*. Its stated purpose is as follows:

'to set out minimum standards which the Civil Aviation Authority (CAA) will require to be satisfied prior to the grant or renewal of parachuting Permissions and any related Exemptions; and to indicate the CAA's requirements for the conduct of parachuting operations'.

Section 6.7, *'Carriage of Passengers'*, states:

'No passengers shall be carried on a flight made for the purpose of parachute dropping except parachutists who are equipped for and intending to make a descent by parachute during the flight or those carried solely for the purpose of acting as jumpmaster or parachute instructor during the flight; except the following:

- a) When pilots are under training or checking, a suitably qualified person may be carried as a passenger for the purposes of that duty.*
- b) At the discretion of the operator a passenger may occupy a co-pilot's seat in multiengine aircraft provided that:*
 - i) this is in compliance with the requirements and limitations stated in the aircraft Flight Manual and applicable Flight Manual Supplements, taking into account the purpose of the flight as deemed by the ANO [Air Navigation Order];*
 - ii) the seat is fitted with an approved safety belt or harness;*
 - iii) the seat is not adjacent to a door that will be removed or opened in flight;*
 - iv) no valuable consideration is given or promised for the carriage of the passenger;*
 - v) the passenger is formally informed that the flight is not being conducted in accordance with the requirements of a flight for the purpose of Public Transport'.*

According to CAP 660, *'the British Parachute Association (BPA) Operation's Manual, as amended represents the accepted standard for sport parachuting in the United Kingdom'*. The BPA's Manual (Section 5.6, dated February 2017) permits the carriage of passengers on single turbine-engine aircraft, if the aircraft is operating under Part-NCO.

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The CAA informed the Investigation that it was in the process of updating and revising its CAP 660 'Parachuting' publication and that a consultation on the CAP's proposed fifth edition which ran from 23 December 2019 to 17 January 2020³¹ included the following revised content in relation to the Carriage of Passengers:

'3.57 No passengers shall be carried on a flight conducted for the purpose of parachute dropping except parachutists who are equipped for and intending to make a descent by parachute during the flight or task specialists such as those carried solely for the purpose of acting as jumpmaster or parachute instructor during the flight.'

3.58 Task specialists can only be carried for a specific task connected with the parachute operation and the task specialist duties must be defined within the organisation's SOPs'.

The CAA stated that with the consultation now closed, it is further amending this paragraph to clarify that the *'only persons to be carried on a parachute operation (either commercial or non-commercial) are the Pilot-in-Command, crew members, and task specialists. This is further to the provisions with Part-NCO-SPEC and Part-SPO of the EASA Operations Regulation (EU) 965/2012 (as amended)'*. The CAA *'aims to have the revised CAP published in the near future'*.

The Investigation asked the skydiving centre in the UK, where the Pilot normally flew, to outline its policies regarding the carriage of passengers. The organisation advised that historically, passengers were occasionally authorised, but that its current procedures prohibit the carriage of passengers, except certain specified personnel (e.g. instructors, examiners or task specialists), who must be authorised by the organisation's chief pilot.

1.17.5 Aircraft Leasing Arrangements

The aircraft owner provided the Investigation with a copy of its standard 'Lease Agreement' document which outlines the terms of a lease. In relation to leasing of the aircraft, no formal agreement document had been completed or signed by the aircraft owner or by the Club. However, an email from the aircraft owner to the Club outlined the terms of the lease arrangements for the aircraft. It stated what the daily payment rate for the Pilot was and that *'payment [is] directly between you [the Club] and the pilot'* and referred to the need to complete the 'Lease Agreement'.

The Investigation reviewed other emails regarding the lease of the aircraft between the aircraft owner and the Club, and between the aircraft owner and the insurer. One of the emails from the insurer to the aircraft owner indicated that the Pilot was being covered under the owner's insurance for the aircraft and that it was the understanding of the insurer that the Pilot was employed by the aircraft owner. The Investigation sought clarification from the aircraft owner on the latter point. The aircraft owner advised that the aircraft was being operated by the Club and would be under the Club's control. The invoices from the aircraft owner to the Club, as reviewed by the Investigation, relate to aircraft hire and ferry costs only. The Club confirmed that they paid the Pilot directly.

³¹ <https://consultations.caa.co.uk/ga/parachuting-edition-5-consultation/>.



As outlined earlier, the Club submitted a declaration to the IAA on 3 May 2018, which included details of the accident aircraft and indicated that the Club was the ‘operator’ of the aircraft. In subsequent correspondence with the Investigation, the Club stated that it considered that the aircraft owner was the operator of the aircraft.

The aircraft owner advised the Investigation that the Club ‘paid this pilot which is a clear record of the employment relationship’. An earlier email from the owner to the Club, outlining the terms of the lease, stated that ‘pilot travel costs are for your account and [...] will organise a schedule with you this week’.

In addition to aircraft leasing activities, the aircraft owner was also involved in the operation of a UK-based skydiving centre³². The owner outlined during interview with the Investigation that the Pilot hadn’t flown with that UK-based skydiving centre for a number of years. The aircraft owner advised that when an aircraft is being leased, they would recommend pilots that they were ‘comfortable with’ to fly their aircraft and would establish who was available. The Investigation asked the aircraft owner whether the carriage of passengers was permitted at the UK-based skydiving centre. The owner advised that other pilots could be carried but that passengers were not permitted. The Investigation asked if there was a policy regarding the carriage of passengers for aircraft that were leased out. The owner said that it varied from operator to operator, depending on each operator’s procedures. The owner also stated that the aircraft was normally leased to organisations operating under Part-NCO.

1.17.6 The Club’s Operations Manual

The Club provided a copy of its Operations Manual extant at the time of the accident to the Investigation. The manual consisted of four parts: Part A (‘General/Basic Information, Policy and Requirements’, dated 11 July 2015); Part B (‘Aircraft Operating Matters or AOM’, dated 1 September 2015); Part C (‘Airfield Information and Briefs’, dated 1 September 2015); and Part D (‘Pilot Qualifications Requirements and Training’, dated 11 July 2015). Pertinent extracts from the manual are included below.

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Part A-Volume 1, Section 5-2 ‘Proficiency Check’:

‘Each pilot shall undergo a Proficiency Check to demonstrate his competence in carrying out normal, abnormal and emergency procedures. The period of validity of a Proficiency Check shall be 12 calendar months in addition to the remainder of the month of issue’.

Part B-Volume 1, Page 2 states that ‘All operations within the [Club] shall be carried out in accordance [with] EU ops SPO operations No.965/2012³³’.

Part B-Volume 1, Section 1-7-q ‘Emergency Procedures’ (Aircraft Unflyable):

‘Airframe strikes, sometimes a parachutist or a parachute can strike the airframe on exit causing damage to the aircraft which can result in control problems. [...]’.

³² This is not the skydiving centre where the Pilot flew on some week days.

³³ The Club informed the Investigation that [subsequent to the accident] ‘the Club have changed their management system to reflect PART SPO Operations. The Club have now in place full Part SPO Operations’.

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If for any reason the aircraft becomes un-flyable and cannot be landed Pilots should bail out using their bail-out rig³⁴.

Bail-out Rig must be worn for all Parachuting activities and Pilots must receive instruction in its use' [The Investigation notes that the Pilot was not wearing a bail-out rig].

Part D, Section 1-1 '*Requirements for becoming a [Club] Pilot*':

'From time to time it will be necessary for new jump pilots to be appointed at the [Club]. All pilot selection and training will be the sole responsibility of the [Club] Chief Pilot (CP). No pilot will operate any parachute aircraft at the [Club] without the prior approval of the [Club] chief pilot and (BOD) Board of directors'.

Part D, Section 1-2 '*Basic Requirements*':

'Hold a valid commercial Licence that is recognised by the IAA. (Commercial operations)

Hold a valid Private PPL Licence that is recognised by the IAA. (Non Commercial Club Para operations ONLY) [...]

Carry out a [sic] 30 Para drops of supervised operations under the supervision of the [Club] Chief pilot or supervising pilot nominated by the Chief pilot.

Must receive a briefing from the [Club] chief club instructor (CCI Para Ops) on parachutes and the requirements from a parachutist's point of view.

Must receive a briefing by a qualified instructor (Para Ops) on the pilot bail out rig and be given the option of doing a static line jump course or Tandem jump as wearing a bail out rig is compulsory'.

The Operations Manual extant on the date of the accident contained no guidance regarding the leasing of aircraft, nor did it contain any guidance regarding the carriage of passengers. The Club advised that they wouldn't have used an aircraft with a second cockpit seat very often.

1.17.7 Interviews with Club Personnel

Several of the Club's management personnel were interviewed by the Investigation. One of those stated that '*every aircraft we operate has to have a commercial pilot*'. The personnel were asked if they inspected the Pilot's licence after he arrived. They stated that they didn't have a copy of the Pilot's licence. One of the management personnel was aware that the Pilot had renewed his medical during the week before the accident. The management personnel were asked if there were procedures in place regarding the carriage of a passenger. One of the personnel stated that once the Pilot was '*comfortable with it*' and the Passenger was suitable, they '*didn't see a great problem with it*' and that if the '*load was comfortable and he [the Pilot] was happy with the weight, he [the Pilot] used to bring him [the Passenger]*'.

³⁴ **Bail-out rig:** A parachute for use in emergency situations.



The Investigation asked if there was a contract with the aircraft owner that defined the responsibilities regarding each aspect of the lease. The Club personnel advised that there was none, but that there was email correspondence. The personnel were asked about the Pilot's schedule on the weekend of the accident. They said that the Pilot, who normally resided in the UK, flew into Dublin Airport on a commercial flight on the day before the accident and was collected by one of the skydivers from the Club and arrived at EICL at approximately 10.30 hrs (local time). The personnel advised that the Club was paying for the Pilot's commuting flights and his local accommodation. The Club's Accountable Manager³⁵ confirmed to the Investigation that the Club was also paying the Pilot. He also advised that there was no chief pilot at the Club at the time of the accident and that the IAA had advised that such a position was not necessarily required. He said that [during the aircraft's first weekend at the Club], he had refused permission for the Passenger to travel on board and that he did not know that the Passenger was on board the aircraft on the accident flight.

Another person from the Club present at the interview said that the aircraft was refuelled before the accident flight, and that the Pilot uplifted all fuel into the left-hand wing [instead of uplifting into each wing] and would fly out with one tank selected [the normal procedure is to select both tanks to *ON*]. The Investigation confirmed that a fuel uplift of 200 litres (352 lbs) was recorded in the aircraft technical logbook. An uplift of 201 litres was recorded in the EICL refuel facility's log.

In a subsequent interview, this person was asked about the Pilot's flying technique. He said that the Club hired several Cessna 208 aircraft over the years, but that this aircraft was the only one he '*saw on the ground before the jumpers*' (i.e. it landed before the skydivers had landed). The interviewee outlined that the flaps would normally be extended on the '*run in*³⁶' to '*get the tail up*', but that he was aware that the Pilot descended the aircraft with the flaps remaining at the 20° position. He also commented on the Pilot's descent technique and noted that the Pilot '*did descend fairly fast*'. A skydiver at the Club advised the Investigation that he had been on board the aircraft [for the duration of a flight] and recalled that the flaps were at 0° (retracted) during the descent on that flight.

Another person associated with the Club, who was the holder of a Private Pilot Licence, advised the Investigation that he sat in the right-hand cockpit seat on the Pilot's first flight at EICL to point out local hazards. He said he also outlined the flight plan requirements and ATC procedures. He was also present when the aircraft was refuelled before the accident flight and confirmed that 200 litres had been uplifted into the left-hand wing.

1.18 Additional Information

1.18.1 Turbulence from Wind Turbines

Turbulence may be caused by the wake from a wind turbine which extends down-wind behind the blades and the tower. The dissipation of the wake and the reduction of its intensity depend on several factors, including the topography (obstacles, terrain etc.) and the atmospheric conditions.

³⁵ **Accountable Manager:** The operator shall appoint an accountable manager, who has the authority for ensuring that all activities can be financed and carried out in accordance with the applicable requirements. The accountable manager shall be responsible for establishing and maintaining an effective management system (Regulation (EU) 965/2012 ORO.GEN.210 (a)).

³⁶ The portion of the flight when the aircraft is correctly aligned with the drop-zone.

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CAP 764 'CAA Policy and Guidelines on Wind Turbines' (sixth edition) was published by the UK CAA in February 2016. It is stated in the document that '*Published research shows measurements at 16 rotor diameters downstream of the wind turbine indicating that turbulence effects are still noticeable*'.

The accident site was 2.1 km away from the wind farm's nearest wind turbine. The diameter of the wind turbines at the wind farm is 100 m and the tower height is also 100m, resulting in an overall height of 150m (492 ft).

1.19 Useful or Effective Investigation Techniques

The Investigation requested the assistance of NTSB in conducting analysis of the video captured by the CCTV camera located at the security hut situated just outside the wind farm complex. The results of this analysis are described in **Section 1.16.1**.

2. ANALYSIS

2.1 Accident Site

The aircraft impacted into a forested peat bog, approximately 2.5 NM (4.6 km) to the north-west of the departure airfield. A CCTV camera system located at a wind farm recorded the aircraft for approximately 11 seconds. The final 3.5 seconds of the recording showed the aircraft descending in a near-vertical (nose-down) attitude, before it disappeared behind a line of trees.

The CCTV camera that captured the imagery was located at a security hut situated approximately 1.2 NM (2.2 km) north-west of the accident site. The final 3.5 seconds of the recording are consistent with the statement of Witness No. 3 who observed the aircraft coming '*straight down*'; he estimated the time from when he first saw the aircraft until it impacted to be three seconds. One of the skydivers' videos also appears to show the aircraft entering trees in a near-vertical attitude. Such an attitude would result in a compact accident site. The compact nature of the site was apparent during the Investigation's examination of the site, which found that only the trees immediately adjacent to the aircraft wreckage sustained damage. The compact nature is also evident in the overhead imagery recorded by a responding search and rescue helicopter.

The impact was such that the entire front section of the aircraft, forward of the main wheels, was submerged below the surface of the bog. The aft fuselage, wings and tail section were above ground. The aircraft's heading in the earlier part of the recording was estimated to be 040°, which is a north-easterly heading. When the aircraft was last seen clearly in the CCTV recording before it disappeared below the line of trees, the ground speed component of the near-vertical descent indicated motion back in the direction from which it had been travelling in the earlier part of the recording. The wreckage above ground was lying towards its left-hand side and generally angled back towards the north-east, which also indicated some degree of travel from this direction.



At the accident site, the underside/lower surface of the aircraft's rear section was facing towards 310° magnetic approximately, which was found to be towards the CCTV camera. One of the final frames of the last 3.5 seconds of the video recording, showed the aircraft with one wing lower than the other (lower image in **Figure No. 14** in **Section 1.11.8**). The orientation of the aft section of the aircraft at the accident site, in conjunction with the disposition of the aircraft's wings (the left wing was lying rearwards, whereas the right wing was lying forwards), and the greater compressive damage sustained by the left wing, particularly towards its tip, indicates that the left wing contacted the ground before the right wing. The Investigation therefore considers that the lower wing in the video frame was likely the left wing.

2.2 Weather and Airflow Conditions

The weather report received by the Investigation indicated that the weather conditions were benign. The Investigation therefore considers that weather was not a factor in the occurrence.

The Investigation also considered the possibility of the aircraft being affected by turbulence arising from the wind turbines located to the north-west of the accident site. According to the CAA's CAP 764, turbulence effects are noticeable at 16 rotor diameters downstream of a wind turbine, which in this case, equals 1.6 km. In the moments before the accident, the aircraft was 2.1 km away from the nearest wind turbine. Furthermore, at the time of the accident, the wind was reported to be 230-240° (south-westerly). Therefore, any airflow affected by the turbines would be to the north-east of the turbines, whereas in the moments before the accident, the aircraft was to the south-east of the turbines. In addition, the maximum height of the wind turbines was 492 ft (150 m) above ground level (AGL), whereas, based on the video analysis, the aircraft was at a height of between approximately 1,168 ft (1,398-230³⁷) and 987 ft (1,217-230) AGL when it was on an estimated heading of 040° in the final moments of the accident flight. The Investigation therefore considers that the possibility of turbulence from the wind turbines was not a factor in the occurrence.

2.3 Examination of Aircraft, Engine and Propeller

2.3.1 General

The videos obtained by the Investigation from the skydivers indicate that all flight controls were present and that the aircraft was flying normally when the skydivers jumped from the aircraft on the accident flight.

2.3.2 Aircraft Examination

When the aircraft was examined at the accident site, it was noted that the right-hand elevator was deflected downwards more than the left-hand elevator. The aircraft was recovered to the AAIU's wreckage examination facility, where it was examined with the assistance of the Aircraft Manufacturer and the UK AAIB. During the examination, the rivets securing the right-hand elevator's torque tube to the elevator actuation assembly were found to have sheared. The torque tube was removed from the elevator and sent to a metallurgist for detailed examination.

³⁷ The height of the accident site was approximately 230 ft AGL.

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The metallurgist's report noted that *'The appearance of the fracture surfaces [of the rivets] was consistent with instantaneous failure in shear'* and that *'there was no evidence of fatigue crack growth'*. The report also noted that *'there were both circumferential and axial components to the loading, which caused [the] failure'*.

Wreckage examination at the accident site identified that the horizontal and vertical stabiliser and flight control surfaces had sustained significant impact loads. The inboard upper surface of the right-hand elevator was in contact with a tree; the trailing edge of the elevator was distorted by the contact. The upper surface of the trailing edge of the left-hand elevator, at its outboard section, was in firm contact with the trunk of another tree. The fracture surfaces of the torque tube rivets indicate the direction of movement of the torque tube's input flange relative to the rivets. This direction corresponds to the right-hand elevator being moved by external loads in a downward direction relative to a stationary torque tube/left-hand elevator or a torque tube/left-hand elevator exerting an upward input to a stationary or downward-moving right-hand elevator. Post-recovery examination found that there was no restriction in the movement of the elevators. The overall severity of impact and the nature of the tail section's contact with the adjacent trees, combined with both axial and circumferential components to the shear failure of the rivets, and the lack of evidence of fatigue, indicate that the failure of the rivets occurred as a result of the impact sequence.

Examination at the accident site found that the elevator trim tab position indicated a slight nose-up trim setting. However, due to the nature of the extent of damage to the aircraft, this may not have been a reliable indication. Also, due to the damage sustained to both wings, it was not possible to positively establish the position of the trailing edge flaps at the accident site. However, during detailed wreckage examination at the AAIU's facility in Gormanston, the flap actuator was found to be extended by approximately 40 mm (**Photo No. 6 in Section 1.12.3.1**). According to data provided by the Manufacturer, this equates to a flap extension of approximately 20°. This is supported by the position of the flaps' guide rollers in their tracks, as observed at the accident site, which indicated some degree of extension.

Video recordings obtained from the skydivers show the trailing edge flaps in a partially extended state as the skydivers exited the aircraft. It is possible that following the extension of the flaps to facilitate the skydivers' jump on the accident flight, the aircraft descended with the flaps remaining in the 20° position. This is consistent with the information received during interviews with Club personnel, one of whom was aware that the Pilot descended with the flaps at 20° on other flights. However, it is also possible that the Pilot retracted the flaps to a position other than 20° for the descent and subsequently extended them in preparation for landing. A skydiver at the Club advised the Investigation that he had been on board the aircraft for the duration of another flight and recalled that the aircraft descended with the flaps retracted on that occasion.

2.3.2.1 Pilot's Sun-Visor

The Investigation noted that there was a defect entered in the technical logbook on 17 February 2018 regarding the pilot's sun-visor. A video recording from a skydiver who was on board the aircraft the day before the accident appears to show that the left-hand sun-visor was actually missing at that time and was likely missing on the accident flight. The Investigation therefore considered the possibility that glare from the sun was a factor.



A skydiver's video from the accident flight shows the Pilot wearing sunglasses. Moreover, solar data from the date of the accident indicates that when the aircraft was on an estimated heading of 040° in the final moments of the accident flight, the sun was effectively behind the aircraft. Consequently, the Investigation considers that the missing sun-visor was not a factor in the occurrence.

Nevertheless, the Investigation notes that the aircraft appears to have been provided to the Club with an outstanding technical defect. According to the aircraft owner, the aircraft was normally leased to organisations operating under Part-NCO, which does not require an MEL. However, when an MEL is not in use, the aircraft should not be operated when any of its instruments, items of equipment, or functions required for the intended flight are inoperative or missing. When an aircraft is being operated under Part-SPO, an MEL, derived from the Manufacturer's MMEL and approved by the State of the Operator, is required in accordance with Article 30 of Regulation (EU) No 2018/1139 and Section ORO.MLR.105 of Commission Regulation (EU) No 965/2012. An MEL developed from the Manufacturer's MMEL would require the defective sun-visor to be rectified within 10 days of it being reported.

2.3.3 Engine and Propeller Examination

The data obtained from the ADAS unit indicated that the engine was performing normally up until the time of impact. Furthermore, the presence of large amounts of organic debris (soil/peat) along the engine's gas path, and the rotational signatures on the engine components, as observed during engine disassembly and examination, also indicated that the engine was performing normally until impact. The Engine Manufacturer noted that the rotational signatures on the engine components indicated that the engine was '*likely in a low to mid power range*' at the time. There was no evidence of pre-impact anomalies with the engine.

The aircraft's propeller blades were severely damaged by the impact sequence. The AAIU shipped the propeller to the Propeller Manufacturer's facility in the USA, where it was disassembled in the presence of the FAA representative who oversaw the work on behalf of the NTSB and the AAIU. The examination found no evidence of fatigue failure or pre-impact anomalies. The Propeller Manufacturer noted that the propeller had '*indications consistent with a mid-level amount of rotational energy absorption (rotation at impact likely with some engine power) during the impact sequence*'. The Investigation found the tip of one of the propeller blades several metres from the main wreckage, which also indicates that the propeller was rotating with a significant amount of energy at impact. This is consistent with the ADAS data and the examination of the engine.

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2.4 Fuel Distribution

The Pilot was reported to have uplifted 200 litres of fuel into the left wing tank before the accident flight. The Investigation considered the possibility that this was because the quantity in the left wing had been lower than what was in the right wing and the Pilot was attempting to correct this during the uplift. However, the Investigation's examination of the light bulbs from the aircraft's annunciator panel (**Section 1.12.3.3**) indicated that the RIGHT WING LOW caution light was illuminated at the time of the accident. This may have been due to the aircraft orientation prior to impact, but could also suggest that the fuel uplift into the left wing tank was not carried out for weight distribution reasons, and actually resulted in the left wing being heavier than the right by up to 352 lbs (200 litres = 352 lbs) on the accident flight. The maximum fuel unbalance permitted by the POH is 200 lbs. A significant quantity of fuel was present at the accident site.

The Investigation notes that, as evidenced by a skydiver's video, the aircraft was being operated on the day before the accident with the red (*Requires Immediate Corrective Action*) FUEL SELECT OFF warning light illuminated and the amber (*May require Immediate Corrective Action*) LEFT FUEL LOW caution light briefly illuminating. The left fuel tank selector was in the OFF position. In this configuration, the red FUEL SELECT OFF warning light will only illuminate if the quantity of fuel in the right wing tank drops below 25 US gallons (which would also cause the RIGHT FUEL LOW light to illuminate) or if the FUEL SEL WARN CB was popped/pulled. The RIGHT FUEL LOW light was not illuminated and therefore the illumination of the red FUEL SELECT OFF warning light was likely due to a popped/pulled CB. Notwithstanding that the right-hand fuel tank on that particular flight likely contained over 25 US gallons of fuel and that following the illumination of the LEFT FUEL LOW caution light, the left-hand tank contained up to 25 US gallons, and also that the aircraft was at all times reasonably close to EICL, its operation in such a configuration was not in accordance with the aircraft's POH.

A photograph provided by a skydiver that was taken on board the aircraft on another flight showed the left fuel tank selected to OFF and the LEFT FUEL LOW, RIGHT FUEL LOW and FUEL SELECT OFF lights illuminated.

Post-accident examination of the aircraft's CB panel identified that the FUEL SEL WARN CB was in the open (popped/pulled) position. If it was in this position during the accident flight, the FUEL SELECT OFF light on the annunciator panel would have been illuminated. However, due to the extent of the damage sustained to the panel, only one of the two bulbs from the FUEL SELECT OFF warning light could be examined. The filament in this bulb appeared to have been in an unlit state at the time of impact, as indicated by shattered, un-stretched filament coils. It is therefore possible that the FUEL SEL WARN CB popped as a result of the impact sequence.



2.5 Flight Data

2.5.1 ADAS Unit

The aircraft's 'ADAS+' unit recovered by the Investigation at the accident site was downloaded by the Engine Manufacturer. Although the unit was not certified as crash-survivable, it was found to have retained data from the entire accident flight and also data from the end of the previous flight. The unit recorded 20 parameters, several of which greatly assisted the Investigation's understanding of the accident sequence. The parameters were recorded at a frequency of 2.045 Hz, i.e. every 0.489 seconds.

According to the IAA's Aeronautical Information Publication (AIP), the runway at EICL has an elevation of 240 ft. The weather report received from Met Éireann indicated that the sea-level air pressure around the time of the accident was 1015 hPa (2 hPa above 'standard' pressure) and that the temperature was approximately 15 degrees (approximately 'standard' temperature). ATC systems adjust the altitude received from an aircraft's transponder, which is calibrated to 1013 hPa and should therefore transmit '0' feet at sea level on a 'standard' day. Around the time of the accident, ATC systems were applying an altitude correction of minus 50 ft.

Altitude data recorded by the ADAS unit is referenced to 'standard' day conditions. Therefore, when the aircraft was on the ground at EICL before taking off on the accident flight, the ADAS unit should have recorded the altitude as 190 ft (240 ft minus 50 ft). However, during the period that the ADAS data indicated that the aircraft was on the ground from the end of the previous flight until the aircraft took-off on the accident flight, the altitude recorded by the ADAS unit fluctuated from -36 ft to 32 ft. This could have been due to wind-induced pressure fluctuations at the static port. The Investigation averaged this as '0'.

The Investigation considers that the discrepancy between the altitude that should have been recorded at EICL and what it actually recorded was likely due to an ADAS calibration issue. To compensate for this and to permit comparison with the data recorded by ATC radar, the Investigation added 190 ft to each altitude figure recorded by the ADAS unit. The Investigation notes that altitude recorded by the ADAS was occasionally repeated in consecutive rows of data and sometimes slightly increased for one row. The Investigation considers that this may have been due to differences in the sampling rate of the transducer used by the ADAS unit to measure static pressure (altitude) and the recording rate of the ADAS unit itself.

The ADAS data indicates the commencement of the take-off roll on the accident flight by an increasing airspeed; the moment the aircraft became airborne is indicated by an increase in altitude, which the Investigation set to an elapsed time of 00:00:00.0 (HH:MM:SS.S). The recorded airspeed at this stage was approximately 77 kts.

Descent commenced approximately 20 minutes after take-off. The recorded fuel flow at this point reduced to '0' (the Engine Manufacturer advised that below 70%-75% Ng fuel flow may not be recorded). The altitude recorded by the ADAS unit (adjusted as outlined above) plotted against time, for the descent phase of flight until the end of the recording is shown in **Figure No. 24**. The Investigation calculated the overall descent rates during each 2,000 ft of the descent from 12,000 ft to 2,000 ft; these are also shown.

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The overall descent rate from 12,000 ft to 2,000 ft was calculated as 3,196 ft/min. The airspeed recorded by the ADAS during this part of the descent was frequently above 155 kts (the aircraft's maximum operating speed with the cargo doors removed) and reached 166 kts at an altitude of approximately 7,900 ft (the degree of accuracy of the recorded airspeed is analysed in **Section 2.5.4**).

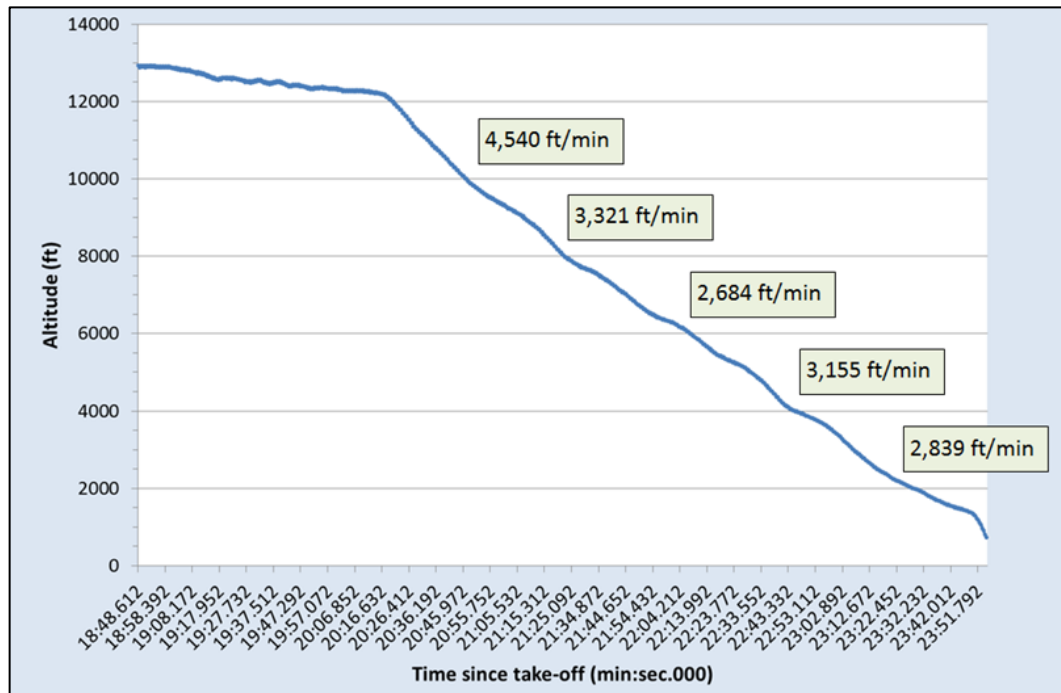


Figure No. 24: Altitude (adjusted) versus time. Overall descent rates also shown

The engine parameters, airspeed and the (adjusted) altitude plotted against time for the final 2,500 ft of the aircraft's descent are shown in **Figure No. 25**. When the (adjusted) altitude reached 2,176 ft (elapsed time of 23:23.43), the fuel flow, having been at zero throughout the descent, increased. There was a corresponding increase in ITT, Ng, and engine torque. This was followed approximately three seconds later by an increase in Np, which continued to increase for the next two seconds. At an elapsed time of 23:27.34 (approximately 27 seconds from the end of the recording and at an adjusted altitude of 2,036 ft), the fuel flow and correspondingly, the ITT had reduced slightly. The torque had also reduced. The overall rate of descent in this period was 2,148 ft/min.

Over the next 6.5 seconds approximately, the fuel flow and correspondingly, the ITT, increased, as did the Ng. During this time, the torque increased from 198 ft lbs to 766 ft lbs. The elapsed time at the end of this period was 23:33.69 (approximately 21 seconds from the end of the recording). The (adjusted) altitude was 1,798 ft. The overall rate of descent in this period was 2,249 ft/min.

Over the course of the next 13 seconds approximately, until an elapsed time of 23:46.90 seconds was reached (7.8 seconds from the end of the recording), all engine parameters remained approximately stable. The (adjusted) altitude at this stage was 1,437 ft. The overall rate of descent was 1,640 ft/min. Then, the fuel flow, ITT and Ng reduced for approximately one second. The torque also reduced from approximately 727 ft lbs to 573 ft lbs. The fuel flow, ITT and Ng then increased for approximately one second. The torque also increased during this period and peaked at 1,535 ft lbs.



The fuel flow, ITT and Ng then reduced over the next 2.5 seconds approximately until an elapsed time of 23:51.30 was reached. The torque also reduced during this time. The (adjusted) altitude at the end of this period was 1,219 ft. The overall rate of descent from 1,437 ft (adjusted altitude) to 1,219 ft was 2,972 ft/min.

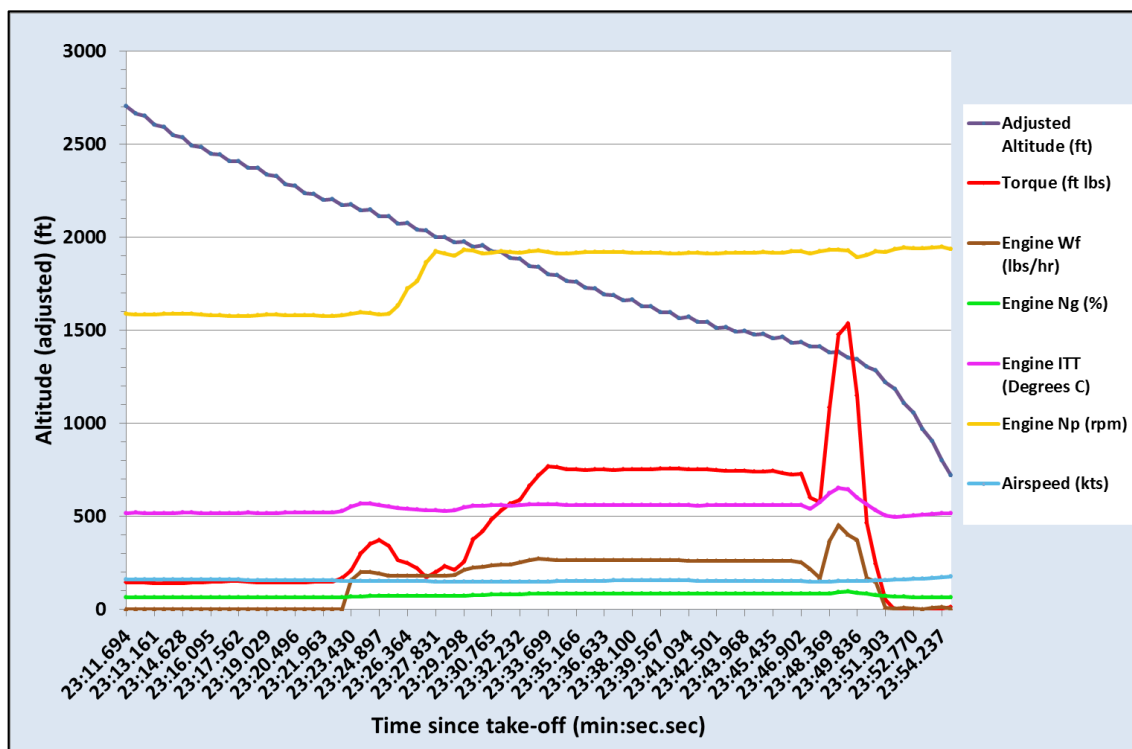


Figure No. 25: The final 2,500 ft of the aircraft's descent

The ADAS unit recorded data for a further 3.5 seconds approximately. The descent rate increased rapidly during this period. The final (adjusted) altitude was approximately 720 ft. The height of the accident site is approximately 230 ft AMSL, which is 10 ft lower than EICL. Therefore, based on the air pressure on the day, the (adjusted) ADAS would have been expected to be approximately 180 ft at impact. This aspect and the likely descent rates experienced during the final 3.5 seconds are analysed further in **Section 2.5.2**. The elapsed time from take-off until the end of the ADAS recording was 23:54.726.

2.5.2 ATC and ADAS Data Comparison

In order to establish the degree of accuracy of the altitude data from the ADAS unit, the Investigation compared this data, which was recorded at 0.489 second intervals, with the altitude data obtained from ATC for the Dublin-based radar head, which was recorded every three or four seconds.

The Engine Manufacturer downloaded the ADAS data into a spreadsheet, with each row of the spreadsheet incrementing at 0.489 second intervals. The time of day recorded by the ADAS unit was incorrect. However, the ATC data from the Dublin-based radar head, which had also been extracted into a spreadsheet, was UTC time-stamped in HH:MM:SS format. To facilitate a comparison of the ATC altitude data with the ADAS data, the Investigation separated each UTC time-stamped ATC altitude reading with the appropriate number 0.489 second intervals. The maximum (adjusted) ADAS altitude value was 12,926 ft.

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The altitude data from the Dublin-based radar head, as received by the Investigation, had not been corrected for the air pressure on the day. A 50 ft baro-correction was in use by ATC software systems that day. Therefore, the Investigation subtracted 50 ft from each Dublin-based radar head altitude value. The maximum altitude recorded by the Dublin-based radar head was 12,900 ft. The Investigation adjusted this to 12,850 ft and aligned it with the maximum (adjusted) ADAS altitude, which the Investigation deemed to be the most appropriate point to facilitate a comparison of all altitude values. The aligned ADAS and ATC altitude data were then graphed (**Figure No. 26**) and it was found that the (adjusted) ADAS altitude data was reasonably consistent with the ATC altitude data.

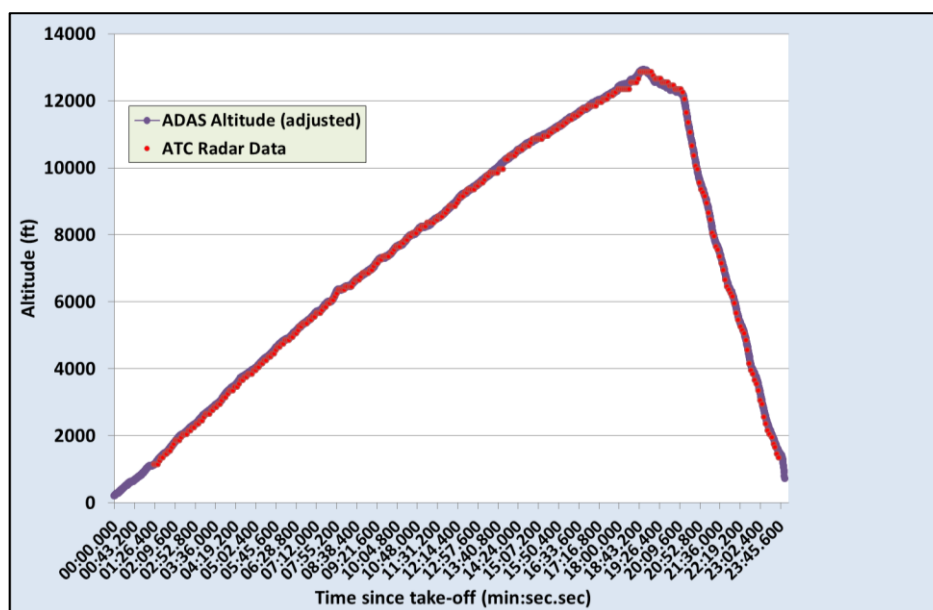


Figure No. 26: ADAS altitude (adjusted) versus data from Dublin-based radar head

The alignment of the ADAS data, which was not UTC-referenced, with the UTC-referenced ATC data, permitted the Investigation to estimate the time of take-off and the time of the accident. It was estimated that the aircraft took off from EICL at time 13:13:49 and that the accident occurred at time 13:37:44.

As outlined in the previous section (**Section 2.5.1**), due to the air pressure on the day, the ADAS unit should have recorded an altitude of approximately 190 ft at take-off from EICL; however, as highlighted earlier, the average value recorded was approximately '0'. To compensate for this, the Investigation added 190 ft to all altitude figures recorded by the ADAS unit. Therefore, at the moment of impact, which was at a location that was approximately 10 ft below the height above sea-level of EICL, the adjusted ADAS altitude should have been approximately 180 ft, whereas it was approximately 720 ft ($529.8 + 190$). The Investigation considered the possibility that the ADAS unit was unable to write the final row or two of data to memory as a result of the impact. However, the final seconds of ADAS data are consistent with what was observed on the CCTV recording. It is therefore considered more likely that the transducer used by the ADAS unit to measure static pressure was incapable of responding to the pressure changes associated with such a high rate of descent as was experienced in the final 3.5 seconds approximately of the flight. It is also possible that the aircraft's unusual attitude at this stage adversely affected the pressure being measured.



The overall descent rate from the (adjusted) altitude of 1,219 ft (obtained approximately 3.5 seconds before the end of the recording and around the time of the commencement of the near-vertical descent) to 720 ft (the final adjusted altitude figure) was calculated as 8,747 ft/min. However, when instead of 720 ft, a figure of 180 ft is used, which was the estimated pressure altitude of the accident site at the time of the accident, and therefore what the (adjusted) altitude should have been, an overall descent rate of 18,212 ft/min (304 ft/sec) in the final 3.5 seconds was obtained. This is equivalent to 180 kts. The final airspeed recorded by the ADAS unit was 174 kts approximately.

2.5.3 Comparison of CCTV Recording with ADAS and ATC Data

A CCTV security system located at a wind farm recorded the aircraft for approximately 11 seconds. The camera which captured the aircraft was located at a security hut just outside the wind farm complex and approximately 1.2 NM (2.2 km) north-west of the accident site. For the first 7.5 seconds approximately of the recording, the aircraft can be seen to be following what appears to be a normal trajectory, before it rapidly descended in the final 3.5 seconds approximately, in what appears to be a near-vertical attitude. At the request of the Investigation, the NTSB analysed this recording.

The Investigation examined the ADAS data in conjunction with the analysis of the CCTV recording. The ADAS data indicates that during the descent from approximately 12,000 ft until when the aircraft reached approximately 2,176 ft (adjusted altitude), the engine power was at a low level. A low power setting during the descent would be normal. To arrest an aircraft's descent, while maintaining airspeed, an increase in engine power would be one of the inputs required by a pilot. When the aircraft reached an (adjusted) altitude of 2,176 ft, which the alignment with the ATC data indicated was when the aircraft had just completed a left-hand turn and was on a straight south-easterly track, back in the general direction of EICL (**Figure No. 27**), the ADAS unit recorded an increase in fuel flow, with a corresponding increase in other engine parameters. Approximately 4.5 seconds later, the recorded propeller speed (Np) had increased to over 1,900 rpm, having been less than 1,600 rpm throughout the descent; this is consistent with the propeller lever being advanced in preparation for landing.

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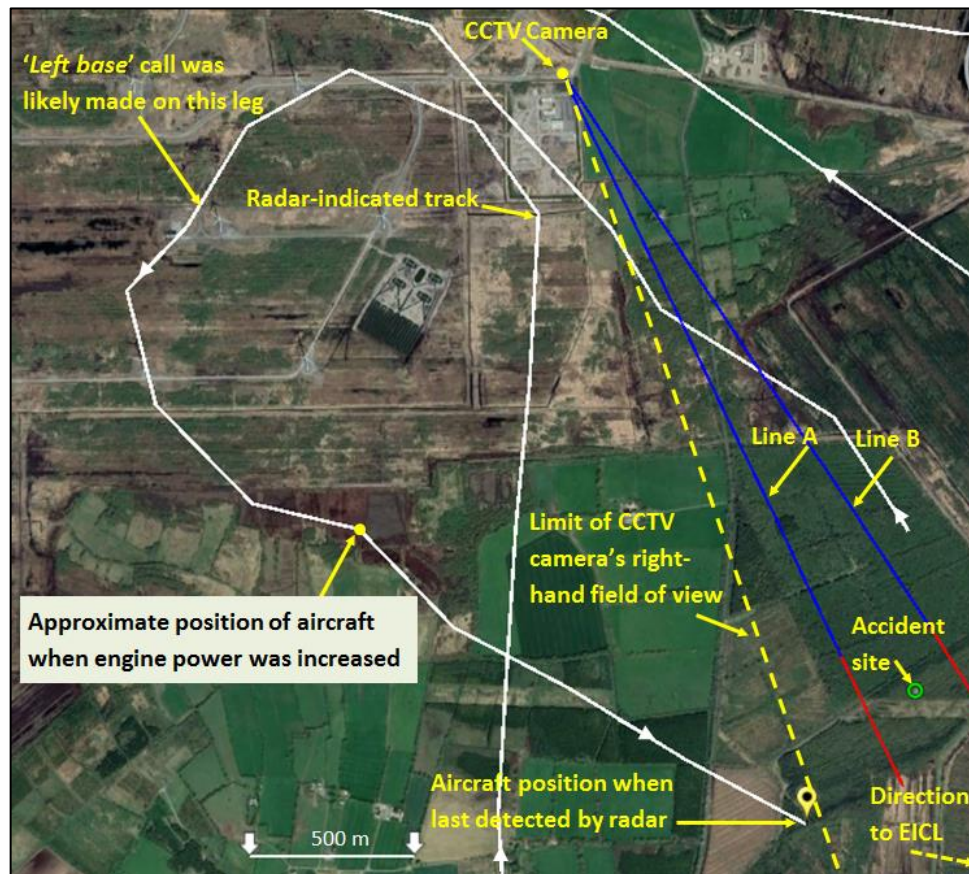


Figure No. 27: Approximate position of aircraft when power was first increased in descent

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The parameters are reproduced in tabular form in **Figure No. 28**; the line of data corresponding with the increase in fuel flow and other engine parameters is highlighted in purple. It is likely that the Pilot's radio transmission to EICL, advising that the aircraft was on 'left base', was made during the earlier part of this turn, while the aircraft was on a south-westerly heading, before the turn continued to put the aircraft on a heading towards EICL. This was the final transmission received from the Pilot.

| | A | B | C | D | E | F | G | H |
|------|----------------------------------|-----------------------|--------------------|------------------|--------------------|--------------------|-------------------|------------------------------|
| 1 | Flight Time (0.489 Second) | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Torque (ft lbs) | Airspeed (kts) | Adjusted Altitude (ft) |
| 2868 | 23:21.474 | 0.000 | 518.332 | 64.863 | 1577.6689 | 147.541 | 155.195 | 2230 |
| 2869 | 23:21.963 | 0.000 | 519.049 | 64.855 | 1576.886 | 145.983 | 154.376 | 2200 |
| 2870 | 23:22.452 | 0.000 | 520.926 | 64.877 | 1576.887 | 148.925 | 154.239 | 2202 |
| 2871 | 23:22.941 | 0.000 | 528.666 | 65.139 | 1578.342 | 169.173 | 153.557 | 2172 |
| 2872 | 23:23.430 | 153.873 | 549.784 | 66.822 | 1587.272 | 206.033 | 153.420 | 2176 |
| 2873 | 23:23.919 | 201.056 | 566.533 | 68.790 | 1594.3051 | 298.444 | 152.738 | 2144 |
| 2874 | 23:24.408 | 200.248 | 568.711 | 71.663 | 1591.124 | 352.090 | 152.738 | 2146 |
| 2875 | 23:24.897 | 190.148 | 560.465 | 72.684 | 1584.202 | 370.953 | 152.328 | 2110 |

Figure No. 28: ADAS data from when aircraft had just completed a left-hand turn and was on a heading back in the general direction of EICL (altitude adjusted)



An extract from the final 11 seconds of the ADAS data referenced to the CCTV recording timings is shown in tabular form in **Figure No. 29** and in graphical form in **Figure No. 30**.

| | B | C | D | E | F | G | H | I | J |
|------|-----------------------|--------------------|------------------|--------------------|--------------------|-------------------|------------------------------|--|-------------------|
| 1 | Engine Wf (lbs/hr) | Engine ITT (°C) | Engine Ng (%) | Engine Np (rpm) | Torque (ft lbs) | Airspeed (kts) | Adjusted Altitude (ft) | Elapsed time aircraft visible in CCTV, referenced to ADAS | |
| 2913 | 261.292 | 559.296 | 83.990 | 1914.557 | 743.538 | 152.192 | 1490 | 0 | First Visible |
| 2914 | 261.178 | 558.946 | 84.008 | 1915.877 | 743.538 | 151.646 | 1495 | 0.489 | |
| 2915 | 260.790 | 559.642 | 83.996 | 1916.868 | 740.423 | 150.554 | 1474 | 0.978 | |
| 2916 | 260.721 | 560.053 | 83.978 | 1917.6949 | 739.384 | 150.281 | 1478 | 1.467 | |
| 2917 | 260.698 | 560.169 | 83.978 | 1913.417 | 741.807 | 150.145 | 1455 | 1.956 | |
| 2918 | 261.018 | 560.019 | 83.966 | 1915.9041 | 731.078 | 150.281 | 1462 | 2.445 | |
| 2919 | 260.676 | 560.190 | 83.960 | 1922.34 | 723.117 | 149.735 | 1433 | 2.934 | |
| 2920 | 253.148 | 560.279 | 83.924 | 1921.673 | 727.444 | 149.735 | 1437 | 3.423 | Line A |
| 2921 | 217.018 | 541.276 | 82.999 | 1912.168 | 597.653 | 149.326 | 1412 | 3.912 | Frame at 3.9 secs |
| 2922 | 169.452 | 573.702 | 81.750 | 1923.629 | 573.945 | 149.189 | 1412 | 4.401 | |
| 2923 | 367.657 | 625.148 | 84.687 | 1930.364 | 1082.204 | 148.780 | 1381 | 4.890 | |
| 2924 | 452.262 | 650.188 | 91.788 | 1929.134 | 1475.208 | 149.735 | 1384 | 5.379 | |
| 2925 | 401.010 | 645.073 | 93.823 | 1925.574 | 1535.604 | 150.008 | 1351 | 5.868 | |
| 2926 | 372.488 | 601.136 | 89.517 | 1892.062 | 1146.580 | 151.100 | 1344 | 6.357 | |
| 2927 | 168.260 | 561.827 | 83.748 | 1901.231 | 463.364 | 152.738 | 1305 | 6.846 | Frame at 6.8 secs |
| 2928 | 147.803 | 529.965 | 76.252 | 1921.866 | 241.855 | 154.376 | 1283 | 7.335 | Start of near- |
| 2929 | 6.188 | 505.403 | 71.925 | 1919.53 | 53.400 | 155.331 | 1219 | 7.824 | vertical descent |
| 2930 | 2.997 | 496.258 | 67.225 | 1934.759 | -2.669 | 157.924 | 1182 | 8.313 | |
| 2931 | 5.993 | 498.884 | 65.823 | 1941.9871 | -6.995 | 159.732 | 1106 | 8.802 | |
| 2932 | 2.997 | 503.198 | 65.192 | 1940.457 | -0.073 | 161.858 | 1054 | 9.291 | |
| 2933 | 0.000 | 508.141 | 65.075 | 1937.75 | -0.765 | 164.360 | 966 | 9.780 | |
| 2934 | 8.504 | 512.325 | 65.039 | 1942.854 | -5.092 | 167.612 | 904 | 10.269 | |
| 2935 | 9.857 | 515.860 | 65.090 | 1946.58 | 2.176 | 170.613 | 800 | 10.758 | Line B |
| 2936 | 2.706 | 517.063 | 65.191 | 1936.095 | 12.213 | 174.246 | 720 | 11.247 | End of recording |

Figure No. 29: Final 11 seconds of ADAS data (altitude adjusted), referenced to CCTV

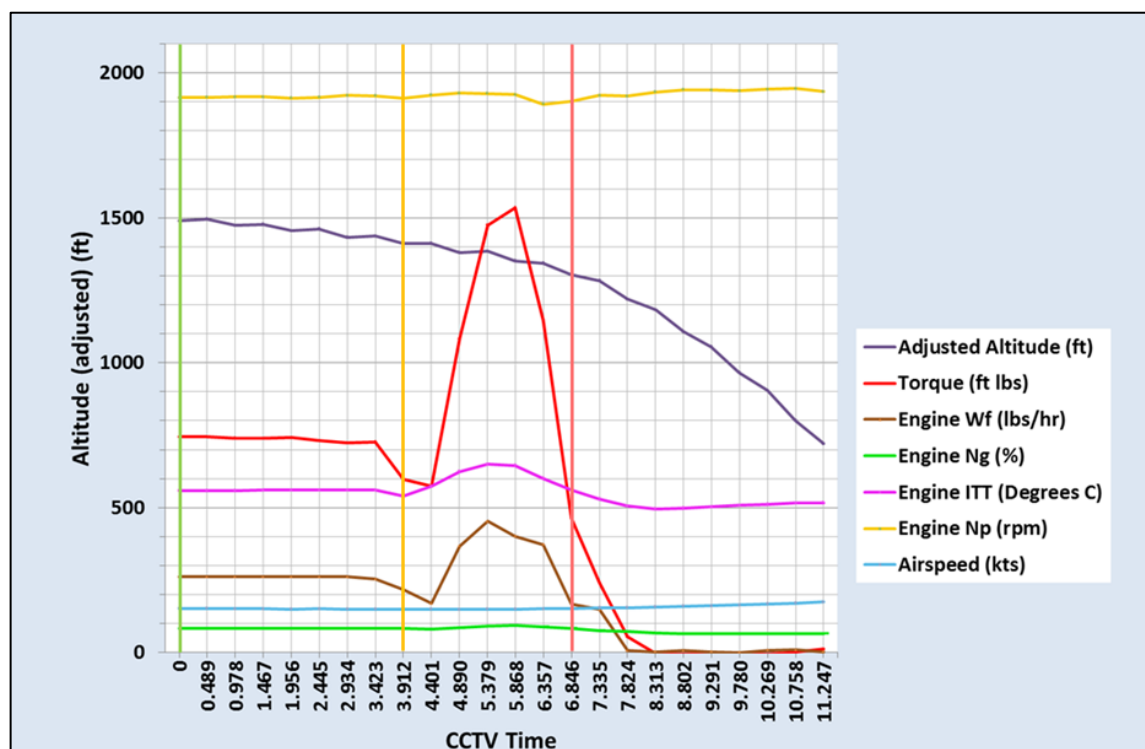


Figure No. 30: Final 11 seconds of ADAS data with reference to CCTV recording timings

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The fuel flow figure of 261.292 lbs/hr recorded around the time that the aircraft was first visible in the CCTV recording (as contained in the row highlighted in green in **Figure No. 29** and indicated by the vertical green line in **Figure No. 30**) had remained constant at that figure (approximately) for the previous 10 seconds, as had other engine parameters, including torque. A review of the descent rates in further detail shows that the aircraft's rate of descent reduced to approximately 929 ft/min between 1,490 ft, which is the (adjusted) altitude corresponding to when the aircraft was first visible in the CCTV recording, and 1,437 ft, which is the (adjusted) altitude of the aircraft corresponding to when it was at Line A (3.3 seconds into the CCTV recording).

A reduction in fuel flow and other engine parameters can be observed in the row highlighted in amber in **Figure No. 29**, and at the matching vertical amber line in **Figure No. 30**. This is the ADAS data that corresponds with the CCTV frame analysed by the NTSB, which was 3.9 seconds after the aircraft was first visible in the recording. The fuel flow continued to decrease for another half second approximately.

In the subsequent one second approximately, the fuel flow rapidly increased, with an associated increase in other engine parameters. The recorded engine torque continued to increase to 1,535 ft lbs over the next half second approximately, before reducing over the course of the next two seconds approximately to 53.4 ft lbs, associated with a now decreasing fuel flow. The data from approximately one second before this (row highlighted in pink in **Figure No. 29** and vertical pink line in **Figure No. 30**) corresponds with the CCTV frame analysed by the NTSB, that was 6.8 seconds after the aircraft was first visible in the recording and just before the aircraft entered the steep descent observable in the CCTV recording, approximately 3.5 seconds before the end of the recording.

The ADAS unit does not measure power lever angle. However, there would be a time lag from when a power lever is moved forward, until when the engine rotational speed (Ng) increases and a subsequent increase in torque is recorded. Therefore, it is likely that the power lever on the accident aircraft was moved forward closer to when the aircraft was at Line A and possibly before it. A similar lag may also have occurred between the altitude recorded in a particular row of ADAS data compared to the aircraft's actual altitude, particularly at higher descent rates, when the altitude is changing rapidly.

The Ng reduced to approximately 65% during the final 3.5 seconds, indicating that the power lever was at a low power setting. The engine torque registered negative values during the period, while the Np increased. The engine torque never registered negative values during the descent up to this point and it is likely that the negative values recorded during the final 3.5 seconds were due to the propeller being driven by the airflow acting on it as the aircraft rapidly descended.

Video analysis estimated that the aircraft's altitude at time 3.9 seconds (after the aircraft was first visible in the recording) was 1,398 ft and 1,217 ft at time 6.8 seconds. Using these figures, the aircraft's estimated rate of descent was approximately 3,745 ft/min. Video analysis estimated the ground speed to be 143 kts (73.5 m/s) during this period. This information corresponds reasonably well with the ADAS altitude data and speed data recorded in that time frame (**Table No. 9**). The descent rate of 2,188 ft/min as calculated from the ADAS data for this period is significantly lower.



| Video-based estimates | | | | Data from ADAS Unit | | |
|-----------------------|----------|-----------|--------------|---------------------|----------|--------------|
| Time | Altitude | Gnd Speed | Descent Rate | Altitude | Airspeed | Descent Rate |
| 3.9 | 1,398 ft | - | | 1,412 ft | 149 kts | |
| 6.8 | 1,217 ft | 143 kts | 3,745 ft/min | 1,305 ft | 152 kts | 2,188 ft/min |

Table No. 9: Comparison of video-based estimates and ADAS data

If the possibility of a lag between the altitude recorded by the ADAS unit compared to the aircraft's actual altitude is considered, and the (adjusted) ADAS altitude data from two rows (0.98 seconds) after each data row corresponding to CCTV times 3.9 and 6.8 seconds is used, the video-based altitudes and descent rate and the ADAS altitudes and descent rate are more closely aligned (**Table No. 10**).

| Video-based estimates | | | | Data from ADAS Unit | | |
|-----------------------|----------|-----------|--------------|---------------------|----------|--------------|
| Time | Altitude | Gnd Speed | Descent Rate | Altitude | Airspeed | Descent Rate |
| 3.9 | 1,398 ft | - | | 1,381 ft | 148 kts | |
| 6.8 | 1,217 ft | 143 kts | 3,745 ft/min | 1,219 ft | 155 kts | 3,313 ft/min |

Table No. 10: Comparison of video-based estimates and ADAS data, with allowance for lag

2.5.4 Airspeed as Recorded by the ADAS Unit

The ADAS data indicates that the aircraft took off at a ground speed of 77 kts. The Investigation estimated that the aircraft's take-off weight was 8,738 lbs. The POH indicates that the take-off speed for a normal (i.e. not a short field) take-off at the maximum take-off weight is 83 KIAS. The Investigation therefore considers the airspeed as recorded by the ADAS unit at lower values to be reasonably accurate (the tolerance for recorded airspeed values is $\pm 5\%$).

The aftercast received from Met Éireann stated that the wind at 2,000 ft was '*Circa 230° at 10-15 kts*'. When an aircraft is in straight and level flight in still air, its airspeed and ground speed will be the same. If an aircraft experiences a headwind in straight and level flight, its airspeed will be higher than its ground speed. Conversely, if an aircraft experiences a tailwind in straight and level flight, its ground speed will be higher than its airspeed. When descending in still air at a constant airspeed, the airspeed would normally be higher than the ground speed, due to the greater '*distance*' travelled. Higher rates of descent would result in a greater difference. The video analysis estimated that the aircraft was on a heading of approximately 040° in the moments before the aircraft descended in a nose-down attitude. Therefore, the aircraft would have been subject to a tailwind. However, when descending at the rates indicated by the data, the effect of the tailwind would likely be reduced. This could result in the airspeed actually being greater than the estimated ground speed, which is what is shown in **Table No. 9**. It should be noted that a $\pm 5\%$ tolerance for airspeed values recorded by the ADAS unit could result in a recorded value of between 142.5 kts and 157.5 kts for an actual airspeed of 150 kts.

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The average ground speed of the aircraft as calculated from the last 20 seconds of ATC radar-indicated values was 150 kts. The airspeed as recorded by the ADAS over the same time period averaged 151 kts. The aircraft was on a heading of 119° during this period and a 10–15kt 230° wind would result in the aircraft experiencing a maximum tailwind component of 5.4 kts ($\sin 21^{\circ} \times 15$). However, as outlined above, the rate of descent would have reduced or possibly cancelled this effect, resulting in the airspeed recorded by the ADAS at this stage of the flight being greater than the ground speed as indicated by ATC radar. The Investigation therefore considers the airspeed recorded by the ADAS unit at higher speeds to also have been reasonably accurate.

During the descent, the ADAS frequently recorded airspeeds above 155 kts (the aircraft's maximum operating speed with the cargo doors removed) and reached a speed of 166 kts at an altitude of approximately 7,900 ft. Maintenance records indicate that a calibration check of the aircraft's two airspeed indicators was performed during a maintenance visit that was certified on 12 December 2017 and therefore were likely recording the correct airspeed on the date of the accident.

Once the skydivers exited the aircraft, the aircraft's weight would have been approximately 5,588 lbs (3,150 lbs subtracted from the estimated take-off weight of 8,738 lbs). This does not include an adjustment for the fuel consumed, which the technical logbook records indicated was 100 lbs per flight. According to the POH, the maximum manoeuvring speed (V_A), above which '*full or abrupt control movements*' should not be made, is 112 kts at an aircraft weight of 5,000 lbs and 125 kts at a weight of 6,250 lbs.

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2.6**The Final Stages of the Accident Flight****2.6.1****Nature of the Turn Performed**

The video analysis estimated the aircraft's bank angle as being either $50^{\circ} \pm 5^{\circ}$ right wing down (i.e. a right turn) or $-130^{\circ} \pm 5^{\circ}$ left wing down between times 3.9 and 6.8 seconds after the aircraft became visible in the CCTV recording. These attitudes would appear as the same profile in the analysis of the CCTV recording; the associated report stated that '*based on the optical analysis alone, it cannot be determined which bank angle estimate is more "correct"*'.

The video analysis estimated that the aircraft was on a heading of approximately 040° between times 3.9 and 6.8 seconds. The Investigation therefore considered the nature of the turn that would be required to bring the aircraft from the last position and track, as indicated by ATC radar data, onto such a heading. At this stage, Line A and Line B were to the aircraft's left when viewed from the cockpit, which indicates that a left-hand turn was being performed. A left-hand turn would permit the Pilot, who was seated in the left-hand cockpit seat, to view the ground during the turn and to optimise his visual scan. The Investigation notes that ATC radar data indicated that the aircraft's previous manoeuvre had been a left-hand turn which had put the aircraft on a heading towards EICL.



The Investigation estimated the radius (r) of the left-hand turn required to reach Line A and take up a heading of 040° to be between 250 m and 500 m (**Figure No. 31**). A turn with a radius of 250 m (dotted white line in **Figure No. 31**) would result in the track indicated by the dashed white line, and the aircraft remaining reasonably close to the accident site, prior to the aircraft's near-vertical descent and within the red-coloured $\pm 10\%$ lengths of Line A and Line B (the minimum and maximum distances of the aircraft to the CCTV camera as estimated in the video analysis). A turn with a radius of 500 m (dotted amber line) would result in the track indicated by the dashed amber line, and the aircraft being beyond the end of Line A, and also further from the accident site.

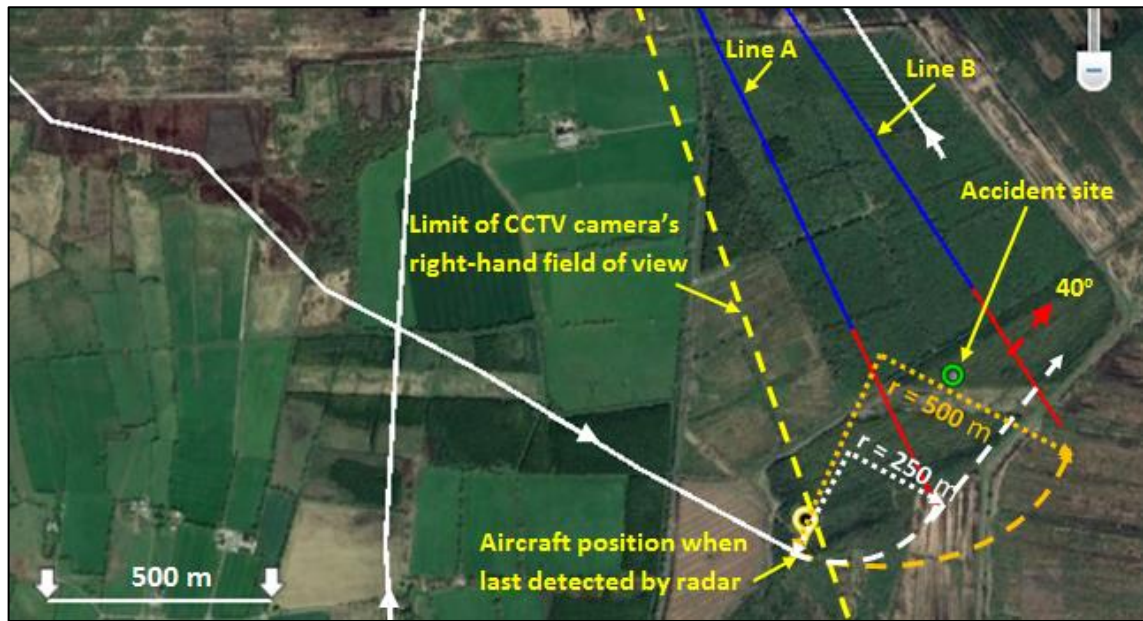


Figure No. 31: Possible turns performed (dashed amber and dashed white lines)

Using the formula below, which the Investigation acknowledges applies to coordinated turns, the Investigation estimated that a bank angle of approximately 46.6° would have been required to perform a turn of radius 500 m at a conservatively estimated airspeed of 140 kts (72 m/s):

$$\tan \theta = \frac{v^2}{(r \times g)} = \frac{72^2}{(500 \times 9.81)} = 1.05688 \therefore \theta = 46.58^\circ$$

Note: A speed of 145 kts (74.59 m/s), results in a bank angle of 48.6° .

To perform a turn of radius 250 m at 140 kts (72 m/s), a bank angle of approximately 64.7° would have been required:

$$\tan \theta = \frac{v^2}{(r \times g)} = \frac{72^2}{(250 \times 9.81)} = 2.1138 \therefore \theta = 64.68^\circ$$

Note: A speed of 145 kts (74.59 m/s), results in a bank angle of 66.2° .

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Based on the foregoing calculations, the Investigation estimated that the bank angle in the earlier part of the manoeuvre (i.e. to reach Line A) was between 46° and 66° , with a bank angle in the upper part of the range considered more likely. A steep bank angle is consistent with what Witness No. 1 observed, who noted that the aircraft was flying '*sideways*' on its left side and Witness No. 2, who observed a wing '*sticking up*'. The Investigation similarly estimated the bank angle of the previous left-hand turn as approximately 45° . The airspeed recorded by the ADAS unit corresponding to when the aircraft first became visible in the CCTV recording and had likely commenced a left-hand turn, was 152 kts approximately, which at the aircraft's estimated weight, was well above V_A , the aircraft's maximum manoeuvring speed (the maximum speed at which full or abrupt control movements may be used without overstressing the airframe).

The aircraft had been operated by the accident Pilot since it arrived in EICL on 21 April 2018. Another pilot, who had experience on the aircraft type, was at EICL on the day before the accident and had witnessed the aircraft's descent on that day. He said that the aircraft descended in what appeared to be a '*very severely pitched down*' attitude and then performed what was described as a '*tight bank ninety degrees*', and that several of these manoeuvres were performed. He described these as flipping the aircraft from '*one side to the other side*' and considered the manoeuvres to be '*aerobatic*' in nature. According to the aircraft's POH, bank angles in excess of 60° are outside the aircraft's certification category.

The alignment of the ATC and ADAS altitude data as outlined earlier resulted in an estimated remaining flight time of approximately 4.4 seconds from the time that the aircraft was last detected on radar until it reached Line A. The Investigation estimated the minimum length of a reasonable flight path for a left-hand turn from when the aircraft was last detected on radar to be approximately 393 m ($2\pi \times 250/4$). At a ground speed of 140 kts (72 m/s) to 155 kts (79.7 m/s), this would take 4.9 to 5.5 seconds to complete. This duration is reasonably consistent with the time available (4.4 seconds) as calculated from the ADAS/ATC data alignment.

2.6.2 Reason for Turn Performed

The Investigation considered why, what appears to be the commencement of a left-hand turn, was carried out when the aircraft had been on a track back in the general direction of EICL. At the time of the last radar return, the aircraft was at an altitude of approximately 1,350 ft (1,110 ft above the height of EICL) and was approximately 2.3 NM (4.26 km) from the threshold of RWY 09. At that distance, in order to achieve a normal approach profile of 3° , the aircraft should have been at a height of approximately 690 ft (2.3×300) above the runway. It is possible therefore that the Pilot intended to perform another left-hand turn, similar to the aircraft's previous turn, to reduce the aircraft's altitude prior to final approach.

The average ground speed of the aircraft as calculated from the last 20 seconds of ATC radar-indicated values was 150 kts. The airspeed as recorded by the ADAS over the same time period averaged 152 kts. The aircraft's landing speed, as stated in the POH is '*75-85 KIAS*', and it is also possible that the manoeuvre was intended to reduce the aircraft's speed, prior to an approach to the runway, which in the prevailing wind conditions, would have been subjected to a tailwind. Another possibility was that the Pilot saw a skydiver still descending under canopy; one of the skydivers' videos showed two skydivers descending with their parachutes deployed shortly before the accident occurred, one of whom was to the north-west of the airfield.



2.6.3 Aerodynamic Aspects

When banking, an aircraft's outside (up-going) wing produces more lift. However, it also produces more drag, which tends to yaw the aircraft in a direction opposite to the intended turn. To keep the turn coordinated, rudder in the direction of the turn is applied (bottom rudder). If the rudder application is excessive, a skidding turn will occur and the corresponding increase in yaw will cause the up-going wing to experience a faster airflow than the inside wing. This will tend to cause the aircraft to overbank into the turn and will tend to rotate the nose of the aircraft towards the ground. Opposite aileron may be required to counteract this tendency, which will increase the angle of attack on the inside wing. An application of opposite aileron would cause an aircraft to be in an uncoordinated cross-controlled situation, in which, in a left-hand turn, left rudder and right aileron are applied. According to the FAA's Airplane Flying Handbook (FAA-H-8083-3B) '*Should a stall be encountered with these inputs, the airplane may rapidly enter a spin*'. Transport Canada's Guidance Notes on '*Stall/Spin Awareness*' (TP 13747) state that when an aircraft is in a cross-controlled condition and a stall occurs, '*The inside wing will stall first resulting in a sudden incipient spin*'.

The Investigation estimated that a left-hand turn with a bank angle of between 46° and 66° would have been required for the aircraft to reach Line A (3.3 seconds after the aircraft was first visible in the CCTV recording) (**Figure No. 31** in **Section 2.6.1**), with a bank angle in the upper part of the range considered more likely. The accident aircraft was also descending during the turn. In descending turns, the inside wing travels down a steeper descent path and therefore has a greater angle of attack than the outside wing.

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The video analysis estimated the aircraft's bank angle between time 3.9 seconds (just after Line A) and time 6.8 seconds after the aircraft became visible in the CCTV recording, was either $50^{\circ} \pm 5^{\circ}$ right wing down, i.e. a right-hand turn, or $-130^{\circ} \pm 5^{\circ}$ left wing down. The video analysis noted that '*based on the optical analysis alone, it cannot be determined which bank angle estimate is more "correct"*'. However, as outlined above, the Investigation determined that a left-hand turn would have been required for the aircraft to reach Line A from its last position and track, as indicated by ATC radar data.

The aircraft's rate of descent, based on the ADAS data, had reduced to approximately 929 ft/min between 1,490 ft, which is the (adjusted) altitude corresponding to when the aircraft was first visible in the CCTV recording, and 1,437 ft, which is the (adjusted) altitude of the aircraft corresponding to when it was at Line A (3.3 seconds into the CCTV recording). Between CCTV times 3.9 seconds and 6.8 seconds, the rate of descent, based on the ADAS data, had more than doubled to approximately 2,188 ft/min and may have reached 3,313 ft/min, if, as outlined earlier, an allowance is made for lag between the altitude recorded in a particular row of ADAS data compared to the aircraft's actual altitude. The video-based descent rate during the period was even higher, at 3,745 ft/min. Such an increase in descent rate, which occurred over a three second period, is indicative of a loss of control and is consistent with the $-130^{\circ} \pm 5^{\circ}$ left-wing-down attitude between CCTV times 3.9 seconds and 6.8 seconds, as reported in the video analysis.

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It is possible that the loss of control occurred during the steeply banked turn, just as the aircraft reached Line A, and was as a result of an under-the-bottom stall, which in his book titled '*Emergency Maneuver Training*', the author (Rich Stowell) states involves:

'[...] turning flight in which the inside wing stalls first. The airplane might then yaw and roll sharply into a steeper bank (possibly even inverted) as the nose pitches forward. This stall behaviour is often encountered in descending turns, in skidding turns, and in steep, level turns. Uncorrected, these stalls can quickly transition into a spin whose direction is the same as the initial turn direction (called an under-the-bottom spin).'

However, notwithstanding that an aircraft will stall once its critical AoA has been reached, regardless of the airspeed, the Investigation considers that the airspeed in this case was particularly high and therefore a stall seems unlikely.

The ADAS data indicates that approximately 3.3 seconds into the CCTV recording (Line A), the fuel flow, and consequently engine torque, had reduced for approximately one second. This was immediately followed by a rapid momentary increase in fuel flow to 452 lbs/hr (a figure of 437.6 was recorded at take-off) and a corresponding rapid increase in engine torque from 573 ft lbs to 1,535 ft lbs (the torque recorded at take-off was 1,795.53 ft lbs). The data indicates that the increase was momentary, lasting approximately 1.5 seconds. This suggests that the power lever was advanced to a high power setting and then retarded. Due to the time-lag from when a power lever is moved forward until when the engine rotational speed (Ng) increases and a subsequent increase in torque is recorded, it is likely that the power lever on the accident aircraft was moved at or before the aircraft reached Line A.

The reaction experienced by an aircraft following a rapid increase in torque (as a result of the power lever being advanced), could tend to roll the aircraft further to the left. Such a torque reaction was identified in the AAIU's Investigation Report into an accident involving a Cessna 208B in 2007, although in that case, the aircraft was operating at a much lower speed and the effect was likely more pronounced. The momentary nature of the increase may indicate a realisation of its adverse effect, followed by an attempted recovery.

It is also possible that the Pilot was attempting to perform a steep-banked manoeuvre similar to those witnessed the previous day and lost control of the aircraft during the manoeuvre, inadvertently rolling it beyond 90 degrees. The rapid and large increase in engine torque recorded by the ADAS may have been part of an attempted recovery; however, due to torque reaction, it was likely a contributing factor in the loss of control. The likely heavier left-hand wing due to the previous fuel uplift may have exacerbated the situation.

One of the final frames of the last 3.5 seconds of video that was recorded showed the aircraft with one wing lower than the other as it descended in a near-vertical attitude (lower image in **Figure No. 14** in **Section 1.11.8**). When considered in conjunction with the disposition and condition of the wreckage at the accident site, the lower wing in the video frame was likely the left-hand wing. An incipient spin following an under-the-bottom stall during a left-hand bank would result in such an attitude and cannot be excluded. However, an instinctive reaction in an aircraft that has rolled to a bank angle of $130^{\circ} \pm 5^{\circ}$ (i.e. almost inverted), such as pulling back on the control column, would also result in a rapid descent towards the ground in a similar attitude.



The ADAS data indicates that the engine power on the accident aircraft was further reduced as it entered what appeared to be a near-vertical descent. This power reduction may have been part of a recovery attempt and is consistent with the POH guidance for spin recovery and other publications on the subject. The condition of the engine components as observed during engine disassembly also indicate that the engine was likely in a low to mid power range at the time of impact. When the aircraft was last seen clearly in the CCTV recording, before it disappeared behind a line of trees, the ground speed component of the near-vertical descent indicated motion back in the direction from where it had been travelling in the earlier part of the CCTV recording. This could be due to the aircraft's aerodynamic characteristics; however, it could also indicate the initial stage of an attempted recovery from the near-vertical descent.

According to the video analysis, the accident aircraft was approximately 987 ft above the ground, just before it entered the near-vertical descent. The corresponding (adjusted) ADAS altitude was 1,305 ft. Subtracting 180 ft from this (which is the pressure-corrected altitude of the accident site) results in a figure of 1,125 ft, which is reasonably consistent with the video analysis. A figure of 1,039 ft (1,219-180) is obtained if a 0.98 second allowance (two data samples), as outlined earlier, is made for lag. The aircraft's remaining height above ground was lost in approximately 3.5 seconds and was insufficient to effect a recovery from the near-vertical descent.

2.6.4 Summary of Pilot's Inputs

The Investigation's analysis of the available data indicates that following several inputs consistent with controlled flight, a loss of control occurred, following which there were indications of attempts at recovery.

The Investigation's analysis of ADAS data, combined with the ATC data, indicated that engine power was increased after the aircraft had just completed a left-hand turn and the aircraft was at an altitude of approximately 2,176 ft. Such an increase in power would be one of the inputs required to reduce an aircraft's descent rate, which is what occurred in this case at that time. Approximately 4.5 seconds later, the recorded propeller speed (N_p) had increased to over 1,900 rpm, having been less than 1,600 rpm throughout the descent; this is consistent with the propeller lever being advanced in preparation for landing.

The descent rate was further decreased when the aircraft was likely in the initial phase of a subsequent left-hand turn. The Investigation's analysis of the ADAS data indicated that a further power increase was then made. This increase was rapid and large, and due to the resulting torque reaction, likely had an adverse effect on the aircraft's attitude. The increase was momentary, which possibly suggests a realisation of its adverse effect and an attempted correction. The ADAS data, combined with the analysis of the CCTV recording, indicates that at the commencement of the aircraft's near-vertical descent, engine power was further reduced, which, in addition to the movement of the aircraft back in the direction from where it had been travelling, as evident in the CCTV recording, suggests an attempted recovery from the near-vertical descent.

2.7 Survivability

The Pilot and the Passenger were found secured in their respective cockpit seats by their five-point restraint harnesses. The post-mortem examination identified fractures to the Pilot's upper limbs. Such fractures are consistent with operating the aircraft controls at the time of impact.

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The Passenger's hands and arms also sustained fractures. It is possible that these occurred as a result of his hands also being on the aircraft controls at the time of impact. However, any control column inputs by the Passenger could have been easily overcome by the Pilot and the Investigation considers it more likely that the injuries occurred as a result of an instinctive, defensive reaction before impact. The accident was not survivable.

2.8 Operational Aspects

2.8.1 Introduction

As required by Section ORO.DEC.100 of Commission Regulation (EU) 965/2012, the Club submitted a declaration to the IAA to inform them that G-KNYS was being operated by the Club and indicated that the aircraft was being operated under Part-SPO, as defined by Commission Regulation (EU) No 379/2014, which amended Commission Regulation (EU) No 965/2012. The Investigation notes that the declaration was made on 3 May 2018, which was a number of days after the arrival and first operation of the aircraft by the Club (21 April 2018). The Club declared on the document that it was the '*operator*' of the aircraft. However, the Club subsequently advised the Investigation that it considered the aircraft owner to be the operator. A signed, formal lease agreement would have ensured greater clarity in this regard, but none had been completed.

The Club's Operations Manual stated that all operations within the Club '*shall be carried out in accordance*' with Part-SPO. The requirements of Part-ORO apply to Part-SPO operations and require the operator to '*establish and maintain a system for exercising operational control over any flight operated under the terms of its certificate, SPO authorisation, or declaration*'. In the case of Part-SPO, the competent authority is the '*authority designated by the Member State in which the operator has its principal place of business or is residing*'. As the Club declared itself to be the operator of the aircraft and conducted skydiving operations at EICL, the IAA was the competent authority.

2.8.2 Pilot Requirements

It is a requirement of Commission Regulation (EU) No 1178/2011 that once a pilot receives remuneration, a CPL is required. The Pilot's Class 1 Medical Certificate (required for a CPL) was renewed on 11 May 2018 and rendered the Pilot's CPL valid at the time of the accident. However, the previous Class 1 Medical Certificate had an expiry date of 20 March 2018. Therefore, the Pilot's CPL was not valid during his first two weekends operating at EICL.

The Club's Operations Manual extant on the date of the accident did not contain any procedures regarding leasing of aircraft or the use of pilots associated with a leased aircraft. Furthermore, there was no formal signed contract setting out the terms and responsibilities for the leasing of the aircraft and the Pilot's employment arrangements during the aircraft lease. However, email correspondence between the owner and the Club, indicated that the Club was paying the Pilot directly. This was confirmed by the Club.



The Club advised the Investigation that following the Pilot's arrival with the aircraft on 21 April 2018, he was accompanied on his first parachute flight by a Club member who held a PPL. It is a requirement of Section ORO.GEN.210 of Commission Regulation (EU) 965/2012 (applicable to Part-SPO operations) that an operator shall have sufficient qualified personnel for the planned tasks and activities to be performed. The Club advised the Investigation that it has since '*changed its management system to reflect Part-SPO Operations*' and that it now has '*in place full Part SPO Operations*'. The Regulation does not specifically require the appointment of a chief pilot. However, the Club's Operations Manual contained a requirement for a newly appointed pilot at the Club to carry out 30 Parachute flights under the supervision of the chief pilot or supervising pilot nominated by the chief pilot; this did not occur in this case. In fact, there was no appointed chief pilot at the Club on the date of the accident.

In light of the foregoing, the Investigation makes the following Safety Recommendation to the Club:

Safety Recommendation No. 1

The Irish Parachute Club should revise its Operations Manual to include specific procedures regarding the leasing of aircraft for operations at the Club and the use of pilots associated with such aircraft operations (IRLD2020001).

2.8.3 Human Factors

The post-mortem examination of the Pilot revealed no evidence of heart disease and toxicological tests did not detect alcohol or drugs. Furthermore, based on interviews with the skydivers who had been on board the accident flight and with the provider of the accommodation where the Pilot stayed the night before the accident, the Pilot was well-rested.

2.8.4 Supplemental Oxygen Requirements

The data from the ADAS unit indicates that, on the accident flight, G-KNYS operated between 10,000 ft and 13,000 ft for a period of less than seven minutes and never exceeded 13,000 ft. Therefore, in accordance with the requirements contained in SPO.OP.195, NCO.OP.190 and NCC.OP.210, supplemental oxygen was not required.

2.8.5 Carriage of Passengers

Article 5 of Commission Regulation (EU) 965/2012, as amended by Commission Regulation (EU) 2015/140, prohibits the carriage of persons on board an aircraft being used for specialised operations other than those indispensable to the mission. This restriction applies to both commercial specialised operations (Part-SPO), under which the accident aircraft was being operated, and to non-commercial specialised operations (Part-NCO). Therefore, a passenger should not have been carried on board the accident flight.

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The Club's Operations Manual extant on the date of the accident did not contain any information regarding the carriage of passengers on aircraft being used for parachute operations. However, it did contain a requirement for all pilots to wear a bail-out rig due to the risk of an aircraft becoming 'unflyable' on a jump flight as a result of it being struck by a skydiver or parachute during aircraft exit (the Investigation notes that the Pilot was not wearing a bail-out rig). This requirement is an acknowledgement of a risk which is specific to parachute or skydiving operations and is one reason why a passenger should not be carried on board an aircraft being used for such activities. Accordingly, the Investigation issues the following Safety Recommendation to the Club:

Safety Recommendation No. 2

The Irish Parachute Club should revise its Operations Manual to specifically prohibit the carriage of persons other than those indispensable to the mission on aircraft being used for parachute/skydiving operations as required by Commission Regulation (EU) 965 of 2012, as amended (**IRLD2020002**).

The aircraft owner did not have a policy regarding the carriage of passengers on aircraft that it leased out for parachuting operations and considered that such carriage depended on each operator's requirements. EU legislation specifically prohibits the carriage of persons other than those indispensable to the mission on aircraft being used for parachute/skydiving operations. While acknowledging that the owner's aircraft could be leased to states other than those subject to EU legislation, and that it is an operator's responsibility to operate the aircraft in accordance with the regulations applicable in the state of operation, the Investigation considers that a specific policy in relation to the carriage of persons other than those indispensable to the mission would highlight that prohibitions do exist. Therefore, the Investigation issues the following Safety Recommendation to the aircraft owner:

Safety Recommendation No. 3

Parachuting Caravan Leasing Pty Ltd should revise its aircraft leasing arrangements to specifically prohibit the carriage of persons other than those indispensable to the mission on aircraft it owns being used for parachute/skydiving operations, unless such carriage is permitted by the state of operation (**IRLD2020003**).

2.8.6 The Role of the IAA

The IAA is responsible for the safety regulation of Irish civil aviation. The initial SPO declaration and subsequent SPO change declarations were reviewed and acknowledged by the IAA as required by Section 'ARO.GEN.345 Declaration – organisations' of Commission Regulation (EU) 965/2012; however, an inspection of the Club was not carried out until 17 May 2019. This was more than a year after the accident, 32 months after the Club's initial SPO declaration was submitted, and 12 months after the SPO change declaration was submitted. Although a significant period of time had elapsed from the date of the initial declaration until when the inspection was carried out, the inspection time frame applied by the IAA is in keeping with the Acceptable Means of Compliance for *ARO.GEN.305 Oversight programme*. Furthermore, the IAA advised the Investigation that the Club did not have a continuous period of SPO operations since its initial declaration.



The IAA published three Operations Advisory Memorandums (OAMs) in relation to parachute operations. Although the OAMs point to the regulations applicable to parachute operations, they do not highlight that the carriage of passengers on flights engaged in specialised operations such as parachute operations is prohibited. The promulgation of such information would assist in raising awareness in this regard. Therefore, the Investigation makes the following Safety Recommendation:

Safety Recommendation No. 4

The IAA should revise its Operations Advisory Memorandums (OAMs) regarding parachute operations to highlight that the carriage of persons other than those indispensable to the mission on aircraft being used for such operations is prohibited (IRLD2020004).

3. CONCLUSIONS

3.1 Findings

1. The aircraft, engine, and propeller were operating normally prior to the accident.
2. The aircraft contained a significant quantity of fuel at impact.
3. The aircraft was owned by a UK-based parachute-aircraft leasing company and was being operated by a Club based in Ireland. The aircraft and Pilot first arrived at the Club on 21 April 2018.
4. The Pilot who flew the aircraft to Ireland and when it was based at EICL was recommended by the owner and paid directly by the Club.
5. At the time of the accident, the Pilot was flying the aircraft for a fourth weekend at the Club.
6. The Club's Operations Manual did not contain any procedures regarding the leasing of aircraft or the use of pilots associated with such a lease.
7. There was no formal signed contract outlining the terms and responsibilities for the leasing of the aircraft or the Pilot's employment arrangements.
8. The Pilot's Class 1 Medical Certificate (necessary for a CPL) was renewed on 11 May 2018 and rendered his CPL valid at the time of the accident.
9. The Club based in Ireland submitted a declaration to the IAA on 3 May 2018, which included details of the accident aircraft and indicated it was being operated by the Club under Part-SPO (Specialised Operations). The Club declared on the document that it was the '*operator*' of the aircraft.

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10. Article 5 of Commission Regulation (EU) 965/2012, as amended by Regulation (EU) 2015/140, prohibits the carriage of persons other than those indispensable to the mission on board an aircraft being used for specialised operations (whether Part-SPO or Part-NCO).
11. The Operations Manual of the Club based in Ireland did not contain any procedures regarding the carriage of passengers.
12. The aircraft owner did not have a policy regarding the carriage of passengers in aircraft that it leased out.
13. The aircraft descended at an overall rate of over 3,000 ft/min from 12,000 ft to 2,176 ft.
14. The aircraft's rate of descent reduced when the aircraft reached an altitude of approximately 2,176 ft, just after the aircraft had completed a left-hand turn and had taken up a south-easterly track back in the general direction of EICL.
15. When the aircraft was approximately 2.3 NM (4.26 km) from the threshold of RWY 09 at EICL, it commenced what appears to have been another descending left-hand turn.
16. This descending left-hand turn brought the aircraft into the field of view of a CCTV security camera system.
17. It is likely that the descending turn, which was executed at a speed in excess of 140 kts, was a steep turn which resulted in the left-hand wing's angle of attack (AoA) being close to its critical AoA.
18. The ADAS unit recorded a speed of 166 kts at an altitude of approximately 7,900 ft when the aircraft was in the descent. The aircraft's maximum operating speed (V_{MO}) while operating with the cargo doors removed is 155 kts.
19. The aircraft exceeded its maximum manoeuvring speed (V_A) (112-125 kts) in the descending left-hand turn.
20. Control of the aircraft appears to have been lost during the descending left-hand turn.
21. A rapid and large increase in engine torque recorded by the ADAS during the descending left-hand turn may have been part of an attempted recovery; however, due to torque reaction, it was likely a contributing factor in a loss of control.
22. During the final 3.5 seconds of the accident sequence, the aircraft descended in a near-vertical nose-down attitude. The height of the aircraft above ground at this stage was insufficient to effect a recovery.
23. Video evidence indicated that the aircraft was being operated on the day before the accident with the amber *LEFT FUEL LOW* caution light and the red *FUEL SELECT* warning light illuminated.



24. The aircraft was being operated under Part-SPO without a Minimum Equipment list
25. The aircraft was being operated with the Pilot's sun-visor missing.

3.2 Probable Cause

Impact with terrain following a loss of control in a steeply banked left-hand turn.

3.3 Contributory Cause(s)

1. The steeply banked nature of the turn being performed.
2. Propeller torque reaction following a rapid and large increase in engine torque.
3. The aircraft's speed while manoeuvring during the steeply banked turn.
4. Insufficient height above ground to effect a successful recovery.

4. SAFETY RECOMMENDATIONS

| No. | It is Recommended that: | Recommendation Ref. |
|-----|--|-----------------------------|
| 1. | The Irish Parachute Club should revise its Operations Manual to include specific procedures regarding the leasing of aircraft for operations at the Club and the use of pilots associated with such aircraft operations. | IRLD2020001 |
| 2. | The Irish Parachute Club should revise its Operations Manual to specifically prohibit the carriage of persons other than those indispensable to the mission on aircraft being used for parachute/skydiving operations as required by Commission Regulation (EU) 965 of 2012, as amended. | IRLD2020002 |
| 3. | Parachuting Caravan Leasing Pty Ltd should revise its aircraft leasing arrangements to specifically prohibit the carriage of persons other than those indispensable to the mission on aircraft it owns being used for parachute/skydiving operations, unless such carriage is permitted by the state of operation. | IRLD2020003 |
| 4. | The IAA should revise its Operations Advisory Memorandums (OAMs) regarding parachute operations to highlight that the carriage of persons other than those indispensable to the mission on aircraft being used for such operations is prohibited. | IRLD2020004 |

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Appendix A: PT6A-114A Engine Details

The PT6 is a reverse flow engine (**Figure No. A1**). The air enters the engine at the rear (1) and is then compressed by a three-stage axial flow compressor and a single-stage centrifugal compressor (2). The air then enters the combustion section (3), where it is mixed with fuel. After the combustion section, the air enters a single stage compressor turbine (4) which supplies the power to drive the compressor. The compressors and compressor turbine form the '*gas generator*' (shaded red in **Figure No. A1**). When the air exits the compressor turbine, it enters a single stage power turbine (5) which drives the propeller through a two-stage reduction gearbox. The compressor and turbine stages incorporate stationary guide vanes and circumferential shrouds.

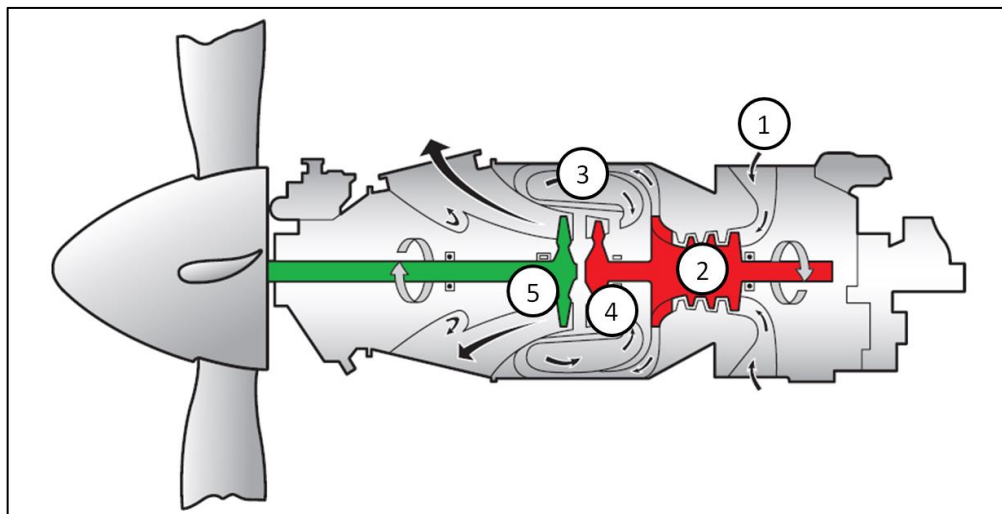


Figure No. A1: Schematic view of engine type

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

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