Air Accident Investigation Unit Ireland

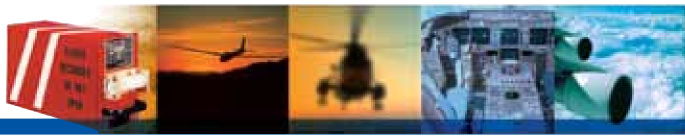
ACCIDENT REPORT
Irish Air Corps 265, PC-9(M)
Cornamona, Connemara, Co. Galway
12 October 2009

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

AAIU Formal Report No: 2011-016
State File No: IRL00909098
Published: 08/11/2011

Operator:	Irish Air Corps (IAC)
Manufacturer:	Pilatus Aircraft Ltd
Model:	PC-9(M)
Nationality:	Ireland (Military)
Registration:	265
Location:	Crumlin East, Cornamona, Connemara, Co. Galway, Ireland N53°32.192'', W009°30.436''
Date/Time (UTC[1]):	12 Oct 2009 @ 16.57 hrs

1 **UTC**: Coordinated Universal Time. Times in this Report are in UTC (local time minus one hour)



SYNOPSIS

The military training flight departed its base at Casement Aerodrome, Baldonnel, Co. Dublin (EIME), on a Visual Flight Rules (VFR) cross-country, navigation-training exercise with Galway Airport (EICM) as the intended destination. Its crew consisted of an Instructor and a Cadet in training who was the handling pilot. The aircraft flew initially northwest and later southwest towards Maum, Co. Galway. As it approached high ground on the western shores of Lough Mask, the weather ahead was deteriorating. The aircraft, keeping in visual contact with the ground, crossed a ridge into a narrow and steep-sided valley. It then commenced a rapid series of steep turns and turned onto a northerly heading while pitching up and climbing into cloud. The aircraft then entered a progressively increasing pitch down attitude while rolling to the right. It impacted the northern slopes of the valley in a steep nose down, wings level attitude at high speed. Both crew members were fatally injured and the aircraft was destroyed.

The Investigation determined that the probable cause of the accident was Controlled Flight Into Terrain (CFIT) attributable to Spatial Disorientation due to a Somatogravic Illusion following the loss of Situational Awareness[2].

NOTIFICATION

Castlebar Fire Station, Co. Mayo initially notified the Air Accident Investigation Unit (AAIU) at 17.10 hrs of a possible aircraft accident. After confirmation, AAIU and Irish Air Corps (IAC) investigation teams were deployed and commenced the investigation at first light the following morning. Members of An Garda Síochána[3] initially secured the accident site and were later assisted by personnel from the Irish Defence Forces.

Whereas initially the IAC took the lead role in the Investigation, the Minister for Defence and the Minister for Transport agreed and directed, pursuant to Regulation 27 (1) of Statutory Instrument No. 205 of 1997, Air Navigation (Notification and Investigation of Accidents and Incidents) Regulations, 1997, that these Regulations would be applied to the investigation of this accident and that therefore the AAIU would conduct the Investigation. Consequently, the Chief Inspector of Air Accidents, on 13 Oct 2009, appointed Paddy Judge as the Investigator-in-Charge (IIC) to carry out a Formal Investigation into this Accident.

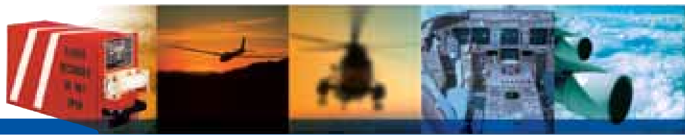
The Minister for Transport appointed three IAC Officers as Inspectors of Air Accidents to assist the IIC in the Investigation. The aircraft and engine manufacturers appointed Advisors who travelled to Ireland to assist the Investigation and an international Expert in Aviation Medicine was later appointed to advise the Investigation.

The sole purpose of this Investigation is the prevention of aviation accidents and incidents. It is not the purpose of the Investigation to apportion blame or liability.

2 These factors are explained in detail in the Report.

3 **An Garda Síochána**: The national police service of Ireland.

INDEX



INDEX

INDEX

INDEX

GRAPHICS

1. FACTUAL INFORMATION

1.1 History of the Flight

1.1.1 General

The Cadet[4] was one of a class of cadets coming to the end of their Pilot Wings course. The Instructor[5] was the aircraft commander and the Chief Flying Instructor (CFI) for the Flying Training School (FTS); he regularly flew with and instructed the class of cadets, as was the case on this flight. The training flight was fourth last in a series of 26 VFR navigational cross-country exercises conducted in accordance with the IAC Pilots Wings course syllabus. The sortie was planned at 1,500 ft QNH[6] with a routing from EIME via Prosperous (Co. Kildare) northwest to Carrigallen (Co. Cavan), west to Maum (Co. Galway) and finally to EICM.

The subject aircraft, 265, was the first of three IAC PC-9(M) aircraft, which departed at 15-minute intervals on the same navigational training exercise. Following completion of pre-flight planning, briefing and pre-departure activity, the aircraft departed EIME at 16.20 hrs, using the call sign "Foxtrot 265" (F265). It was followed in sequence by two other PC-9(M) aircraft, namely F261 and F266. After take-off, the aircraft followed its planned route northwest to Carrigallen, which it passed at 16.38 hrs. At that point, it turned west towards its next waypoint at Maum.

Due to deteriorating weather and high ground on the western shores of Lough Mask, the crew commenced (point A on **Figure No. 1**, page 9) an alternative routing northwest through the Partry Mountains and thence to Maum. This routing was discontinued and the aircraft turned southwest towards Maum keeping in visual contact with the ground (point B on **Figure No. 1**). It crossed a ridge into the narrow and steep-sided Crumlin Valley where it was seen by a number of witnesses. The aircraft then commenced a rapid series of steep turns and turned onto a northerly heading while pitching up and climbing into cloud. The aircraft then entered a progressively increasing pitch down attitude while rolling to the right. It impacted in a steep nose down, wings level attitude at high speed.

The accident site was on the crest of the second and lowest of a series of three ridges on the northern slopes of Crumlin Valley at an altitude of approximately 735 ft. The location was about half a mile north of the direct track between Carrigallen and Maum, 2 nautical miles (NM) northeast of Maum, and 2 NM northwest of the village of Cornamona. Crumlin Valley is enclosed on three sides by high ground (circa 1,500 ft) and has a generally east/west orientation with a narrow entrance to the east.

A local resident of Crumlin Valley called the Emergency Services at 17.02 hrs and reported a possible aircraft accident while other residents searched the mountain. Enquiries at Shannon Low Level Air Traffic Control (ATC), who had been in communication with the three aircraft, established that F261 and F266 were still in communication while F265 was not responding. ATC then requested F261 to search for a missing aircraft but this search was unsuccessful and was abandoned due to rapidly deteriorating weather.

The Marine Rescue Coordination Centre (MRCC) launched an Irish Coastguard Search and Rescue (SAR) helicopter, which took-off from Shannon Airport at 17.35 hrs. It subsequently arrived in the search area at 18.29 hrs, but reported *"difficult foggy weather in the area"* and consequently discontinued the search.

4 **Cadet:** The cadet on F265 is referred as the "Cadet". All other cadets are referred to as "cadet".

5 **Instructor:** The instructor on F265 is referred as the "Instructor". All other instructors are referred to as "instructor"

6 **QNH:** An altimeter barometric setting that displays altitude above sea level.

Two local residents, who had seen the aircraft, climbed to and located the accident site. They found the crew fatally injured, advised An Garda Síochána by mobile phone and later directed the Emergency Services to the accident site. Although visibility and communications were poor, Gardaí arrived at 19.14 hrs and secured the site pending arrival of the investigation teams.

Due to the presence of pyrotechnic devices in the aircraft's ejection seats, no further action was taken during the night. These devices were identified and disarmed the following day by IAC specialist personnel.

1.1.2 Witnesses

1.1.2.1 Witnesses who saw F265

Witness No. 1 **(Figure No. 1)** was located on the south-western shore of Lough Mask, to the northeast of Crumlin Valley, and observed the aircraft from his house at about 16.50 hrs. He saw it turning right, to the northwest, towards a valley and "*into cloud*". This was the only witness of F265 who was not located in Crumlin Valley.

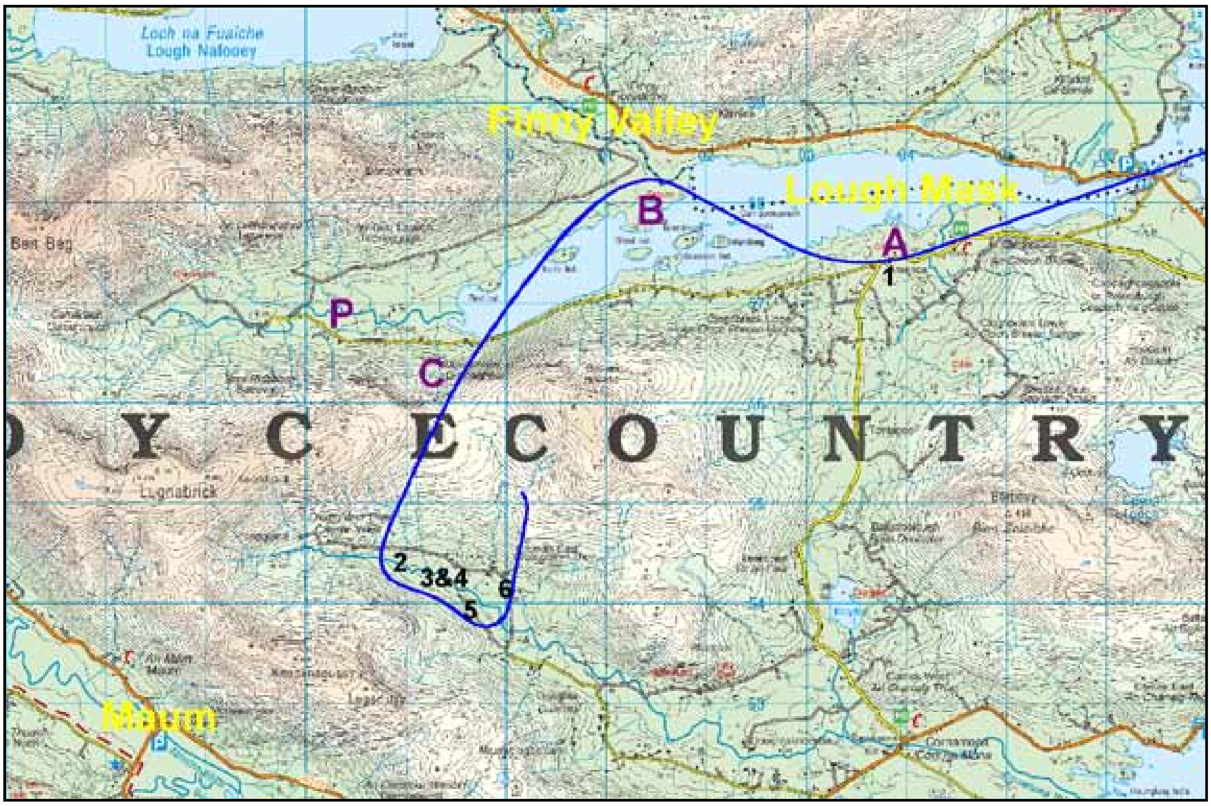


Figure No. 1: Track of F265 and witness locations

Note: The blue track in **Figure No. 1** is the track[7] flown by F265. Witness positions are numbered.

7 **Track:** This track is derived from smoothed F265 position data. See Section 1.11.5.

Witness No. 2 saw the aircraft flying east down Crumlin Valley at a very low height[8]. He saw the aircraft make a steep turn to the left and it then disappeared into cloud. He subsequently heard a noise but assumed at the time that it had come from his lawnmower.

Witness No. 3 observed the aircraft from the rear of his house and heard it coming from the west. It appeared "*out of the fog*". It turned to the right in the valley. He lost sight of the aircraft. He then heard noises like gunshots and then a thump. He believed it had crashed and discussed this with his wife, Witness No. 4 and shortly afterwards with Witness No. 5.

Witness No. 4 heard the aircraft coming from the west and saw the aircraft turning in the valley. She reported that the engine of the aircraft was making an unusual or "*crackling sound*". She too heard a loud bang followed by a possible thud and was sure that the aircraft had crashed. Having conferred with her husband, Witness No. 3, she immediately called the Emergency Services by phone.

Witness No. 5 was farming in the valley at Crumlin East when he saw the aircraft. He said that it seemed to be very loud and he thought the engine was "*spluttering*". He was sure the aircraft was upside down and that he could see the pilot's head clearly through the canopy with ground in the background. The aircraft entered cloud shortly afterwards; he heard two loud "*smacks*" and believed that the aircraft had crashed.

Witness No. 6 was located closest to the point of the aircraft's final northerly turn and observed the aircraft turning to the left very steeply over his house and then climbing, at an angle he estimated to be 45 degrees, before entering cloud. He was sure that it was not inverted as it disappeared. He then heard loud bangs after the aircraft had disappeared.

Witnesses No. 3 and 5 climbed the mountain together and located the aircraft wreckage. They stated that both pilots were fatally injured. They reported that the visibility was very poor and that they had found the wreckage by following the smell of fuel.

1.1.2.2 Other Witnesses

As a result of a media appeal several other people reported seeing an aircraft at low level in the general area outside of the Crumlin Valley. The times and locations at which the aircraft was observed coincided with the navigational track information derived from the search aircraft F261.

1.1.3 Crew F261 (Search Aircraft)

The crew of F261, the following PC-9(M) that searched the area, also consisted of an instructor and a student cadet. They were interviewed by the Investigation.

8 **Height:** Height is the vertical distance of the aircraft above the ground whereas altitude is the vertical distance of the aircraft above mean sea level i.e. aircraft height is altitude less terrain height.

1.1.3.1 F261 Instructor

The F261 instructor, who was also the deputy CFI of FTS, stated that he and his student cadet had discussed the forecast weather for the sortie during their pre-flight briefing. In particular, they had discussed the likely affects that the warm front, approaching the Maum area from the northwest, would have during the period that they were scheduled to arrive in the area. The F261 instructor said that he felt that the weather would preclude them from over-flying the Maum waypoint and consequently he had anticipated that his cadet would abort that leg at some point before Maum and route directly to EICM. Although he and his cadet had discussed the weather in detail he did not remember if he had discussed the weather with the Instructor that morning.

They departed EIME at 16.36 hrs, 16 min behind the accident aircraft F265, and flew the planned route with the cadet as Pilot Flying (PF). The F261 instructor stated that after commencing the Carrigallen to Maum leg they encountered high overcast cloud. He recalled that this initially improved the horizontal visibility, as the glare of sun, which they had been flying towards, was no longer present. As they approached the eastern shore of Lough Mask he could see that the higher ground ahead was obscured by cloud. He said that his cadet assessed the weather in the mountains ahead and gave his decision to abort the leg to Maum, due to low cloud base and reduced visibility, and to route directly down Lough Corrib to EICM. He concurred and recalled wondering, as they routed south, why he had not had a communication from F265 regarding the weather but assumed that the weather conditions F265 encountered must have been better and that they had not encountered any difficulties.

Shortly afterwards Shannon ATC requested him to search for a missing aircraft in the Cornamona area. He did not connect this request with the absence of communication from F265, which he assumed had already landed at EICM.

He took control of the aircraft and directed his cadet to assist with the navigation. There was some initial confusion over the search area, which they understood to be further north, so he informed Shannon ATC that he was "*circling back*" and routed to the northwest through a valley in the Partry Mountains. The weather in that area was poor so he turned back towards Lough Mask and shortly afterwards informed Shannon ATC that he was abandoning the search, as he was very concerned about the deteriorating weather situation.

The F261 instructor then communicated directly with the following PC-9(M) aircraft, F266, and arranged separation by holding over Upper Lough Corrib until F266 had passed. He then followed F266 to EICM. Upon landing, he saw that there was only one aircraft (F266) on the ground at which point he realised that F265 was the missing aircraft.

He had previously conducted the Instructor's instrument rating check and said that the Instructor had displayed accurate flying of a high proficiency. He personally held the Instructor in high regard, both as a pilot and as a professional. The F261 instructor said that he had also regularly instructed the Cadet during the course and believed that the Cadet had become one of the better performers in his cadet class.

1.1.3.2 F261 Cadet

The F261 cadet reported to FTS at 12.30 hrs. He stated that he had completed his pre-flight planning along with the Cadet of the accident aircraft F265.

He stated that they prepared their "domestics" or documentation, which included a flight plan, flight authorisation, aircraft status and weather. He then completed briefing with his own instructor and they reviewed his domestics. He confirmed that he and the Cadet had discussed the warm front that was forecast to approach the Maum area around their scheduled time of arrival and had reviewed the Standard Operating Procedures (SOPs) options for bad weather diversion and/or aborts.

The F261 cadet said that during the flight, he could see that the weather ahead was disimproving. When approaching Lough Mask he could see that the cloud base was low on the western side of the lake, i.e. towards the Maum area. He told his instructor he was not happy to continue to Maum so they turned south for EICM. They were then asked to search for a missing aircraft, which they did. They broke off the search but by the time they returned to Lough Corrib the cloud base had dropped to 1,000 ft. He said that the standard holding speed was 180 kts in IFR[9] conditions, but that this could be reduced to 120 kts with flaps up if visual. They only carried charts of a scale 1:500,000 on board for this exercise but commented that these were poor in mountainous areas as they provided little detail.

The chart that the F261 cadet used during the flight was supplied to the Investigation. The Investigation was informed that it was the same as the Cadet's chart and had the navigational track and timings marked in a similar fashion. This chart showed the track between each waypoint marked in minutes with details such as fuel and Minimum Safe Altitude (MSA) recorded. The MSA for the Carrigallen to Maum leg was shown as 3,300 ft.

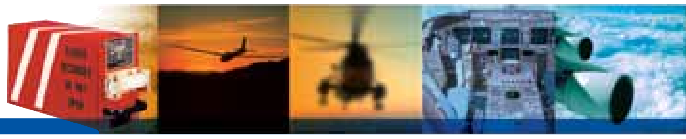
1.1.4 F266 Instructor

The F266 instructor, on the third and last PC-9(M) aircraft in the group, stated that the navigational exercise was a daytime VFR flight with an away-from-base transit stop, to be followed by a night time return flight to base. Its purpose was to give the cadets additional navigational training, night flying and a transit stop away from base. The end of VFR (daylight) determined the timing of the flights. The route selected had been based on the level of difficulty in finding the waypoints; at this advanced stage in the course, they tended to be small towns that could be difficult to identify. Visual navigation exercise flights were planned at a groundspeed of 240 kts with drift and groundspeed to be accessed during the flight. He believed that the Instructor (F265) in his role as CFI had probably determined the route for this planned exercise late the previous week. He also said that it was unlikely that the Instructor would have changed the routing in light of the forecast weather, as at this stage in the course the cadets should be well capable of dealing with the forecast weather. The Instructor had given flight details to the cadets at about 13.00 hrs so that they could commence flight planning.

The F266 instructor said that, prior to his own flight, he and his student had reviewed the flight plan and weather data, during which the forecast frontal system approaching from the west was discussed. He agreed with his student's contingency plan to avoid the high ground and route directly to EICM if the weather was found to be unsuitable on that leg. However, he said that a cadet would tend be more cautious than an instructor when making this type of decision.

The F266 instructor was of the opinion that all the instructors and cadets on the sortie were quite aware of the weather approaching from the west, but he had not personally discussed the weather with the Instructor, as his flight was 30 minutes later.

9 **IFR:** Instrument Flight Rules.



During the flight, he heard the accident aircraft being called but thought that there might be communication difficulties due to shielding by high ground. He saw the frontal system ahead and the cloud base dropped down to 1,200 ft or 1,300 ft about 5 min before Maum. They turned towards EICM, bypassing Maum, and descended to 1,000 ft over northern Lough Corrib to remain visual. As they continued south, the weather disimproved with the cloud base dropping further. Ultimately they descended to 500 ft AGL[10] over the lake to stay visual but, since the weather in EICM was good, they continued to that destination.

The F266 instructor had flown the previous week with the Cadet and described him as being "*well above average standard*". His overall impression from that flight was that the Cadet had good situational awareness and managed the cockpit and mission progress with a high degree of competency.

1.1.5 F266 Cadet

The F266 cadet was also interviewed by the Investigation and said that the Cadet had assisted him by preparing a fuel plan for him that morning because he (the F266 cadet) had been flying earlier that day. He stated that he himself was aware of a warm front approaching the West of Ireland and had anticipated that the weather would preclude completing the flight as planned. He said that during their flight, the weather deteriorated deceptively with occasional patches of good visibility that suddenly and unexpectedly reduced. In view of the deteriorating weather and the high ground ahead, he advised his instructor that he believed they should not continue towards Maum. They circled over the southern shore of Lough Mask for a short time to ensure clearance from F261 before flying directly to EICM.

The F266 cadet said that the Instructor was pleasant to fly with and had a "*relaxed*" instructional style. Although the Instructor had criticised all the cadets the previous week for not completing assigned ground tasks and confined them to barracks for one night; the cadet felt that this criticism was reasonable.

1.1.6 Instructor Off-Duty Activity

The Instructor's partner informed the Investigation that the Instructor had been off duty for the two-day weekend prior to the accident. He had run his first 10 km cross-country race the previous day (Sunday) and had come in tenth position, among the leaders. He had previously run a number of other road races including one marathon the previous year. Later, after dinner on Sunday evening, he retired at his usual time and slept well.

She had spoken to him on the morning of the accident (Monday) and again later that day and commented that he appeared to be relaxed, in good spirits and was looking forward to his first overseas posting, due to commence in January 2010.

The Instructor was one of the three committee members of the IAC's Representative Association of Commissioned Officers (RACO) and had attended an on-base committee meeting at 10.00 hrs on the day of the accident.

A committee member, who worked closely with the Instructor, commented that the Instructor was alert, appeared to be in good form and contributed to the meeting in his normal fashion.

10 **AGL:** Above Ground Level.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	0	0
Serious	0	0	0
Minor/ None	0	0	

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

A small crater was created in the hillside at the point of the initial impact. Fuel from the aircraft was distributed across the debris field following the impact, which resulted in localised contamination in the area of the wreckage site. This was advised by the Investigation to the Local Authority representatives. The main cockpit section and engine impacted a net wire fence at the bottom of the ridge, just short of a stream. The fence was torn through at this point.

1.5 Personnel Information

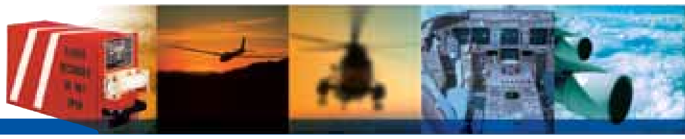
1.5.1 Instructor

The Instructor joined the IAC as a cadet in 1994 and later qualified as a flying instructor in 1999. He was then posted to the IAC Flying Training School (FTS), initially as Grade 2 instructor and, after a 12-month consolidation period, upgraded to a Grade 1 instructor. In 2001 he was appointed as Chief Ground Instructor (CGI) and in 2005 appointed CFI and PC-9(M) Chief Weapons Instructor. He was the approved IAC PC-9(M) singleton aerobatic display pilot. In addition, the Instructor had evaluated and determined the IAC approved Operational Low Flying (OLF) routes (heights between 250 ft to 1,000 ft above ground level) through the valleys in the mountains in the West of Ireland. Part of one of these routes was a west to east transit through Finny Valley (**Figure No. 1**).

The Investigation reviewed his personal and flying record files, which portrayed a record of consistent improvement during his career. No record of any disciplinary infringements was found. His Air Corps Headquarters (ACHQ) file was complete up to 1996 and from 2000 onward but no entries were found from 1997 to 1999. His personal file was located and was complete with the exception that one annual report (2003) was missing from the file. The annual reviews by his superiors rated the Instructor highly.

As a cadet, the Instructor had written a paper that covered inter alia, Spatial Disorientation and Illusions. He had more recently been involved in constructing a Crew Resource Management (CRM) course that included a module on Spatial Disorientation and had undergone a CRM Instructors Training Course in 2008. Training in this module of the 3 year CRM training cycle was scheduled for 2010.

The Instructor's Military Pilot Rating, instrument rating and medical were valid.



Personal Details:	Male, aged 32 years
Military Rating:	Instructor Grade 1
Last Type & Instrument Rating:	11 September 2009
Medical Certificate Class 1:	11 June 2009 to 11 June 2010

Flying Experience:

Total all types:	2,523	hours
Total all types P1:	2,212	hours
Total on type:	865	hours
Total on type P1:	857	hours
Last 90 days:	52	hours
Last 28 days:	13	hours
Last 24 hours:	0	hours
Instrument flying total:	Not available	
Instrument flying last year:	38	hours
Instrument flying last 30 days (dual):	3	hours

Duty Time:

Duty Time up to accident:	7 hours	30 min
Rest period prior to duty:	62 hours	30 min

IAC records showed that the Instructor recorded 38 hours 05 min instrument flying in the previous twelve months, of which 10 hours 20 min were during the past 90 days. During the last 30 days his records showed 3 hours but practically all of this was as an instructor with a student. He had satisfactorily renewed his Green Instrument Rating[11] 6 weeks previously. He had recorded one detail of solo instrument flying 5 months previously giving a personal instrument flying total of at least 2 hours 25 min in that period.

11 **IAC Instrument Ratings**: Green (experienced), White (inexperienced). The Green rating requires twice the level of accuracy of a White rating.

1.5.2 Cadet

The Cadet joined the IAC in 2006 as part of the 27th Air Corps Cadet Class. He was in the final advanced stage of his Pilot Wings course. His Military Pilot Rating, instrument rating and medical were valid.

Personal Details:	Male, aged 21 years
Military Pilot Rating:	Student
White Instrument Rating:	28 July 2009
Medical Certificate:	25 March 2009 to 30 April 2010

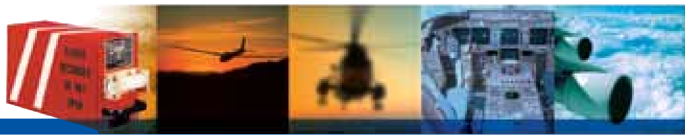
Flying Experience:

Total all types:	193	hours
Total all types P1:	48	hours
Total on type:	193	hours
Total on type P1:	48	hours
Last 90 days:	64	hours
Last 28 days:	18	hours
Last 24 hours:	0	hours
Instrument flying total:	53	hours
Instrument flying last year:	53	hours
Instrument flying last 30 days (dual):	10	hours

Duty Time:

Duty Time up to accident:	5	hours
Rest period prior to duty:	67	hours

The Investigation noted that neither the Instructor's nor the Cadet's Type and Instrument Rating reports contained any written comments other than "*Nil*", which the Investigation was informed was standard IAC practice.



1.6 Aircraft Information

1.6.1 General Description

The IAC PC-9(M) is a low wing, 2 seat, un-pressurised aircraft powered by a single Pratt and Whitney PT6A-62 gas turbine engine driving a four-bladed variable pitch propeller. It is fitted with a retractable tricycle undercarriage and a ventral airbrake. The seating consists of tandem Martin Baker ejection seats, the rear seat being raised to improve forward visibility. The flight controls are manually operated with electric trimming on rudder, ailerons and elevators. A Trim Aid Device (TAD) assists the pilot by automatically adjusting rudder trim to compensate for the effect of the propeller on the airframe. All major controls, services and avionics can be operated from either cockpit. The aircraft is certified by the Swiss Civil Aviation Authority Federal Office of Civil Aviation (FOCA), to operate in the aerobatic category of Federal Aviation Regulation (FAR) Part 23 with defined permitted manoeuvres. The aircraft is used primarily for pilot training but can be fitted with a weapons system. At the time of the accident, no weapon system was fitted. The aircraft is also equipped with a Head Up Display (HUD) in the forward cockpit that provides flight information and weapon delivery information; a repeater screen is provided in the rear cockpit.

The PC-9(M) is in use with a number of military and civilian operators. The accident aircraft was delivered new to the IAC from the manufacturer in 2004. It had a maximum operating speed of 320 kts (Mmo[12] 0.65 Mach) and a service ceiling of 25,000 ft. Its on-board systems support anti-G suits, as the aircraft is certified from +7G[13] to -3.5G in clean configuration. An over-G alarm activates when G levels exceed +6G or -2.5G.

1.6.2 Leading Particulars

Aircraft type:	Pilatus PC-9(M)
Manufacturer:	Pilatus Aircraft Ltd
Constructor's number:	660
Year of manufacture:	2004
Length:	10.2 m
Wingspan:	10.2 m
Maximum Operating Speed VMO:	320 kts
Maximum Manoeuvre Speed VO (maximum weight):	205 kts
Maximum Roll Rate (205 kts):	130° per second
Military Registration:	18 May 2004
Military Approved Maintenance Programme - IAC MS008:	Fully Compliant
Total airframe hours:	1,041 hours
Engine:	Single PT6A-62
Maximum Take-off torque:	67.4 psi
Maximum continuous torque:	63.8 psi
Maximum Take-off weight: Standard Configuration:	3,200 kg
Actual Take-off weight:	2,422 kg
Estimated weight at time of accident:	2,275 kg
Centre of Gravity limits (at accident weight):	22% to 30%
Centre of Gravity at time of accident:	28.2%

12 **Mmo:** Maximum Mach Operating speed (maximum certified speed at altitude).

13 **G**: Applied acceleration is called G in aviation and expressed as a multiple of the acceleration due to gravity.

1.6.3 Aircraft Maintenance

Aircraft records showed that the aircraft was maintained in accordance with the approved Military Airworthiness Authority (MAA) Maintenance Programme. Examination of technical records showed that all mandatory modifications and airworthiness directives were complied with.

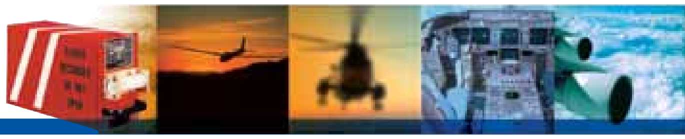
No significant problems were reported with the IAC fleet. The aircraft had completed a 150 hour inspection on 24 July 2009 and its last annual or 300 hour inspection on 13 November 2008. Five minor defects were recorded and deferred in the Aircraft Technical Log, in accordance with the MAA approved Minimum Equipment List (MEL). Two of the deferred defects related to the HUD system.

1.6.4 Electronic Limiter Unit (ELU)

The Electronic Limiter System (ELS) consists of an electronic limiter unit (ELU), an electrically driven interface valve operating on the fuel control pressure (Py), an isolating solenoid valve, sensors, and interconnecting wiring harness. The system is a torque and temperature limiting system that is intended to reduce pilot work load during critical stages of flight, such as take-off and aerobatics. The function of the ELS is to limit engine operation to maximum torque (Tq) and maximum temperature (TS/ITT) when the power lever is set to the maximum position. It also provides power turbine overspeed protection in the event that the propeller governor, the overspeed governor and/or the propeller malfunction in such a manner as to cause an overspeed condition to develop.

The ELU limits the fuel flow to the engine to prevent maximum values of torque and inter-turbine temperature (ITT) from being exceeded. It therefore permits power setting without the need for frequent visual monitoring of the engine's operating limits. In addition, the ELU is designed to maintain selected power if the reference torque pressure drops due to a momentary loss of engine oil pressure during aerobatics. The ELU also monitors the engine turbine speeds, torque and temperature.

If the ELU FAIL warning illuminates, full (i.e. not limited) engine power can be set, but aircrew are required to monitor the engine instrumentation to ensure that ITT and Torque limits are not exceeded. In this case the pilot can reset the ELS in flight once stable conditions are re-established.



1.7 Meteorological Information

1.7.1 Weather Aftercast

Met Éireann, the Irish Meteorological Service, provided the following aftercast:

Meteorological Situation:	A weak warm front was embedded in an anticyclone centred just south of the Scilly Isles. The front extended southwards along the west coast of Donegal, intersecting the north Connemara coast east of Belmullet and exiting the south Connemara coast west of Spiddal. A slack S/SSW airflow was maintained over the area.	
Wind:	Surface:	180-190°/05-08 kts.
	2,000 feet:	200-210°/10 kts.
Surface Visibility:	The visibility deteriorated across and behind the front from 10+ km to less than 5,000 m (at least intermittently) at surface. The rise in dew-point from 9°C ahead of the front to 12°C behind meant that visibility would have been significantly reduced in hilly terrain, possible below 1,000 m at times at or above 800-1,000 ft.	
Surface Weather:	Intermittent light drizzle; fog on hills.	
Cloud:	SCT005 BKN010 OCNL BKN008 across and behind the front.	
Surface Temp/Dew Pt:	12/09°C ahead of the front, 13/12°C behind front.	
MSL Pressure:	1029 hPa.	

1.7.2 Weather Reports by Airports

The weather reports for Ireland West Knock Airport (EIKN), 33 NM to the northeast of the accident site, about the time of the accident were:

EIKN 121800Z 18004KT 9999 SCT016 BKN036 12/09 Q1029 NOSIG
EIKN 121700Z 17004KT 9999 SCT017 BKN035 12/09 Q1029 NOSIG
EIKN 121600Z 19006KT 9999 BKN021 BKN040 12/08 Q1029 NOSIG
EIKN 121500Z 19006KT 160V220 9999 SCT021 BKN040 13/08 Q1029 NOSIG
EIKN 121400Z 17006KT 9999 SCT047 SCT250 13/08 Q1029 NOSIG

The following weather observations were reported by EICM Tower, 24 NM to the southeast of the accident site, to aircraft inbound to EICM about the time of the accident:

EICM 121515Z CALM 9999 BKN040 15/11 Q1029
EICM 121645Z CALM 9999 BKN022 BKN040 14/11 Q1029
EICM 121805Z CALM 9999 SCT008 BKN015 13/(no dew point transmitted) Q1029

The weather reports for the time closest to the accident are highlighted in bold text. Weather forecast details are provided in **Appendix A – Weather Information.**

1.7.3 Weather Reports by Witnesses

Witnesses in Crumlin Valley described rapidly changing weather conditions at the time of the accident with mist and cloud lifting and falling very quickly, even by local standards. Witness No. 3 said that from his position, the southern wall of the valley was clear but the northern slopes obscured.

A photographer in the valley to the north of Crumlin Valley (in the general area of **P** in **Figure No. 1**) provided time stamped photographs taken about the time the accident occurred. These showed that the cloud base and visibility were reducing over the period and are included in **Appendix B – Weather Photographs.**

The F261 instructor stated that he was "*shocked*" by the rate at which the weather had deteriorated, from the conditions they first observed when they arrived over Lough Mask to the time they returned. He said that he had never previously experienced such a rate of deterioration. He estimated that during this elapsed time, approximately 12 min, weather conditions over Lough Corrib had become very poor with a cloud base descending to almost 500 ft. However, this improved as they travelled further south and increased to 1,100 ft with good visibility when they entered the EICM Control Zone (CTR).

1.8 Aids to Navigation

The PC-9(M) is equipped with a KLN 900 Global Positioning System (GPS), that provides position information, and an Inertial Reference System (IRS), which supplies attitude and directional information to the flight instruments (it does not calculate position). The aircraft was not equipped with an Enhanced Ground Proximity Warning System (EGPWS) or with a moving map display as they were not available options.

1.9 Communications

1.9.1 PC-9(M) Radios

The PC-9(M) is equipped with both VHF and UHF radios. Whereas normal ATC communication is conducted through VHF channels, inter-military communication uses UHF. Consequently, inter-aircraft communication between the PC-9(M) aircraft on this navigational exercise was generally on UHF.

1.9.2 Flight Plan

A flight plan was filed for F265 with ATC EIME at 15.55 hrs. The flight plan was for a VFR flight at 1,500 ft from EIME to EICM, which with a planned groundspeed of 240 kts; it estimated it would reach EICM at 18.10 hrs.

The flight plan gave an estimate of 16.32 hrs for the Dublin ATC boundary. Thereafter the flight would operate in Class G[14] airspace until it reached 10 NM from EICM.

14 **Class G**: Uncontrolled airspace where ATC does not provide separation but gives, where practicable, advisory information on other traffic.

1.9.3 Radar

Shannon Radar recorded the aircraft en-route from Carrigallen to Maum at an altitude of 1,500 ft to 1,600 ft. It passed south of Castlerea, Co. Roscommon at 16.46 hrs and the last radar contact was at position N53°35.04', W009°22.18' at 16.52 hrs, over the centre of Lough Mask and 23 NMs northeast of EICM. At that time, the aircraft was on a heading of 254°M, a groundspeed of 238 kts and at an altitude of 1,200 ft tracking directly towards Maum. From that point onwards the aircraft was shielded by terrain and no further radar contact was recorded.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

1.11.1 General

The aircraft was fitted with a MADRAS Combined Voice and Flight Data Recorder (CVFDR) manufactured by L3 Corp. The unit records 27 items of data information (spread over 74 channels) for a minimum of 25 hours, following which the data is overwritten. The Crash Survivable Memory Module (CSMU) of the CVFDR was found in the debris trail, having separated from the recorder chassis as a result of the impact. The CSMU could not be read locally and was therefore taken by an AAIU Inspector to the original equipment manufacturer in the USA. Both the voice recording and flight data were successfully downloaded there under his supervision and they were then returned to the AAIU for analysis. The aircraft Manufacturer assisted the Investigation in the recovery of the available data from the final, incomplete sub-frame of the recorded data.

The CVFDRs from the other aircraft on the sortie, F261 and F266, were also downloaded and evaluated by the Investigation.

1.11.2 Flight Data Recorder (FDR)

The data recorded by F265 was of good quality and revealed that all the recorded aircraft systems, engine and propeller were operating normally up to impact. The FDR records the deflections of the control surfaces but does not record which cockpit position operates the controls.

The FDR data recording of the flight commenced at engine start. Position information recorded by the FDR showed that the aircraft flew from EIME to Carrigallen and then turned southwest towards Maum. The aircraft crossed Lough Mask and entered an inlet at the south-western corner of that lake.

It altered course to the right towards Finny Valley but turned, as it was about to enter the valley, back southwest towards Maum, about 4.5 NMs away.

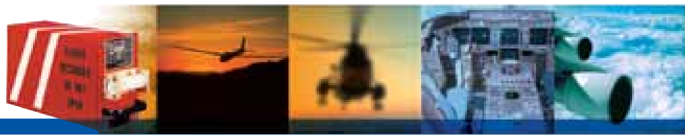
As the aircraft approached the northern ridge of Crumlin Valley a Radio Altimeter (RADALT) warning occurred indicating that the height of the aircraft above the ground was less than 900 ft at that time[15]. It then crossed the ridge and entered Crumlin Valley at an altitude of 1,350 ft and airspeed of 220 kts. (The lowest height recorded by the RADALT was 436 ft.) 9 seconds later it made a sudden 103° bank turn left at +4.8G[16] onto a heading of 110°M. This was followed immediately by a 48° right bank at +3.4G onto a heading of 135°M. On reaching 135°M, the aircraft immediately banked left at a 111° bank angle, at +5.1G onto a heading of 010°M. During this steep turn the nose of the aircraft dropped from +15° to –12° pitch[17] (altitude 1,250 ft descending to 1,010 ft) and the speed of the aircraft dropped from 206 to 185 kts. On reaching 010°M at –12° pitch, a rolling +4.5G pull up was commenced during which, the aircraft initially rolled to a 15° right bank before returning to wings level and a maximum nose up attitude of +34° was reached. A RADALT warning occurred during this pull up manoeuvre.

A progressive pitch-down/push-over then commenced, accompanied by a right roll. The aircraft had reached an apogee of 1,787 ft at 150 kts before commencing a rapidly increasing rate of descent to reach –60° pitch at 93° right roll angle and –3G. During the final second of the recording, the aircraft rolled rapidly left to almost wings level and began to pitch up. The final FDR record showed –55° pitch, a speed of 208 kts and a heading of 306°M. **Figure No. 2** shows the final 13.5 seconds of the recording.

15 **RADALT Warning**: This short aural warning tone is triggered by descending through a selected height. IAC procedures for this exercise required that this height was set at 900 ft during the pre-flight.

16 The values for bank angle and G listed are the maximum values recorded during each manoeuvre.

17 **Pitch**: (+) indicates nose up pitch attitude whereas (–) indicates nose down.



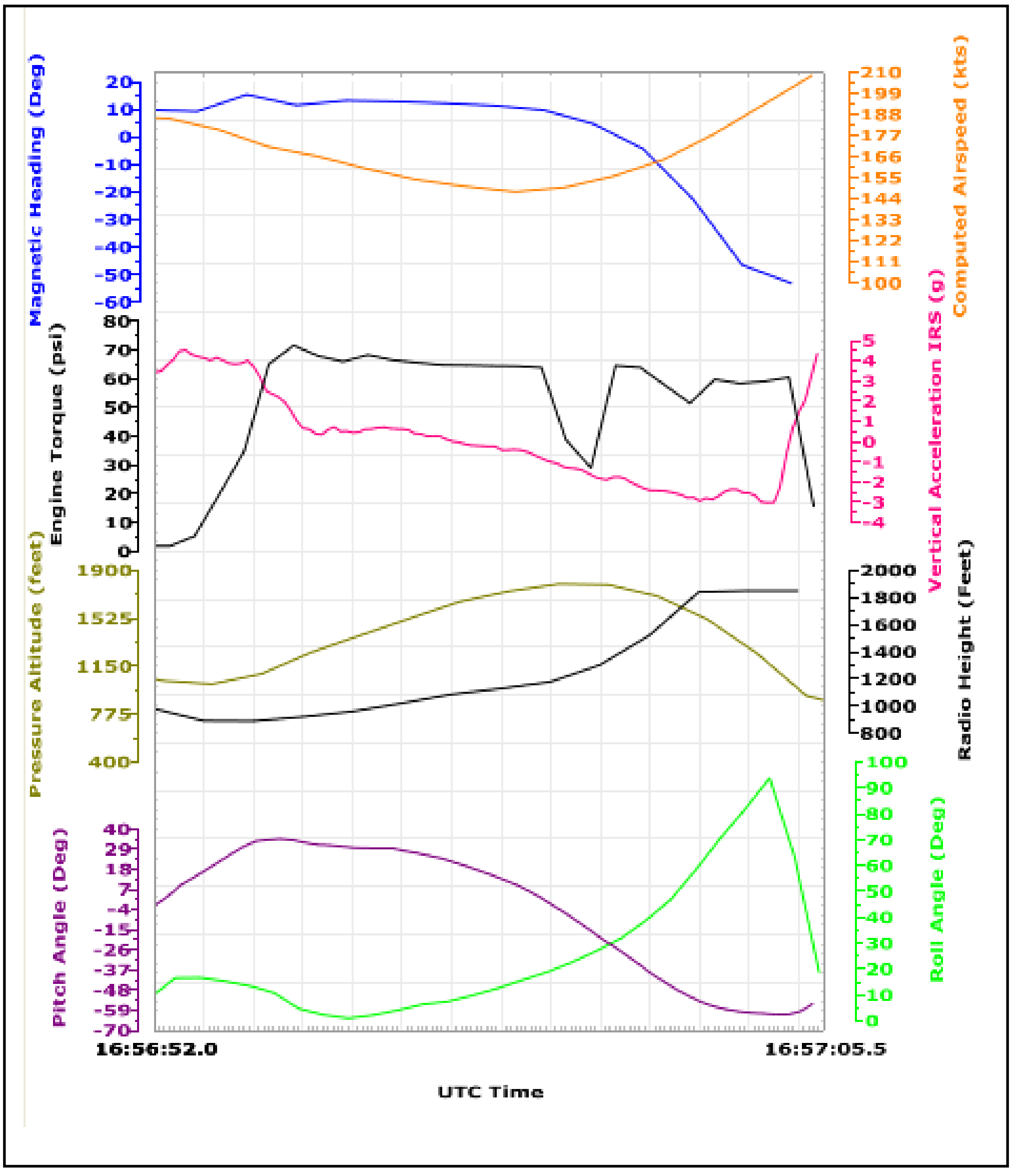


***Figure No. 2:** FDR Data extract showing the final 13.5 seconds*

Notes:
Heading (blue line) is referenced to North, which shows as 0, with plus values to east and negative to the west.

RADALT values recorded the radar response from the ground vertically underneath the aircraft. When pitch and roll attitude became excessive data was unreliable.

Further information regarding the momentary reduction in torque at time 16.57:00 is contained in **Section 1.16.4.**

The difference in the number of samples of different parameters available at the end of the recording is due to the individual parameter sample rates and the exact point at which recording ceases.

The following Table No. 1 shows the last 34 seconds of the FDR in tabular format. This table formed the basis of the schedule used in the subsequent evaluation flights conducted by the Investigation to assess the final manoeuvres of F265.

Time in/ out	Position	Max Roll	Hdg M	Pitch	Max G	Torque p.s.i.	Speed kts	Alt ft
16.53:31	**Lough Mask West**	0°	255°	+3°	+1	45	238	1,500 1,000
16.55:25 **16.55:41**	**Turn for Finny Valley**	40°R	255° 302°	+4°	+1.2	47	223	1,000
16.55:49 **16.56.07**	**Turn back towards Maum**	60°L	302° 222°	0°	+3	49	223	1,000 1,060
16.56:26 **16.56:35**	**Into Crumlin Valley**	15°L	222° 210°		+1	47	220	1,350
16.56:35 **16.56:40**	**First steep turn**	103°L	210° 110°	+15°	+4.8	35 47	215 200	1,360 1,400
16.56:40 **16.56:45**	**Parallels south side of valley**	48°R	110° 135°		+1.5 +3.4	47 35	201 205	1,300 1,250
16.56:45 **16.56:52**	**Second steep turn**	111°L	135° 010°	+15° to -12°	+5.1	37 0	206 185	1,250 1,010
16.56:52 **16.56:56**	**Pitch up**	16°R →0°	015°	-12° to +34°	+4.5	0 72	186 152	1,010↓ ↓ 1,787
16.56:56 **16.57:05**	**Pitch down**	93°R	316°	-60°	-3.0	<65	150	1,787
16.57:05	**End of recording**	18°R	306°	-55°	+4.8	15.6	208	855

Table No. 1: *Final 34 seconds of FDR*

1.11.3 Cockpit Voice Recorder (CVR)

The CVR records up to two hours of standard audio and a minimum of 30 minutes of high quality audio on three channels; the front pilot, the rear pilot and an area microphone located behind the front pilot. All three channels were recovered and were of good quality. Pilot comments and transient noises were consistent with the FDR recording. The recordings showed that the Cadet was the handling pilot until Finny Valley. Normal training patter[18] was evident up to that point. Normal en-route checks were accomplished at regular intervals by the Cadet who gave regular, detailed patter and completed his FOEL[19] checks at regular intervals. The Instructor in the rear of the tandem seated aircraft interjected infrequently giving positive feedback with occasional advice about timing and cross track error elimination. Adherence to normal operating procedures was evident up to Lough Mask.

18 **Patter**: Routine phraseology used during instructional flights.

19 **FOEL Check:** Fuel, Oxygen, Engine & Electrics, Lookout & Location.

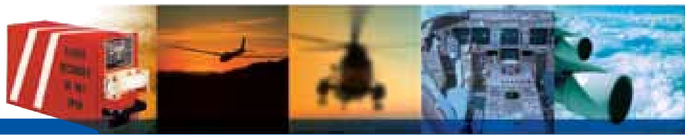


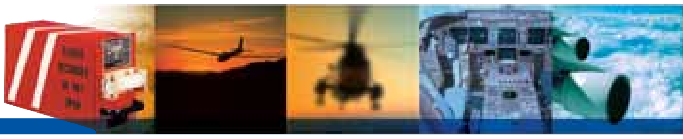
Table No. 2: CVR Transcript Extract contains the CVR recording from 16.52:28 hrs to 16.57:05 hrs.

Time	**Who**	**Comment**
16.52:28	Cadet	*The location just coming up on the south of Lough Mask now and there's Ballinrobe*
16.52:35	Cadet	*OK Maum, situated just on the western side of the mountains valley to the inlet to the right which I can see is my lead in feature another one to the right of that again which is to the north I can see that I can not climb over that high ground with the weather the way it is*
16.52:57	Cadet	*Fifteen hundred feet two five four two three nine I have for the headwind back to two three seven now no traffic to affect ahead*
16.53:10	Cadet	*OK neither valley has a low altitude where I could come around I'm going to have to cut across the front sir and cancel my time check at Maum*
16.53:25	Instructor	*OK hang on let's continue in and let's look at our options when we get in a bit further alright*
16.53:32	Cadet	*OK sir*
16.53:35	Cadet	*OK sir if I continue on now and it is US*[20] *I have the hill in our eleven O' clock I could come around the back of that*
16.53:41	Instructor	*Exactly*
16.53:41	Cadet	*Where there's low ground*
16.53:45	Instructor	*OK we've also got two valleys that we can fly up eh we've got that one in our twelve to one o'clock OK*
16.53:51	Cadet	*Seen sir*
16.53:52	Instructor	*And we can follow that up eh and it breaks slightly right and we come around from the north of Maum*
16.53:59	Cadet	*OK sir*
16.53:59	Instructor	*Or the northwest of it*
16.54:02	Cadet	*OK sir I can see that yeah where it breaks to the right*
16.54:04	Instructor	*OK*
16.54:05	Cadet	*Just with that kind of island effect with the cloud over it now it comes round the back of that*
16.54:11	Instructor	*Exactly*
16.54:16	Instructor	*OK so let's drop it down*
16.54:18	Cadet	*OK sir*
16.54:21	Instructor	*Give us a better eh view ahead anyway*
16.54:24	Cadet	*One two sir*
16.54:26	Instructor	*Say again*
16.54:27	Cadet	*One thousand two hundred sir*
16.54:28	Instructor	*I'd suggest down to a thousand feet if we can get it*
16.54:30	Cadet	*OK sir*
16.54:34	Cadet	*OK sir the cloud is no lower apart from covering the mountain tops ... to the west*
16.54:38	Instructor	*OK just turn your head up display down a little bit it's up a little bit high*
16.54:41	Cadet	*I actually eh I wasn't using that sir but I can't turn it down at all eh*

20 **US**: The Investigation considers that this aviation expression is in the context of the weather being unserviceable or unsuitable.

16.54:44	Instructor	*Ah .. Is it on day or night*
16.54:47	Cadet	*It's on auto sir I'll switch it on to day and it's eh gone off there*
16.54:50	Instructor	*Alright*
16.54:54	Instructor	*OK so our escape route is a one eighty*
16.54:57	Cadet	*Yes sir*
16.55:00	Cadet	*Apart from that then we're breaking right across behind this high ground*
16.55:04	Instructor	*OK if we wanted we could go just hold the track hold the track*
16.55:07	Cadet	*OK sir*
16.55:11	Instructor	*OK so what's what's your decision … we have to get to Maum somehow*
16.55:16	Cadet	*Yes sir*
16.55:17	Instructor	*So how're you going to do it*
16.55:18	Cadet	*With the cloud as it is it looks like I can break to the right*
16.55:20	Instructor	*OK*
16.55:21	Cadet	*Down that valley I could break to the left there's some cloud there*
16.55:23	Instructor	*Let's go right*
16.55:24	Cadet	*OK sir*
16:55:25	Cadet	*Looking out to the right turn is clear high ground is clear I'm going to expect the RADALT to go off as we cross over between this water area*
16.55:37	Instructor	*Straighten out here*
16.55:45	Instructor	*Now just keep an eye on that on the left hand side*
16.55:47	Cadet	*OK sir*
16.55:47	Instructor	*Go left*
16.55:58	Instructor	*OK you got the track. Do you see where we're going*
16.56:02	Cadet	*Yes sir*
16.56:02	Instructor	*OK you've control*
16.56:03	Cadet	*OK sir just to the gap in the mountain ahead*
16.56:05	Instructor	*Yeah*
16.56:07	Cadet	*Power on to get some altitude*
16.56:09	Instructor	*No no no hold it there*
16.56:10	Cadet	*OK sir*
16.56:10	Instructor	*We want ground contact*
16.56:16	Cadet	*High ground on the right not to affect*
16.56:17	Aircraft	**RADALT tone**
16.56:18	Cadet	*RADALT high ground not to affect and descending away from us*
16.56:25	Cadet	*Keep that ground contact*
16.56:31	Instructor	*OK*
16.56:33	Instructor	*I've control* [Spoken quickly]
16.56:34	Cadet	*You've control sir*
16.56:39	Instructor	*Bad decision now*
16.56:52	Aircraft	**RADALT tone**
16.57:02	Aircraft	**Over-G alarm**
16.57:05		*End of recording*

***Table No 2:** CVR Transcript Extract*



1.11.4 CVR Other Recordings

During the examination of the CVR the Investigation found a 600 Hz warning tone at the end of the voice recording. This tone was established as having been generated by the G warning sensor since negative G values exceeded the triggering value of -2.5G.

The Investigation also identified a mechanical grinding sound recorded by the area microphone noise during the last seconds before impact. This noise had a fluctuating 400 Hz component. This issue is further discussed in **Section 1.16.4 Evaluation Flights.**

1.11.5 FDR Navigational Position Data

Navigational Position Data was recorded by the CVFDR. The initial output regarding the aircraft's navigational position showed discontinuities. However, the Manufacturer indicated that the navigational position recorded by the FDR is based on the GPS, which goes into a Dead Reckoning (DR) mode if the satellite signal is temporarily lost (e.g. if obscured by terrain or during manoeuvres involving significant bank angles). In this case, the DR position then generated is an approximate position based on the last known position updated by inputs from the aircraft's air data and IRS.

Due to the high bank angles of the aircraft, the plot of the recorded navigational positions resulted in a segmented but distorted track in the valley that generally agreed with witnesses' observations, but not in detail. The GPS track data was then edited to remove the obvious DR track positions and the result was subjected to mathematical smoothing. This resulted in the track portrayed in **Figure No. 1**, and **Figure No. 3,** which shows the track overlaid with a CVR transcript.

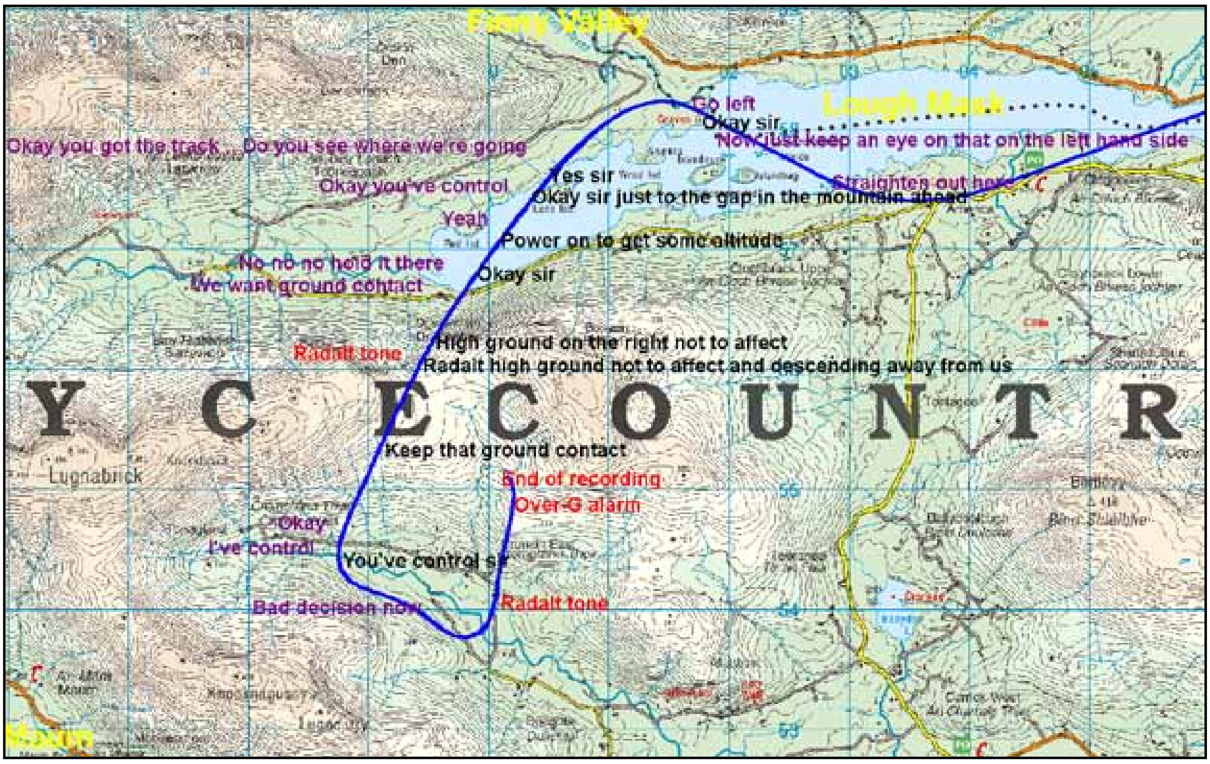


Figure No. 3: Track with CVR transcript extract

1.12 Wreckage and Impact Information

1.12.1 Site Inspection

The aircraft initially impacted the crest of a ridge on the upper reaches of the northern slopes of Crumlin Valley at high speed. The area is locally known as Mám Dearg and is covered by soft blanket peat bog to a depth of over half a metre. An impact crater or scar in the outline shape of the fuselage of the aircraft was formed measuring 10.5 m across with a maximum depth of 0.6 m (see **Photo No. 1)**. The debris trail was distributed along a 90 m long down-slope from the impact point and was characteristic of a high-speed impact.

Examination of the debris trail showed that the aircraft impacted with a significantly nose down attitude (circa –45°) and approximately wings level. The debris trail, as measured from the initial impact point to the fuselage, was on a track of approximately 330°M. A large boulder (circa 0.5 m in diameter) had been unearthed in the crater. Scoring on the boulder indicated that the aircraft had made significant contact with this object on impact.

The horizontal tailplane had separated immediately at impact and remained on the rim of the impact crater. The boulder had penetrated the rear fuselage immediately forward of the tail attachment points causing these points to fail and brought the tailplane to an immediate stop. Both wing tip fairings and navigation lights had dislodged and were found embedded in the ground at the extremities of the impact crater in a position consistent with a wings level impact. Both wings, with significant ruptures and deformation, were separately found about 35 m forward of the impact point along the debris trail.

***Photo No. 1:** Tailplane, impact crater and initial debris trail (in the direction of travel)*

Components of the aircraft were found scattered along the debris trail and some had penetrated the peat (see **Appendix C – Debris Trail)**.

The engine and main wreckage came to rest separately at the bottom of a slope about 85 m from the initial impact point, partially arrested by and entangled in a net wire fence. The height drop from the initial impact location to the final position of the fuselage was approximately 14 m.

The propeller blades had separated from the hub, suffering damage consistent with a high-speed impact when the engine was providing power. The CVFDR was located 55 m from the initial impact point with its data/memory module detached but intact. The Emergency Location Transmitter (ELT) was found 40 m from the impact point along the debris trail, with its transmitter antenna cable severed and significant damage to the body of the unit.

Some documents were recovered from the accident site. These consisted of the aircraft's technical log, checklists and three navigational charts. The Cadet's navigational chart was not found.

1.12.2 Wreckage Removal

The wreckage was removed from the site under the supervision of the Investigation Team. Due to the nature of the terrain, it was necessary to utilise an IAC helicopter to airlift the wreckage in cargo nets or bags to lower ground (see **Photo No. 2)**. Afterwards it was removed to the AAIU examination facility at Gormanston, Co. Meath, by road.

***Photo No. 2:** Recovery operation showing the nature of the terrain in the valley*

1.12.3 Examination of Wreckage

The wreckage was laid out in the AAIU facility by the Investigation Team with the assistance of the IAC and the Manufacturer. On examination, it was found that all major components and almost all of the aircraft had been recovered from the accident site. Control continuity was established for the elevators and the left aileron but not for the right aileron, which was missing a component.

It was not possible to establish continuity of the rudder as the rudder cables were disrupted. However, the rudder trim actuator was found extended by 5.5 mm and the pitch trim actuator by 3.3 mm from the null (0) position. The Manufacturer subsequently determined that the rudder trim tab position was a 32% left deflection (i.e. about 1/3 right rudder) and the pitch trim tab position was about 35% up (i.e. trimmed about 1/3 nose down). The Manufacturer confirmed that these trim positions are compatible with normal operations associated with high-speed flight within the normal flight envelope.

1.12.4 Powerplant Examination

The engine was disassembled by the Investigation assisted by maintenance personnel from the IAC and a Pratt and Whitney engine Advisor. The engine was covered in organic debris and dirt. The engine and most of its components showed severe impact damage, deformation and compressive damage. As a result there was a partial separation of the exhaust case, resulting in the gearbox being displaced upwards by approximately 45°. All gearbox accessories had detached. No pre-existing defects or abnormalities were identified. The results of this teardown indicated that the engine was operating and providing power at impact.

1.12.5 Electronic Limiter Unit (ELU)

The ELU was found in a damaged condition and was sent to the manufacturer Honeywell for examination. Its Non Volatile Memory (NVM) could not be downloaded nor could a functional test be performed, as the casing was heavily damaged. The memory chip was removed and installed into a slave unit for download. Although the data log was found to contain some previous fault indications, there was no associated time or date stamp, since the NVM is a Fault Code Register and does not save "Parameters". The ELU therefore did not provide any useful information.

1.13 Medical Information

The Investigation examined the medical records held by the IAC for both pilots. The records indicated that neither pilot had any pre-existing medical condition.

Post-mortem examinations were performed on both pilots at Galway University Hospital on 14 October 2009. The examinations of both pilots revealed no evidence of any pre-existing medical condition that could have contributed to the accident. In addition, the toxicology reports showed no evidence of alcohol, illicit or prescribed drugs in either pilot.

A consultant pathologist reviewed the pathological radiology results to assess if it could be determined which pilot was on the controls at impact. This review concluded that this was not possible.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Accident site examination confirmed that both pilots, who had been wearing G-Suits, had been strapped to their Martin Baker ejection seats at impact. These ejection seats, which were found severely damaged, can be used to abandon an aircraft in emergencies and have the capacity to eject pilots from the aircraft at any height provided the speed is greater than 60 kts. Following activation of the ejection sequence (by pulling on the ejection handle) the pilot is ejected through the canopy. The system has a facility to allow, when selected, the rear pilot to eject both pilots using the command ejection sequence. The front pilot has the option to eject himself alone.

The seats are fitted with nine cartridges that fire in a specific sequence when an ejection is commanded. Safety pins are used to deactivate the ejection seats on the ground and are removed immediately before take-off and replaced after landing. No safety pins were found inserted in the seats as the crew had correctly removed them before flight. On examination of the seats on site and subsequently at the AAIU facility, it was determined that two cartridges had detonated in each seat, the Barostatic Time Delay and Drogue Gun Secondary cartridge. The Investigation noted that these are not the first cartridges to fire in the ejection sequence. The damage to the ejection pyrotechnics was consistent solely with impact.

The PC-9(M) Flight Manual cautions regarding the increased risk associated with ejecting when close to the ground while inverted or at high speed in a dive.

1.16 Tests and Research

1.16.1 Emergency Locator Transmitter (ELT)

The ELT was recovered in a damaged condition and sent to the ELT manufacturer for examination. The manufacturer reported that the ELT was highly damaged and the severity of the crash most likely exceeded the certification standards of the unit.

Following examination the manufacturer reported that the antenna cable was found cut, which was consistent with the nature of the impact. The inertia mono-axis sensor (G-switch) was also damaged, probably by the impact sequence. The internal output cable was disconnected from its socket, again probably for the same reasons. When the internal output cable was connected, all parameters tested satisfactorily. The manufacturer concluded that the ELT had not been activated but that the beacon could have transmitted in normal conditions, assuming that all connections remained intact.

The switch on the ELT unit, which was installed in the avionics bay, was found to be in the "off" position when examined by the Investigation, though its normal position is "on".

Although it was not possible to determine its position at the time of the impact, the Investigation considers it likely that it was switched off during the accident sequence when the unit detached from the aircraft or during the subsequent debris recovery process.

1.16.2 Fuel Analysis

Fuel samples were taken from fuel system components on the accident site and the fuel bowser at EIME, where the aircraft had refuelled. These were sent to an independent laboratory for analysis.

The results of these tests indicated that the fuel was clear and bright with no free water, sediment or bacteria present and that the distillation results were within the specifications limits for Kerosene.

The other aircraft on the navigational exercise, 261 and 266, were also refuelled from the same fuel supply source prior to departure and reported no fuel related problems.

1.16.3 Oil Analysis

An oil sample was obtained from the engine oil filter and sent to a laboratory for analysis. The laboratory reported that metal and physical test results of the oil sample were within specified limits and comparable to a reference oil, which the Investigation supplied.

The laboratory analysis also showed that there was a small amount (0.005 grams) of material present in the sample. Of this, approximately 90% of the material present consisted of both inorganic and organic deposits, mainly paint/sealant/lacquer particles and fibrous matter. About 5% was aluminium-based material from possible sources such as shaft couplings, pump sleeves, covers and housings. A small amount of other particles were found which the analysis suggested were brass with a possible source such as a bearing cage.

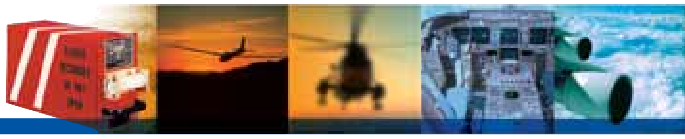
1.16.4 Evaluation Flights

A series of profiles were developed by the Investigation to replicate and examine the manoeuvring recorded by the CVFDR of F265 in the period immediately before the accident. In particular, the profiles sought to examine the controllability and operation of the aircraft during such manoeuvres and also how the PC-9(M) responded in terms of yaw and roll, when a significant negative G push-over was initiated. In addition, the evaluation sought to gain an appreciation of the potential physiological and spatial disorientation effects of such manoeuvres. Furthermore, the Investigation wished to determine if the mechanical grinding noise heard in the last seconds of the recording could be replicated.

Two flights were conducted in IAC PC-9(M) aircraft identical to 265, namely 267 and 262. They were flown by an IAC pilot accompanied by an AAIU Inspector (pilot) in the rear seat. Subsequently, the CVFDRs of both flights were downloaded and evaluated.

During the first flight, the accident flight profile was replicated and G limits restricted to +5G and –1.5G. Following this flight the CVFDR data was examined but HUD data recording was not available due to problems associated with downloading the recorded HUD data. These problems were resolved and a second flight was flown with limits extended to +6G and –3G (see **Section 1.18.4**).

During the second flight test, a "grinding noise" was heard similar to that recorded during the final sequence of the accident flight. This was initially heard on board at -2.7G. Analysis of the flight test recordings then found this sound in the area microphone recordings when negative G values exceeded –2.4G. It became more evident as the magnitude of the negative G values increased without any subsequent adverse effect on the aircraft.



A short reduction in powerplant RPM/torque was observed on 262 in association with negative G, similar to that recorded on the FDR of 265 during its final manoeuvre. However, this RPM/torque reduction was not observed on 267.

The Investigation notes that there is an advisory note regarding this PC-9(M) characteristic in the FTS Operations Manual.

As a result of these flights, the Investigation was satisfied that the PC-9(M) aircraft was stable, easily controlled and that the visibility from the rear cockpit was good. The stick control force required to cause the –3G manoeuvre was significant, though not such as to require two hands. Furthermore, physiological problems, such as blackout or red-out, were not experienced during the evaluation flight profiles.

The AAIU Inspector, who was not the handling pilot, did not experience a compulsion to push forward after initiating the steep climb when without visual reference. This was not unexpected and is further discussed in **Appendix D**. He also noted that there was no sense of roll rotation to the right during the push-over and rolling sequence but rather a pervading sensation of significant negative G. A sensation of being inverted was experienced at the end of the sequence while the aircraft was rolling level.

1.16.5 Manufacturer Evaluation of FDR Data

The last 60 seconds of the FDR recording was supplied to the Manufacturer's Advisor for analysis. The Manufacturer observed that there was no evidence of any aerodynamic anomaly in the recording and that the aircraft's behaviour was consistent with control input and surface deflections. In addition, it stated that no departure from controlled flight was observed and that the aircraft did not approach a stall condition at any point. The Manufacturer's test pilot also flew the flight path in the Pilatus Engineering Simulator and said, inter alia, "*…everything makes sense until the aircraft starts the –3G*".

1.17 Organisational and Management Information

1.17.1 IAC Organisation

The IAC is the air component of the Irish Defence Forces and is based at Casement Aerodrome, Baldonnel, Co Dublin. It comprises Air Corps Headquarters (ACHQ) along with six Wings or Units: Two Operational (one Fixed-Wing and one Rotary-Wing), Training, Maintenance, Administrative and a Communication/Signals Unit. Its Commanding Officer is the General Officer Commanding Air Corps (GOC AC) and Director of Military Aviation to whom the Wings, the Staff Officers, the Flight Safety Section (FSS) and Military Airworthiness Authority (MAA) report directly.

The GOC AC is the Officer responsible for all military flying missions. (Two Colonel Staff Officers assist the GOC AC but are not in the chain of command between Wing Commanders and the GOC AC). Subordinate Lieutenant Colonel Wing Commanders are responsible for the operational control and maintenance of the aircraft assigned to them and report to the GOC AC. Squadron Commanders of Commandant rank are responsible for the squadrons' operational, training and routine activities and report to Wing Commanders. Captains and Lieutenant aircraft commanders report to the Squadron Commanders. A Squadron Commander is responsible for the day-to-day authorising of all flights assigned to that squadron or in his absence his deputy.

The IAC Training Wing is known as the Air Corps College (ACC) and trains all Air Corps cadets, apprentices and recruits as well as providing further training for Air Corps personnel. The Officer Commanding (OC) ACC is a Lieutenant Colonel and, as with other operational flying wings, a pilot. ACC comprises a Headquarters (HQ) element and three schools; the Military Training School (MTS), the Technical Training School (TTS) and the Flying Training School (FTS).

1.17.2 Flying Training School (FTS)

OC FTS is in charge of the FTS, which carries out all aviation related training for Air Corps cadets. It is equipped with PC-9(M) aircraft (delivered in 2004), a PC-9(M) fixed-base simulator and computer-based ground-school training facilities. FTS staff include, inter alia, the CFI, CGI and flying instructors.

The Investigation was informed that IAC officers normally move between appointments, as part of career development. From IAC records the Investigation found that in the past the majority of Commandants appointed to the post of OC FTS had experience of ab-initio training on FTS aircraft.

In this Report the term ab-initio refers to training for those who have not flown as a pilot previously. It is however noted that the IAC considers a cadet ab-initio until he/she is formally appointed as a military officer. This is not the context in which the term is used in this Report since a cadet can have up to 200 hours on type before appointment.

In summer 2008, an OC FTS was appointed who had no experience of ab-initio pilot training. The new OC FTS had qualified as an ab-initio flying instructor in FTS and had previously trained cadets on single and twin engine aircraft. However, he did not hold a PC-9(M) type rating. His appointment was due to the fact that he was considered by the IAC to be the most suitably qualified commandant to serve as OC FTS.

1.17.2.1 OC FTS

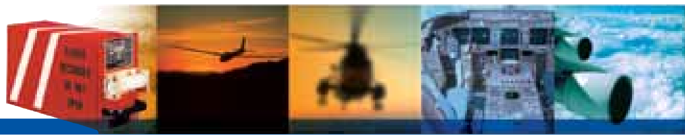
The OC FTS informed the Investigation that he was flying the IAC Learjet when he was informed of his appointment as OC FTS. He verbally informed the Squadron Commander (Learjet) that he would require a PC-9(M) course and type rating. The Squadron Commander informed him that this would be discussed with the GOC AC. He was subsequently verbally informed that he was to remain current on the Learjet, while concurrently serving as OC FTS. He stated that he elected to forfeit most of his leave in order to fulfil both taskings.

He further stated that the Instructor, whom he regarded highly, communicated daily with him regarding FTS flying details, which he approved. Although he had been informed that the Instructor was approved to authorise flights he had not seen any documentation to that effect but had no reason to doubt it.

1.17.2.2 CFI FTS

At the time of the accident, the Instructor was the most senior FTS officer flying the PC-9(M), though he held the rank of Captain.

The Instructor had served in FTS for the previous 10 years, from the completion of his instructor's course up to the time of the accident. The Investigation was informed that the normal duration for such an assignment was 5 to 6 years. He was due to leave FTS for overseas service in December 2009 and on return would have been appointed to a different Unit.



1.17.3 Flight Safety Section (FSS)

The IAC FSS is headed by a Lieutenant Colonel who reports directly to the GOC AC. The Investigation requested copies of previous audits of FTS conducted by the FSS. FSS Internal Audit Reports of FTS and ACC dated 16/9/2003, 1/11/2004 and 19/2/2009 were made available to the Investigation and were reviewed. Operations Audits of FTS, dated 22/11/2005, 18/10/2006 and 20/11/2007 were provided and reviewed. During the period 2004 to 2009 FSS audits of other squadrons were conducted.

1.18 Additional Information

1.18.1 Defence Force Regulations (DFRs)

The DFRs regulate Defence Force activity. DFR A 1, Statutory Powers, Duties & Functions, Para 3, Sub Paragraph 5, deals with command succession and states inter alia:

(5) Whenever and so often as any officer who is declared to be a commanding officer by subparagraph (1), (2), (3) or (4) of this paragraph for the purposes referred to in these subparagraphs is unable to exercise the powers vested in him or her by virtue thereof, or is temporarily absent, then those powers shall vest in and be exercised by the officer who succeeds him or her in temporary command in accordance with the provisions of Defence Force Regulations A.18 for the period of such succession and to the same extent.

1.18.2 Air Regulations Manual (ARM)

The ARM contains IAC Regulations and is subsidiary to the DFRs. The ARM is composed of six parts that include Part A, General. Part A provides the structure and basic operating philosophy and procedures for the IAC. It includes among other subjects: Crew Composition and Qualification Requirements, Operational Procedures and Rules of the Air.

The ARM in Part A, Section 2.0, Supervision, outlines safety policy, operational control and authorisation requirements. The power to authorise flights is delegated by GOC AC to listed Authorising Officers. The Manual states, inter alia:

2.4.1 General

> *…. The power to authorise pilot officers to fly in service aircraft and to delegate this authority is vested solely in GOC Air Corps. All such authorising officers will receive a written warrant outlining their responsibilities and limitations where appropriate. Officers to whom this power is delegated cannot in turn delegate it to a third party. Authorisation is the authority given to an Aircraft Commander and his aircrew to fly a particular aircraft on a specified mission or duty.*

2.4.2 Authorising Officers:

> *Pilot Officers holding the following appointments listed in the Annexes (Annex 'B'), are hereby designated as authorising officers without limitation. Wing Comds may apply to GOCAC for Limited Authorising Officer status for particular operational or training situations that arise. Such authorisation if granted will be subject to specific conditions. …*

All flights of IAC aircraft require authorisation from a designated Authorising Officer. An Authorising Officer is required to sign a Flight Authorisation Form (ACF 102). However, where a written form cannot be issued there is provision in the regulations to accept a verbal authorisation.

Annex 'B' lists six appointments that may authorise without limitation, which includes the OC ACC. Seven positions, which include OC FTS, are listed that may authorise with the limitation that their authorisation is limited to their own squadron aircraft. The CFI was not included in these lists. The Investigation requested a copy of the warrant issued to OC FTS. It was informed that warrants had not been issued as the warrant system was still in development.

In May 2007, the OC FTS applied to the GOC AC for the CFI (the Instructor) to be granted Limited Authorisation Officer Status for Cadet, Postgraduate and Staff Continuity Training (SCT) when OC FTS was not available. The intention was that the CFI would be allowed to authorise normal training activity when OC FTS was unavailable. The Investigation was informed that this application was approved but supporting documentation was not found.

1.18.2.1 FTS Standing Orders

FTS Standing Orders, dated 20/11/2007, are subsidiary to the ARM and regulate the activity of the FTS. FTS Standing Orders state, inter alia:

4.1 The 2 I/C FTS will take over all the functions of OC FTS during his/her absence.

4.2 He/She is also the Chief Flying Instructor (CFI) in FTS and is responsible for the day-to day running of the courses in FTS. .....

4.5 He/She will with OC FTS ensure that all flights are properly authorised and detailed.

1.18.2.2 FTS Authorisation

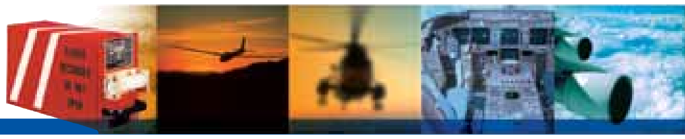
IAC records for the month prior to the accident showed that of the 140 flights authorised, OC FTS authorised 23, two of which were for flights by the Instructor. The Instructor authorised 117 flights for various activities that included cadet and officer training and flights by a senior officer, air firing, formation flying and a fly-past. Of these he self-authorised 26 flights where he was the Pilot In Command (PIC) and 5 flights where he was Pilot Non Flying (PNF).

1.18.3 FTS PC-9(M) Visual Navigation

1.18.3.1 General

Visual navigation involves the pilot flying along a pre-determined route at a set groundspeed by chart reference; in this accident the chart used was an ICAO 1:500 000 chart of Ireland. A visual navigation flight for a PC-9(M) is planned and flown at a groundspeed of 240 kts (i.e. 4 NM per minute) and an altitude of 1,500 ft. During the pre-flight planning phase, the pilot is required to identify a series of "*Events*" (e.g. turning points, crossing a fix, fuel check and radio calls) and mark the planned time and position for each event clearly on the chart.

Visual navigation procedures are published by FTS in the Instructor Training Manual (ITM), Issue 1 of December 2006, Section 2.2 and the IAC Student Pilot Training Manual (SPTM) – Basic Flying Training, Issue 1 of December 2006, Section 2.2. These contain the procedures by which a visual navigation exercise should be conducted and also demonstrates how charts should be marked and used. The Investigation noted that documentation obtained from F261 and F266 conformed to these procedures. As previously noted the relevant documentation from F265 was not recovered at the accident site.



The IAC weather limits for a visual navigation exercise were a minimum visibility of 5,000 m and a minimum height (above the ground) of 1,000 ft. Accordingly, procedures were to set the RADALT warning at 900 ft. In the event that terrain rose, aircraft altitude had to be increased accordingly to maintain minimum height. The minimum en-route height, without specific low-flying authorisation, was 500 ft.

1.18.3.2 FTS Visual Navigation Procedures

FTS procedures for weather avoidance state: that if there is bad weather ahead, there are four basic alternatives: Lateral Avoidance, Vertical Avoidance, a Turn Back and an Emergency Low-Level Abort. IAC SPTM, Section 2.2.5.7, contains these procedures:

(i) Lateral Avoidance using 30°, 45°, or 60° Dog Legs:
Route around the poor weather by aborting the current navigation leg and routing in clear weather to the next available waypoint on the flight plan, thence:
Dog-leg to a parallel track or,
Divert along ground feature, such as a railway line, river, etc;
(ii) Vertical Avoidance:
Route over low-level weather in clear weather to the next available waypoint on the flight plan.
(iii)Turn Back:
A 180° turn back to clear VFR conditions.
(iv)Emergency Low-Level Abort:
An emergency pitch up and climb.

1.18.3.3 FTS Emergency Low-Level Abort

SPTM, Section 2.1.3.8, contains procedures for an Emergency Low Level Abort manoeuvre. It cautions:

This is an emergency procedure to get the aircraft away from ground as quickly as possible in IMC[21]. It is a risky procedure; if it is your only option, you should have taken a better course of action earlier. The emergency low-level abort is your last chance to get things right.

Do not wait until you go IMC before initiating the low-level abort. It is much better to roll the wings level visually before you go into cloud, as there is then much less likelihood of getting disorientated. The procedure is as follows:

1. *Roll the wings level, ideally visually, and apply MAX power.*
2. *Transfer to instruments.*
3. *Pitch to 30° nose-up and hold the attitude.*
4. *Trim as the speed reduces.*
5. *As the speed approaches 120 kt, gently lower the nose and climb at 100 kt.*
6. *Level off above safety altitude or when VMC on top; accelerate to cruise speed.*

Make sure that you roll wings level before pulling. A rolling pull while transferring from visual to instrument flight can cause severe disorientation.

21 **IMC**: Instrument Meteorological Conditions

Until you are above safety altitude or VMC on top, concentrate on the procedure completely and do not deviate from it until safe conditions are achieved.

Although you will maintain proficiency in the emergency low-level abort, it is possible to lose control and get into an unusual position. If you recognise that you have lost control during an emergency low-level abort, EJECT immediately.

At the time of the accident FTS did not conduct in-flight training for Emergency Low Level Abort manoeuvres. However, the Investigation has been informed by the IAC such training has subsequently been introduced.

1.18.3.4 FTS Procedures Regarding Disorientation

Pilot disorientation is covered in SPTM Section 3.1.2.3, Disorientation, and states:

Flying by reference to instruments is necessary because you cannot trust your normal senses in flight when you have no clear visual references.

At times, your senses will tell you that the aircraft is flying a different manoeuvre from the one shown on the instruments. …

It also states:

ALWAYS BELIEVE YOUR INSTRUMENTS.

The subject of spatial disorientation is later addressed in SPTM Section 7.5.3.3, Sustained Linear Accelerations, where sensory physiology and illustrations of some illusions are addressed. It discusses linear acceleration illusion including pitch up and states,

The false sensation on acceleration is particularly dangerous if you attempt to correct it by pitching down.

Guidance on preventing disorientation is given in Section 7.5.4, stating:

The first thing to realise is that you will never be completely successful at preventing disorientation. All pilots can be affected from time to time. But you can reduce the likelihood of becoming disorientated by taking the following measures:

- *In the absence of adequate visual cues, fly on your instruments and believe their indications. Remember that you cannot fly by the seat of your pants.*
- *Avoid large or rapid head movements.*
- *Where possible, avoid a rolling pull. Try to keep the rotation to one plane at a time.*
- *Make all control inputs smoothly and slowly. Do not use sudden and harsh control movements to correct errors you have just noticed.*
- *Do not make any control inputs, or attempt to change the aircraft attitude, unless you are looking at the attitude indicator.*
- *Do one thing at a time, slowly and deliberately*
- *When carrying out tasks such as cockpit checks and setting radio frequencies, break up the activities with frequent checks of the aircraft attitude. Never go for more than a few seconds without checking attitude.*
- *Keep in practice at instrument flying.*
- *In deteriorating weather, establish flight on instruments before you go IMC.*

- *Avoid flying if:*
    - *You have a cold.*
    - *You are taking any form of medication unless you are cleared to fly by the medical officer.*
    - *You are mentally or physically tired.*

1.18.3.5 Visual Flight Rules (VFR)

VFR and IFR flights are permitted in Class G airspace. Irish Regulations regarding VFR are published in Statutory Instrument 72 of 2004, Rules of the Air, Part II, Rule 3 states the minimum heights an aircraft can be flown at. This states that the aircraft shall not be flown:

(i) closer than 150 metres, (500 ft) to any person, vehicle, vessel or structure, or
(ii) at a height less than 150 metres (500 ft) above the ground or water,

Part III, Section 34 states that in Class G airspace VFR requires that an aircraft flown at and below 300 metres (1,000 ft) above terrain, whichever is the higher, must remain clear of cloud and in sight of the surface. Normally an in-flight visibility of 5 km is required. This visibility distance can however be reduced to:

(a) 3 kms. Flight Visibility for aircraft operated at an indicated airspeed of 140 kts or less;
(b) lower flight visibilities to a minimum of 1,500 m may be permitted for aircraft operating:

(1) at speeds that, in the prevailing visibility will give adequate opportunity to observe other traffic or any obstacles in time to avoid collision, or
(2) in circumstances in which the probability of encounters with other traffic would normally be low,
e.g. in areas of low volume traffic and for aerial work at low level;

1.18.3.6 Foreign Military Visual Navigational Flight Standards

For comparative purposes, information was sought from other military operators of similar aircraft regarding their standard navigation training profiles with respect to en-route speeds, altitude, weather limits and type of charts used. The Investigation noted that the IAC procedures were comparable with those of other military organisations.

1.18.4 Head Up Display (HUD)

1.18.4.1 General

The PC-9(M) HUD system is a supplemental display in the front cockpit of the aircraft that provides flight path information using projected symbology in the pilot's line of vision. Thus, the pilot can be aware of the dynamics of the aircraft while looking out.

An active matrix LCD screen (also referred to as the HUD Repeater) is installed in the rear cockpit. This shows the HUD symbology superimposed on an image of the outside world, which is taken by a video camera located in the front cockpit. There is no limitation given on the use of the HUD Repeater in the AFM.

The system is used to train pilots in the use of the HUD. HUD symbology is displayed when the aircraft is electrically powered, unless manually dimmed. It is required operationally to perform weapons air firing.

In accordance with the approved AFM Supplement, the HUD is a supplemental display certified only for use in VMC and must always be compared with real world attitude information and the primary flight instrumentation. Consequently, it is not required to be serviceable in order to dispatch the aircraft for flight.

The HUD information may be recorded on a Removable Memory Module (RMM) (see **Section 1.18.5**).

1.18.4.2 HUD Technical issues

The Investigation was informed that in 2007 issues associated with the HUD display symbology were raised by the IAC with the Manufacturer. Records show that these issues related to intermittent oscillations, position shift of pitch symbol display and occasional display loss. The Manufacturer and the IAC worked together to identify and resolve these issues but they had not been solved at the time of the accident. The Manufacturer informed the IAC that these issues did not affect the information displayed on the normal flight instruments i.e. the Primary Flight Display (PFD) and standby instruments.

In November 2008, the Manufacturer issued a Concession - Technical Memo 'MCC TM 08 015'. This described the problem and clarified limitations associated with the use of the HUD system. It granted the IAC a concession to continue HUD operations in the PC-9(M) within prescribed limitations and in accordance with the AFM.

1.18.4.3 F265 HUD Defects

At the time of the accident, 265 carried two deferred defects relating to the HUD system; a defect regarding HUD symbology loss in flight (one instance earlier in the year and one shortly before the accident) and a defect regarding the HUD Dim/Brightness control fault. The earlier defect had been deferred but the "*Concurrence/Non Concurrence*" strike out at the bottom of the front page had been omitted by the inspector. Both deferrals contained the restriction that the HUD could be inoperative if not required for the mission.

1.18.5 Mission Data De-briefing System (MDDS)

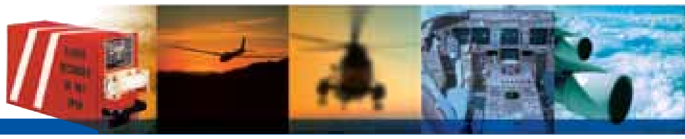
The MDDS is comprised of the RMM, a download station and replay software. It records HUD symbology, the forward looking video camera imagery, communications and intercom audio. The Investigation was informed that MDDS was included as part of the purchase of the PC-9(M), to assist in training debriefing and to record training in weapons air firing. As such, it was not considered essential for normal flight operations.

The MDDS system was unserviceable during periods in 2009 due to software incompatibility when hardware was connected to its two servers. The integration proved to be incompatible with the RMM decoding software.

In 2010, action was taken to restore the MDDS system to full operational status. This included resolution of hardware issues and introducing procedures for the use of the MDDS. For the above reasons the MDDS was only available for the second evaluation flight.

1.18.6 ELU Protection

Following examination of a previous engine over-torque incident by the Investigation, it emerged that there was a difference in understanding in the IAC regarding the function and protections provided by the ELU against over-torque occurrences. Accordingly the technical documentation regarding the ELU was examined by the Investigation.



1.18.7 Previous IAC Events

1.18.7.1 IMC Event

Although the IAC had an on-going CRM training programme, an IAC investigation of an IMC occurrence in 2007 made the following Safety Recommendation.

- **AC SR 02-2007.**
  GOC Air Corps should ensure that the IAC continues the ongoing CRM Training Programme on an annual basis, with an emphasis on;
  - Decision-making and the authority of the Aircraft Captain,
  - The roles and responsibilities within the cockpit, particularly where the experience gradient, or the crew composition are abnormal.
  - Procedures for handover of control of aircraft.
  - Loss of situational awareness – recognition and immediate actions.
  - The dangers of inadvertent or sudden IMC flight, and the consequent crew priorities.

This Safety Recommendation resulted in IAC contracting an external aviation training organisation to provide a course and training for CRM instructors, which addressed these issues among others. This programme was spread over three years and utilised a CRM Instructor Manual and CAP 737 Crew Resource Management (CRM) Training guidance document issued by the Civil Aviation Authority (CAA) UK. The module regarding situational awareness and the dangers of sudden IMC flight was scheduled for 2010.

1.18.7.2 Low Level Pass

The Investigation became aware that in 2005 the Instructor had been grounded as a result of conducting a low level pass along the runway at EIME. The Investigation understands that this manoeuvre had been authorised at sub-Unit level, but authority at ACHQ level had not been granted. The Investigation interviewed the then GOC AC in relation to this event. His recollection was that he had grounded the Instructor for a month as a caution. The incident was not severe enough to generate a formal reprimand and consequently was not recorded in the Instructor's personal file.

The GOC recalled no other disciplinary incident involving the Instructor and regarded the Instructor highly as a very competent officer who was the most experienced PC-9(M) pilot in the IAC and who had his confidence.

1.18.8 Pre-Flight Documentation

The Investigation examined F265's pre-flight documentation and noted that the flight authorisation form (AF 102) contained the Instructor's own signature as the Authorisation Officer but he had omitted to initial the PIC column.

The pre-flight documentation also included a Sortie Risk Assessment Form completed before the flight. This Form contained two scores; that for the daytime navigation exercise flight from EIME to EICM and that for the night-time return flight from EICM to EIME. Both assessments were scored as Low Risk.

This assessment was the result of estimating the cumulative risk to the flight in Mission, Environment and Crew categories with each category having a number of parameters that require assessment e.g. day or night. It was noted that a value was not entered for Visibility.

1.19 Human Factors

The following human factors are considered in this Report:

(1) Situational awareness.
(2) Spatial disorientation:
False horizon, Coriolis and Somatogravic Illusions.

1.19.1 Situational Awareness (SA)

Situational Awareness requires that a pilot maintains an accurate and adequate mental overview of the progress of the flight; the aircraft's flight path, location and environment while taking into account operational and flight constraints. It is frequently referred to as keeping up to speed with the aircraft and is the result of mental rather than physical processes. It is a fundamental requirement that all pilots must exercise when flying.

1.19.2 Spatial Disorientation (SD)

Spatial disorientation, on the other hand, results from physical processes - the confusion of the senses that determine balance and orientation. This can result in a mistaken perception of one's position and motion relative to the earth.

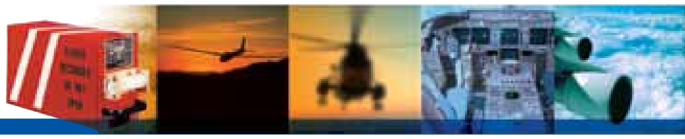
In visual flight, a pilot can judge the aircraft's attitude in pitch and roll by reference to the horizon. However, once the visual horizon is lost, attitude can only be determined by reference to flight instruments. Thus the normal method of establishing instrument flight is to prepare well in advance by establishing stable flight conditions and developing a full flight instrument scan in advance of entry into IMC conditions.

If the visual horizon is lost suddenly and/or the pilot is unprepared for the transition from visual to instrument flight, the pilot may become disorientated unless he immediately follows his instruments, thus ignoring his instinctive sensations. Further information is contained in **Appendix D – Spatial Disorientation and Somatogravic Illusions.**

The following in-flight SD illusions were considered by the Investigation.

1.19.2.1 False Horizon Illusion

Sloping cloud or terrain formations can create the illusion that the aircraft instruments are not correctly aligned with the true horizon. This can lead the pilot to suspect that his flight instruments are incorrect and result in disorientation.



1.19.2.2 Coriolis Illusion

This illusion is associated with a sudden tilting of the pilot's head while the aircraft is turning. This can occur when looking down, up or to the side (e.g. at a chart, overhead panels or at terrain during steep turns).

This can produce an overwhelming sensation that the aircraft is simultaneously pitching, rolling and yawing. The Coriolis Effect is generally caused by an underlying sustained rotation lasting 10 seconds or more.

1.19.2.3 Somatogravic Illusions

These illusions are caused by linear accelerations and involve the inner ear and somatosensory system providing sensory information that may be misinterpreted by a pilot in the absence of external visual information. They are most likely to occur where external visual reference is either unavailable or unreliable and include False Climb and Inversion Illusions.

When reliable visual reference is not available (i.e. no horizon can be seen) during in-flight horizontal acceleration the pilot can experience a pitch-up illusion. This is because the pilot experiences two forces, inertia pushing the pilot back into the seat and gravity pushing him down. The combination of these two forces results in the pilot experiencing a single "Gravitoinertial" force and he may sense that his seat is tilting backwards and the aircraft is pitching up. This is termed a False Climb Illusion. If the pilot then applies stick forward to "correct" this perception, it compounds the problem by allowing the aircraft to further accelerate, thus causing an increasing escalation of the illusion. If the force and pitch-up is sufficient, a sense that the aircraft has become inverted can be generated, which is known as the Inversion Illusion. When such events happen at a low height, the aircraft can, as has been noted in a number of accident reports, impact terrain in a generally wings level, nose down attitude while under power. Further details are contained in **Appendix D.**

1.19.3 FAA Advisory Circular 60-4A

In 1983 the FAA published Advisory Circular 60-4A. It stated that at that time during a previous 5 year period there were almost 500 spatial disorientation accidents in the United States and that over 90% of those resulted in fatalities. It further stated that "*Tests conducted with qualified instrument pilots indicate that it can take as much as 35 seconds to establish full control by instruments after the loss of visual reference with the surface*".

2. ANALYSIS

2.1 General

The Investigation determined that the crew was properly qualified and experienced to undertake a visual cross-country navigational exercise. CVFDR data showed that the training flight had been routine with procedures being adhered to until the aircraft approached the eastern shore of Lough Mask.

2.2 Aircraft

The aircraft was 5 years old and had accumulated 1,041 hours. The Investigation is satisfied that there were no significant issues with the IAC PC-9(M) fleet, or 265 specifically and any deferred defects recorded in the Aircraft Technical Log were minor in nature. Maintenance records showed that the aircraft was appropriately maintained and serviceable at dispatch from EIME.

2.2.1 Engine

The Investigation conducted a full teardown of the engine. The results of this teardown indicated that the engine was providing power at the time of impact. This is supported by site observations regarding propeller damage, etc. In addition, the data from the FDR showed that the engine was operating normally and showed no anomaly.

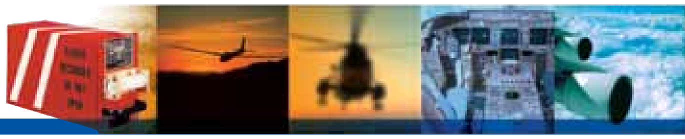
Analysis of a fuel sample from 265 showed that the sample was free of contamination and was of the correct fuel type. Oil analysis likewise showed that the condition of the engine oil was good. The Investigation concluded that the very small amount of material present in the oil sample probably resulted from damage sustained by the engine at impact.

A grinding sound was heard on the CVR recording during the final moments of the flight. A similar grinding noise was recorded by the area microphone at negative G values of a magnitude greater than –2.4G during the second evaluation flight. The Investigation is satisfied that this acoustic signature is a characteristic of the PC-9(M) when operated close to the negative (-3.5G) limit of the flight envelope.

Two residents in Crumlin Valley reported hearing unusual engine noises. The Investigation found no evidence of any malfunction in the engine. It is possible that the noises reported were due to reverberations in the enclosed valley.

A short reduction in powerplant RPM/torque was observed on FDR data from 265 during the final manoeuvre shortly after entering negative G. The Investigation observed a similar reduction on the evaluation flight of 262. The Investigation notes that there is an advisory note regarding this PC-9(M) operational characteristic in the Operations Manual. As this reduction occurred after commencement of the push-over and is a known characteristic of the aircraft it is not considered a factor in the accident or push-over initiation.

The Investigation is therefore satisfied that the engine of 265 was operating normally throughout the flight.



2.2.2 Electronic Limiter Unit (ELU)

While not relevant to this accident the Investigation found a variation in interpretation of the protection that the ELU provided regarding its function and operation. In particular, this concerned the protection that it provides during the operation of the powerplant, especially during vigorous handling such as aerobatics. Although some operational information on ELU function is provided in the aircraft's technical documentation the Investigation believes it lacks operational clarity and that the IAC should seek further information from the Manufacturer.

2.2.3 Airframe

The Investigation determined that all damage to the control runs for roll, pitch and yaw was consistent with impact damage. Consequently, the Investigation is satisfied that full continuity of flight controls was present prior to impact. In addition, the FDR data showed consistency in the aircraft's response to control input and nothing to the contrary was heard on the CVR.

2.2.4 Head Up Display (HUD)

There were two deferred HUD defects at dispatch - a problem with a dimming switch (in the front cockpit) and an occasional loss of HUD symbology in flight. Although there was a discussion in the CVR regarding HUD brightness, there was no further comment that indicated any defect in that system or with the aircraft. The fact that the HUD was routinely used during normal flight conditions was evident from comments in the CVRs of both the accident aircraft and the other aircraft on the exercise. Although the HUD was logged defective on F265 its display was active on the accident flight, as evidenced by the Instructor's comments that it was "*up a little bit high*". The Cadet stated on the CVR recording that he was not using the HUD.

It is not possible to see the HUD (other than its reflections on the canopy) from the rear seat but there is a video repeater in the back cockpit instrument panel. However, this video repeater is solely for training purposes and is not part of the flight instrumentation of the aircraft. It is not particularly easy to see in low light conditions, especially since the large well illuminated PFD is immediately below. Therefore it is considered unlikely that the Instructor was using it for flight reference. This is especially so since the HUD system was only authorised for VMC flight.

The Investigation was informed that the nature of the HUD symbology defects on the PC-9(M) aircraft involved symbology drift, loss or movement and not misleading pitch and roll information. It is unlikely that the Instructor, because of his intimate knowledge of the HUD system, its defects and operational limitations, would have used it in the circumstances that pertained in the final moments of this flight.

The Investigation is therefore of the opinion that the HUD system or its defects were unlikely to have been a factor in the accident.

2.2.5 Evaluation Flights

As a result of the evaluation flights the Investigation concluded that the controllability, performance and ergonomics of the PC-9(M) were not factors in this accident.

2.3 The Navigational Exercise

The navigational exercise, a daytime VFR flight with a transit stop and a night return, took place towards the end of the cadets' wings course. The departure time, determined by the end of VFR (daylight) to provide for a night return, was suitable Whereas general flying limits are provided in the ARM the Investigation notes that specific altitude or height limits for a visual navigation exercise were not clear. The Investigation notes that, subsequent to the accident, specific VFR limits were published in the ARM Part B Supplemental

Although references in the SPTM were made to conducting weather avoidance procedures in VMC, the procedures did not state that the visual navigational exercise must remain VMC at all times. The Investigation believes that the information available to student pilots regarding the visual navigation training exercise should clearly describe the limits associated with the exercise. Accordingly, a Safety Recommendation is issued to the IAC to review the presentation and dissemination of the limitations associated with visual navigation exercises in the Flying Training School.

2.3.1 Flight Plan

The waypoints selected, the small villages of Carigallen and Maum, were appropriate for this advanced stage of the pilot wings course. In particular, the location of Maum, in a valley immediately after crossing high ground, made navigation more difficult and thus required precise navigation. In the normal course of events this would have provided added interest and teaching opportunities e.g. the flight was planned at 1,500 ft and therefore terrain considerations were important with the consequent requirement to climb to maintain a 1,000 ft terrain clearance over mountains. Both EICM and the final destination EIME had full facilities, including instrument approaches where the aircraft could land if the weather deteriorated from VFR or the flights were delayed.

The cadets on F261 and F266 stated that the Cadet had prepared "domestics" and a navigational chart. Although no flight planning documentation from the aircraft was found at the accident site, it is evident from the CVR that the Cadet was operating from a similar chart with a correctly planned track and marked timings in accordance with the SPTM procedures. It is therefore probable that the chart was destroyed in the impact.

2.3.2 Sortie Risk Assessment

The Sortie Risk Assessment Form had rated the flight as Low Risk but the weather visibility forecast for the Maum area was not factored properly. Had this been done it would still have resulted in a Low Risk assessment. However, the decision to continue in reducing visibility towards high terrain rendered the pre-Sortie Risk Assessment void. Furthermore, had the flight diverted in accordance with IAC visual navigation weather avoidance procedures the low risk assessment would have been appropriate.

Whereas low flying has a certain risk level, low flying through mountains at high speed in reduced visibility has a higher risk. Operation in or through high terrain was not included as a risk factor in the Sortie Risk Assessment Form. The Investigation notes that the IAC has subsequently amended this form to include high terrain and has re-adjusted risk values.

More importantly the assessment form completed on the day of the accident did not properly assess the forecast visibility. In addition, if the risk level was assessed as high there was no requirement on the Form for a pilot who self-authorises to consult another.

The Investigation therefore considers that the Sortie Risk Assessment process should be reviewed and issues a Safety Recommendation in this regard.

2.3.3 The Sorties

None of the three flights encountered a problem until approaching Lough Mask. There they encountered weather related problems that are later discussed in **Section 2.4 Weather.** Of the three aircraft, the latter two completed their flight to EICM, though weather problems had caused both to abandon the planned route and forced them lower than their intended flight plan altitude. It should be noted that being unable to pass over a waypoint, due to weather avoidance or other operational reasons, did not invalidate the navigational exercise.

Having examined this visual navigation exercise and the associated documentation that was available post flight, the Investigation concluded that the exercise was planned according to IAC SOPs and that the exercise was appropriate for that stage of cadet development.

The visual navigation exercise was planned at 1,500 ft altitude with a minimum visibility of 5,000 m and a minimum height of 1,000 ft. Whereas a RADALT indicates the actual height over the ground, estimating visibility is more difficult and is normally achieved by looking at the ground ahead.

2.4 Weather

2.4.1 General

The F261cadet stated that he and the Cadet had prepared their domestics together and part of this included weather details. It is not known if the option of bypassing Maum was discussed during the F265 crew's pre-flight briefing and no related discussion was recorded on the CVR. Nevertheless, when the Cadet indicated that he intended to cancel his time check and bypass Maum the Instructor expressed no surprise. It is therefore probable that the crew of F265 had discussed the warm front that was forecast to approach the Maum area during their pre-flight and that the SOPs for weather diversion and aborts were covered, as was the case of F261 and F266.

2.4.2 Forecast

The Synoptic Chart forecast showed that a weak warm front was approaching the West with a slack airflow. This also is shown on the Low Level Significant Weather chart for 12.00 hrs; the 18.00 hrs version of that chart forecasts the front as having transited the area but without any real improvement in the general weather conditions with occasional broken stratus at 500 ft.

The local area forecasts for EICM show operational conditions but a temporary reduction of visibility to 5,000 m and broken cloud at 1,500 ft with light drizzle or rain.

The aftercast also indicated that visibility would have been significantly reduced in hilly terrain, possibly below 1,000 m at times at or above 800-1,000 ft with drizzle or fog.

The Investigation is satisfied, from examining copies of the documentation provided to the crew, that the weather information provided to the crew was adequate and that the weather forecasts generally predicted the weather conditions experienced on the day.

2.4.3 Actual Weather

During the flight the CVR recording confirmed that the Cadet was keeping a lookout and that the crew was monitoring the weather ahead. When the aircraft was over the eastern shore of Lough Mask, or about 6 NM from the mountains, the Cadet commented *".. the cloud is no lower, apart from covering the mountain tops"*. It is noted that photographs (**Appendix B – Weather Photographs)** show that earlier the area was clear and it is therefore probable that weather conditions were better to the east, from where the aircraft was approaching, than to the west - the general direction from which the front was approaching and towards which the aircraft was flying. Nevertheless, the photographs taken about the time of the accident showed that the weather had deteriorated significantly. The F266 cadet subsequently commented that the weather deteriorated deceptively with occasional patches of good visibility that would suddenly and unexpectedly reduce. It is likely that this was the case with F265 though less so, since that flight was 16 min earlier.

The F261 instructor, who searched the area, stated that he had been "*shocked*" by the rate at which the weather had deteriorated in the 12 min from the time they first arrived over Lough Corrib to the time they returned. He said that the weather conditions over Lough Corrib had become very poor with the cloud base descending to almost 500 ft. This improved as they travelled further south and increased to 1,100 ft with good visibility near EICM.

The deceptive nature of the weather probably led the Instructor to initially believe that Maum could be reached through Finny Valley and, having abandoned that idea, that he could route directly to Maum. Later CVFDR records showed that the crew, at 1,350 ft altitude, had visual contact with the ground. The aircraft was therefore below cloud as it crossed the northern ridge into Crumlin Valley where residents reported very variable conditions, with visibility lifting and dropping rapidly, even for that area where changeable weather was typical.

The rapidity with which the Instructor took control and the steep bank that followed leads the Investigation to believe that visibility on the southern side of the valley at the aircraft's height had significantly and unexpectedly reduced. This was probably due to the aircraft skirting underneath the cloud base with the slant visibility along the valley floor disguising a much reduced horizontal visibility ahead. Nevertheless, the southern side was evidently visible since the aircraft paralleled it and was observed doing so, after turning east.

The final turn was to the north, towards what a witness reported as a "*foggy*" northern side. Two witnesses saw the aircraft pitch up and climb into cloud immediately before its final push-over, which was consequently conducted in IMC conditions.

Because of this, and the rapidly variable weather conditions in the valley the Investigation considers weather a significant factor in this accident.

2.5 Crew

2.5.1 General

The Crew on the aircraft were a combination of the CFI and one of his cadets. The Instructor was an officer, the CFI, the approved Low Level Display Pilot on the fleet and very experienced. The Cadet had limited experience. While there was a significant cross-cockpit gradient, in command, skill and experience, this is normal in a training situation.

Despite the differences, the dialogue between the crew was professional in nature and task focussed. Until shortly before the accident, the flight was flown accurately and smoothly with adherence to normal procedures. Overall, the CVR showed that this was a normal military training flight with an alert Cadet in the front taking instruction from an experienced instructor in the rear.

2.5.2 Cadet

Both instructors interviewed considered the Cadet one of the better students in the class. The Cadet had, according to the F261 cadet, prepared the pre-flight documentation and it is likely that the pre-flight briefing was according to IAC SPTM procedures, since the CVR records accurate and regular checks during the flight with good forward planning and anticipation. Accordingly, the flight progressed as planned until the Cadet said he would have to bypass Maum.

He was instructed to continue and to look at their options later, which he proceeded to do. At that point, tactical decision-making passed from the Cadet to the Instructor. Thus the Cadet had little further input into decisions and was evidently unsure as to what further decisions on the direction of the flight he was expected to make. As a result his workload and stress level would have increased significantly at that time.

Twice the Instructor took over control; initially without advising him (to turn away from Finny Valley), and finally, in Crumlin Valley, formally taking control. From that latter point onwards, there is no evidence that the Cadet had any further input into the operation of the aircraft.

2.5.3 Instructor

From the interviews conducted with his superiors, peers and the cadets it was evident that the Instructor was respected, both as a professional officer and as a pilot. He was a skilled aircraft handler, the Chief Weapons Instructor, the approved singleton aerobatic display pilot and his personnel records showed that he was highly rated. Although he had spent longer than average in FTS as an instructor, this appears to be as much due to organisational requirements as personal volition, considering the regular turnover of FTS Commandants. He was considered to be one of the most experienced IAC PC-9(M) pilots.

Although the Instructor had been previously grounded for a low level pass along the runway at EIME, he would not have conducted this at his base in full view of senior officers had he not understood that he had been granted permission. The Investigation is satisfied that this grounding appears to have been due to a lapse in communication between FTS and ACHQ.

While the Instructor was recorded as proficient in instrument flying, the Investigation was initially concerned that lack of instrument flying currency may have been a factor. Although records showed his proficiency, it proved more difficult to establish his currency, since the vast majority of his recorded 38 hours 05 min instrument flying in the previous 12 months was on instructional details with cadets who would have conducted most of the handling.

Specifically the Investigation determined that he had a least 2 hours 25 min instrument flying as handling pilot in the previous two months and quite probably more. The Investigation notes that his instrument rating 6 weeks beforehand was recorded as satisfactory without other comment, since the IAC had a policy of not recording any comment unless unsatisfactory. The Investigation spoke to his Examiner who confirmed that the Instructor's instrument flying was of a high standard and the Investigation is therefore satisfied that the Instructor's instrument flying was not a factor in the accident.

The Instructor was reported to have slept well the previous night and was looking forward to a posting abroad. In addition, he attended a meeting at 10.00 hrs that morning at which he was reported to be his normal self.

2.5.4 Inter-Crew

Although the Instructor had operated in that role for the previous ten years, there was no evidence of instructor fatigue in the CVR recording. On the contrary, the CVR revealed an instructor demonstrating good instructional technique, requiring SOPs, accurate navigation and flying from his student and guiding his student by providing positive feedback. The Cadet regularly used "sir" in the recorded dialogue; but this is normal military parlance while addressing a superior officer and the inter-cockpit atmosphere did not appear tense and was conducive to good learning.

Approaching Lough Mask, the Cadet considered the conditions ahead unsuitable and said that he would *"cancel my time check at Maum"*, thus bypassing Maum. This in itself is not exceptional as cadets tend to be conservative in their decision making (**Section 1.1.4**), especially when flying with a CFI.

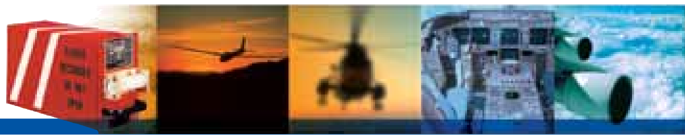
The Instructor acknowledged this but said *"Okay hang on let's continue in and let's look at our options when we get in a bit further alright".* A cadet would be very unlikely to disagree with such a direction by an instructor.

The outcome of this direction was that the crew no longer had a shared view of what the sortie entailed, since the briefed exercise was no longer being followed. This resulted in the Cadet initially offering options and becoming unsure of the detail of the revised plan, thus having to consult the Instructor more. This was manifested on the CVR recording by the Cadet outlining options and waiting for the Instructor to provide guidance on which to select, while the Instructor was expecting the Cadet to make decisions.

Following a command to hold the track, the Instructor asked the Cadet *"what's your decision?"* and added *"We have to get to Maum somehow"*. One interpretation of this direction is that the Instructor was determined to press on to Maum in order to complete the navigational exercise.

Another more likely interpretation is that he wanted to exercise a good cadet in coming up with an alternative routing to Maum in a demanding situation, as is not unusual in an instructional context.

It is also possible that the Instructor believed that the weather conditions at that time and in that location were adequate for continued navigation. In any case the aircraft was rapidly heading towards high terrain and an immediate decision needed to be made. The outcome was that, after the Instructor led the Cadet to identify Finny Valley as a viable route to Maum, he told him to go there.



Having turned right towards the valley the Instructor apparently became concerned, possibly over weather conditions in the valley, and directed "*Go left*". He probably assumed control shortly afterwards since, for the first time on the CVR, an order by the Instructor was not immediately acknowledged by the Cadet who would have done so had he understood the instruction. At this time, normal cockpit procedure was beginning to break down as events happened faster and the Instructor became increasingly involved in handling the aircraft.

2.5.5 Situational Awareness

The Instructor then set the aircraft on a heading, placing it on a track for a gap on the northern ridgeline of Crumlin Valley and, when satisfied that the Cadet had this identified, handed back control telling him not to climb but to maintain ground contact. It is probable that the Instructor progressively lost situational awareness after this point, as it is likely that he was under the impression that Maum was on the far side of that ridge rather than the sheer walls of the south side of Crumlin Valley.

The rising ground of the ridge caused the visual navigation height restriction of 1,000 ft to be broken and the vocal acknowledgement of the 900 ft RADALT warning, triggered by the rising ground, was immediate, since the crew were evidently expecting this. In fact by keeping ground contact the IAC minimum height restriction of 500 ft was broken when crossing the ridge (the minimum RADALT recorded was 436 ft). From this point on, the briefed 180° backtrack escape became more difficult to accomplish, due to the presence of high ground on three sides.

After crossing the ridge the crew commented that high ground was descending away from them. The lack of comment from either crew indicated that the visibility that allowed them to see into Crumlin Valley did not raise any alarm, although the aircraft was crossing the 1 NM wide Crumlin Valley at high speed towards high terrain.

GPS data shows that the aircraft (at 1,400 ft) was tracking directly towards a 1,500 ft mountain with sheer slopes. 10 seconds after crossing the ridge the Instructor said quickly "I've control". He took control, retaining it for the remainder of the flight, and over-banked (103° left) in a steep, evasive manoeuvre, probably because the steep mountain ahead came into sight. It is possible a false horizon visual illusion, created by the adjacent sloping terrain, may have contributed to this over-bank.

It is likely, based on the rapidity and the rate of turn, that the horizontal visibility at that point and in the direction of flight, was of the order of 1,000 m. Consequently, a significant deterioration in horizontal visibility had not been detected. Following this turn the aircraft was then heading southeast, paralleling the south valley wall.

The Instructor then commented "*Bad decision now*". Nothing further was spoken on the CVR. The tone of this comment did not convey a sense of alarm. However, the FDR parameters portray vigorous manoeuvring.

Significant variations in pitch, roll and yaw in response to control inputs are recorded, probably due to mounting stress and anxiety levels as the Instructor strove to remain visual and avoid obstacles. The aircraft banked right at 50° resulting in a 25° heading change to the right. It was then on a heading towards the entrance to the valley, with rising ground at the 11 o'clock position, that shields the north side of the valley. This ground (at 843 ft) was lower than the aircraft (1,250 ft).

The aircraft immediately made a 111°/5G left bank turn. The Investigation cannot positively determine the reason for this turn but it is likely that it was an attempt to turn back towards the ridge on the north side of the Valley, an area that he knew was clear and over which the aircraft had entered the valley. This would have been in conformance with the original 180° Turn Back briefing. If the aircraft had continued ahead and down the valley before this turn, it would have exited the valley towards Lough Corrib, but it is likely that this exit was obscured by low cloud.

During this final 111°/5G turn, the pitch varied from an initial +15° to −12°, the aircraft banked to a 111° left bank angle with a high rate of roll during which the rate of descent momentarily reached −4,500 ft/min. It is again possible that over-banking was due to lack of adequate visual references, but in any case, aircraft handling was symptomatic of overload and very high stress levels.

This over-bank, through the vertical to partially inverted, accounts for the differing witness observations regarding the attitude of the aircraft. Their view depended on their location and angle the aircraft was viewed from; Witness No. 5 observed the aircraft inverted while Witness No. 6 did not.

2.5.6 Emergency Low Level Abort

As the aircraft exited from this final turn the FDR data showed that it was rolled towards wings level and pitched up to +34° while high power was applied; during this time a RADALT warning tone sounded. The pitch up was consistent with the initiation of an Emergency Low Level Abort manoeuvre. This procedure, inter alia, requires that having pitched up to +30°, the attitude should be held and the speed then allowed to reduce to 120 kts with a trim to a 100 kts climb.

FDR data showed that, after establishing a nose up attitude, a gradual levelling of the aircraft commenced with the stick being eased forward. The reason for this control input could not be positively determined. It may have been a conscious attempt to simply recover the pitch to +30°, or possibly the sensation that the aircraft was climbing at too steep a pitch, since it had pitched up through 46° (from –12° to +34°) when the standard manoeuvre called for a pitch up to 30°. Although the aircraft may have been perceived to have pitched up more than it actually was, the reducing airspeed associated with the 30° nose-up attitude should, to some degree, have had the opposite effect.

The aircraft was not in a steady state (in terms of heading, pitch, roll, airspeed or altitude) throughout the final 30 seconds of flight and the Instructor's vigorous handling of the aircraft, probably an expression of his increasing sense of alarm, would have produced some powerful dynamic sensations that in the absence of external vision probably felt all too real.

Whatever the reason, FDR data showed that levelling off commenced, pitch was progressively reduced and the aircraft entered a −3G push-over, during which it rolled 93° right and reached a nose down pitch angle of −60°. During this push-over the Over-G alarm activated due to negative G values exceeding -2.5G.

The final FDR readings indicate that the aircraft was rolling level and pitching up immediately prior to impact. This is consistent with regaining visual ground contact and attempting to avoid impact with the aircraft responding to control inputs.

Up to the +34° pitch-up point, the manoeuvring of the aircraft is understandable due to terrain avoidance being paramount. However commencement of this Emergency Low Level Abort manoeuvre was a rolling pitch-up into cloud, which followed vigorous manoeuvring. The rapidity of manoeuvring due to the proximity of terrain precluded this manoeuvre being conducted in accordance with the IAC Emergency Low Level Abort procedure, which requires stabilisation of the aircraft and establishing on instrument flight before initiation of the pitch up (see **Section 1.18.3.3**).

2.5.7 Spatial Disorientation

It is noted that FAA Advisory Circular 60-4A states that it can take as much as 35 seconds to establish full instrument control following loss of visual reference. It is clear from subsequent events that the Instructor did not transfer fully to his flight instruments, or if he did, the disorientation he experienced was so compelling as to cause him not to believe them, notwithstanding that he was an experienced pilot.

The SPTM (**Section 1.18.3.4)** gives adequate guidance on spatial disorientation. Probably all the causal factors listed in that document were present to some extent. It is likely that the Instructor had been trying to maintain visual ground contact and may have used large or rapid head movements while trying to do so. The pitch up was a rolling pull. The control inputs were fast and large and it would have been difficult to monitor attitude indication while manoeuvring vigorously without a clear horizon amid high terrain at low level and high speed. It was not possible to do "*one thing at a time slowly and deliberately*" due to the rapidity of events and, most importantly, stable flight on instruments was never established before entering IMC. Therefore he was mentally and physiologically unprepared for and unlikely to have expected the onset of somatogravic effects. Having earlier lost situational awareness and with high stress levels, the rolling pitch up manoeuvre was conducive to spatial disorientation, as indicated in the IAC SPTM.

As no sustained rotation of over 7 sec existed in the manoeuvres preceding the accident the conditions for the onset of a Coriolis Illusion are not considered to have been present.

2.5.8 Somatogravic Effects

In the absence of visual reference (i.e. a horizon) there can be a subconscious transfer to an attitude perception resulting from the forces experienced by a pilot.

Equating that frame of reference with the true vertical results in an incorrect perception of the aircraft's attitude. This incorrect perception can be so compelling that it may lead to a situation where a pilot no longer trusts or follows his flight instruments. This is discussed in **Appendix D**.

Eyewitnesses stated that F265 was finally seen climbing into cloud and, as the impact was in a wings level, nose down attitude under power, the Investigation sought to determine if False Climb and/or Inversion Illusions effects were factors in this accident.

The FDR data elevator position showed that an increasing nose down displacement was commanded over -9 to -6 seconds prior to impact, which resulted in a continual reduction in pitch attitude (see **Figure No. 4** and **Appendix D** for detail). The normal (Gz) and longitudinal (Gx) F265 FDR acceleration data were then used to calculate the magnitude and direction of the Gravitoinertial vector during the final manoeuvre thus giving the perceived pitch attitude at that moment. This resulted in the blue line in **Figure No. 4.**

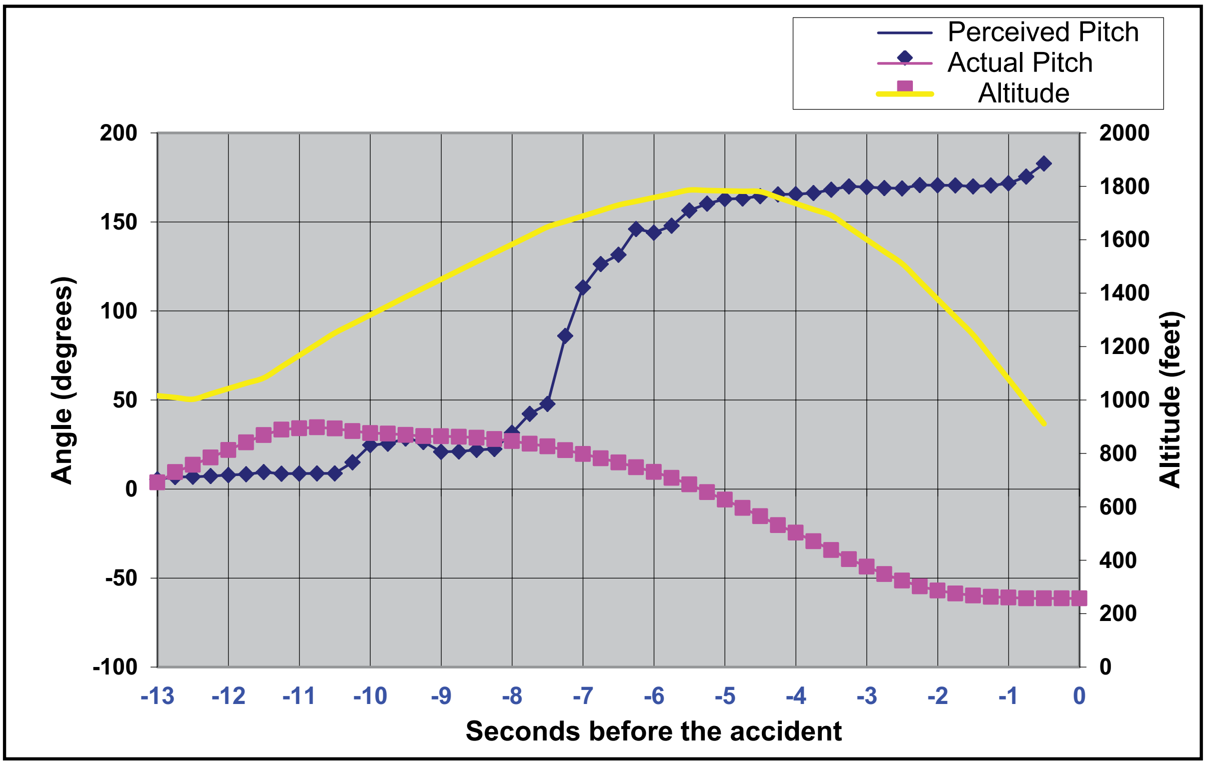
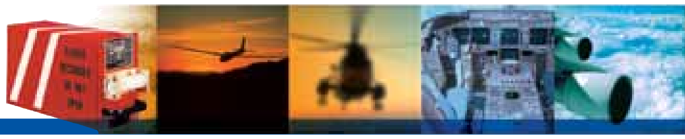


***Figure No. 4:** Perceived versus Actual Pitch, with Altitude*

This plot of the Gravitoinertial force indicates that a False Climb Illusion probably commenced at 8 sec before impact. This False Climb Illusion rapidly progressed into an Inversion Illusion over a very short period.

This is shown in **Figure No. 5** where the aircraft symbol is the actual recorded pitch attitude of the aircraft and the lower figure is the perceived pitch that would result from the Gravitoinertial force.



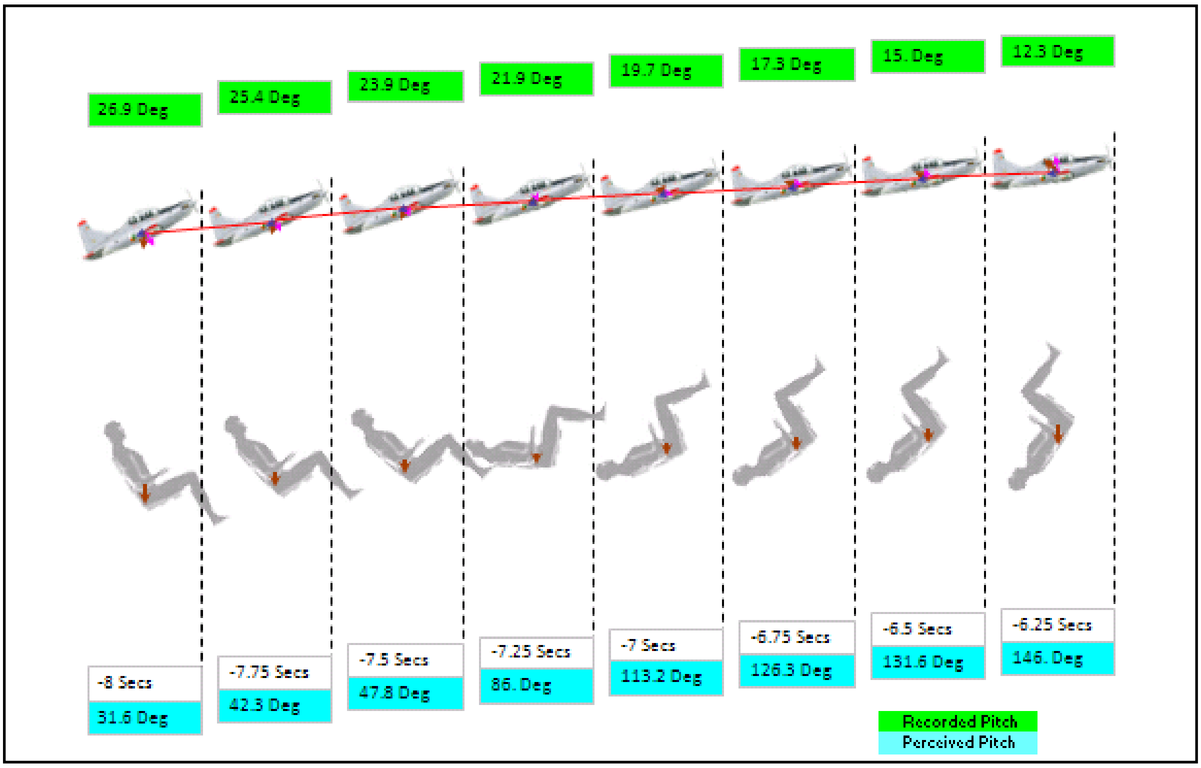


Figure No. 5: Actual Pitch versus Perceived Pitch

It was noted during the evaluation flights, which replicated the flight path of F265, that roll change was not noticed when flying without visual or instrument reference. This may in part explain why F265 rolled to the right during the push-over manoeuvre when flight instruments were not followed.

The Investigation considers that spatial disorientation probably commenced following initiation of the final pitch up and entry into cloud. This would have been disorienting and disconcerting and provides a probable explanation as to why the Instructor, who had been flying the aircraft visually up to that point, did not trust and/or follow his flight instruments.

2.5.9 Human Factors - Disorientation and Illusions

The Investigation notes that an IAC investigation of an occurrence in 2007 resulted in a Safety Recommendation being issued regarding loss of situational awareness, its recognition, the immediate action, the dangers of sudden or inadvertent IMC flight and the consequent crew priorities. Subsequent to this Safety Recommendation, the IAC introduced a CRM programme, which aircrew are required to undergo annually. This accident shows the necessity for such training. The Investigation notes that the CRM module on Situational Awareness was completed by all IAC aircrew in 2010 and that covering Spatial Disorientation will be completed by the end of 2011.

The Instructor produced a paper which included a discussion of illusions involving the somatosensory system when he was a cadet. He was later involved in briefing cadets on the subject as part of each cadet course.

More recently the Instructor was associated with production of the CRM training course and Instructor's Manual where these subjects are also covered. The Investigation is of the opinion that adequate information on this subject was provided within FTS documentation and that the Instructor had knowledge of the phenomena.

Instrument and on-going recurrent training are designed to enable a pilot to control his aircraft solely by reference to flight instruments. This training consequently attempts to provide a pilot with the ability to ignore in-flight false kinaesthetic or the sensory illusions outlined in this Report. When experiencing these illusions, such training will not be successful unless a pilot trusts his instruments and ignores sensations.

Somatogravic Illusions and the conditions that give rise to them can be present on any flight where there are no visual references. Studies suggest that all pilots, irrespective of experience or ability can be subject to such illusions depending on the circumstances. Because of this, the confident and expert pilot, though less likely than those lesser experienced, can succumb to the insidious effects of somatogravic illusions.

While the Investigation notes that substantial information on Spatial Disorientation and Somatogravic Illusions is provided in the IAC SPTM, it is of the opinion that the IAC should consider the regular dissemination of this information to flight crew and a Safety Recommendation is made in this regard.

At the time of the accident FTS did not conduct in-flight training for Vertical Avoidance or Emergency Low Level Abort manoeuvres. The Investigation has been informed that Vertical Avoidance has been removed from the FTS training syllabus. However, training for an Emergency Low Level Abort manoeuvre has been introduced. As a consequence no Safety Recommendation is considered necessary.

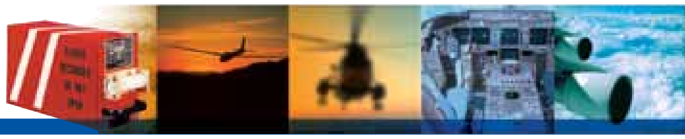
2.6 Organisational Issues

2.6.1 Navigation Procedures - Speed

An important aspect of this accident was the rapidity of events in the final stages. From the moment the first avoiding turn was taken in Crumlin Valley until final impact, the aircraft was never in a steady state (in terms of heading, pitch, roll, airspeed or altitude) and was continually and rapidly manoeuvring at high speed in a narrow valley with variable and limited visibility.

Data obtained by the Investigation regarding military use of similar aircraft indicates that the IAC operational procedures for navigational training exercises are generally in line with other military operators. The comparisons however, did highlight some specific criteria that required further examination. The Investigation noted that, at the time of the accident, FTS visual navigation procedures laid down that the exercise was to be flown at 240 kts. There was no provision or caution regarding speed reduction *en route*, if reducing visibility or cloud base was encountered. Good airmanship would suggest that speed should have been reduced from 240 kts in the prevailing conditions. This would have provided more time to keep abreast of happenings by slowing down the rapidity with which events occurred, especially when operating at a lower altitude than the prescribed 1,500 ft.

The Investigation notes that subsequent to the accident FTS introduced procedures for reducing speed in poor weather and or visibility and accordingly the Investigation makes no Safety Recommendation in this regard.



2.6.2 Navigation Procedures – Charts

The charts used were appropriate for the planned visual navigation exercise. They were not suitable for low-level navigation through mountains as the scale was too small to allow topographical features to be depicted in detail.

The Investigation notes that detailed maps are available in FTS for planned low-level navigation. Because the planned exercise did not involve low-level navigation it was not required or appropriate to carry such detailed maps.

2.6.3 FTS Authorisation of Flights

Documents provided to the Investigation subsequent to the accident showed that F265 had been authorised by the Instructor but he had not countersigned the form. The Investigation does not consider this administrative omission significant.

The IAC ARM states that authorising officers receive a written warrant and states that officers to whom this authorisation power is delegated cannot in turn delegate it to a third party. However, DFRs and FTS Standing Orders stated that the 2 I/C (the CFI/Instructor) would take over the functions of an absent OC FTS.

This was confirmed by the then GOC AC whose view was that the Instructor was adequately qualified to authorise PC-9(M) flights and was probably the best positioned officer to do so. The Investigation notes that warrants were not issued. In addition, no written approval record of what the Instructor was permitted to authorise was found.

2.6.3.1 FTS Oversight

The Investigation was informed that the OC FTS at the time of the accident had no experience of training ab-initio pilots and did not hold a PC-9(M) type rating, although he was a qualified flight instructor. The Instructor had served in the FTS for a period of 10 years and was the most senior FTS officer flying the PC-9(M), though he held the rank of Captain. The Investigation also notes the regular turnover of OC FTS during those 10 years and is concerned that IAC succession was unable to prevent a situation whereby the officer commanding FTS was not required to have a type rating on the PC-9(M) while overseeing the school.

Although a higher authority should authorise a flight, such an authority needs sufficient competence and operational experience to assess the appropriateness of flight and to balance its purpose and circumstances. In addition, the level of risk associated with the flight requires to be evaluated. Because of these requirements and the absence of PC-9(M) experience at a higher rank, self-authorisation by the Instructor was usual and oversight was accordingly reduced.

The Investigation notes that the Instructor was frequently mentioned as de-facto in charge of PC-9(M) operations. This was because of his long experience in FTS, the fact that he was the lead pilot on the PC-9(M) and probably also his ability and competence.

OC FTS did not have operational experience on the PC-9(M) and his flying duties were in a different Wing, which required him to be regularly away from base. Because of these factors the Investigation considers that this situation was not ideal and not conducive to optimum oversight of the flight training school.

In light of this safety concern a Safety Recommendation is issued to the IAC that it reviews the type rating and duty requirements for the OC FTS post holder.

2.6.3.2 Self-Authorisation

Examination of FTS records found that the Instructor, not the OC FTS, normally authorised FTS flights and that self-authorisation by the Instructor, as for F265, was the norm. The Investigation considers that self-authorisation for routine operations such as training is not in accordance with good safety practice as it reduces supervisory oversight. It is of the opinion that self-authorisation is not appropriate except in exceptional circumstances.

The ARM provides that when a written authorisation form cannot be signed by an Authorising Officer a verbal authorisation can be accepted. Flying records for the previous month show that this provision was occasionally used. The Investigation therefore considers that it should always be possible to get at least verbal authorisation for FTS flights, particularly at the IAC main base where there are up to six other authorising officers.

The Investigation is of the opinion that the issues of authorisation of flights and self-authorisation should be reviewed and a Safety Recommendation is made in this regard.

2.6.3.3 Instructor Experience

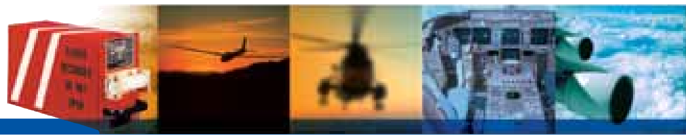
The Instructor was the CFI, the Chief Weapons Instructor and the IAC singleton aerobatic display pilot. He was one of the most experienced IAC PC-9(M) pilots and was held in high esteem. This may have generated a level of self-belief that there were few conditions that he could not recover the aircraft from.

Consequently, after the decision was made to continue visually into forecast poorer weather under the MSA, that decision was not revisited or re-evaluated in light of the developing and deteriorating situation.

2.6.4 Operational Oversight

At the time of the accident FTS procedures did not require the MDDS system to be operational. The MDDS was not operational and the ability to record and monitor flights and to examine them post flight was unavailable. While the MDDS was not intended for oversight, a potential tool for post-flight training evaluation and oversight was unavailable.

The Investigation notes that the software issues associated with the MDDS were subsequently addressed and that new management and control procedures regarding the use of this equipment were implemented. Consequently, the Investigation is of the opinion that no Safety Recommendation is required.



2.6.5 Operational Flight Data Monitoring (OFDM)

The Investigation notes that FTS now requires the use of the RMM on all flights and that they can be reviewed post flight by FTS staff. However, using the MDDS to manually review each flight is labour intensive and cannot cover all flights. In addition, the MDDS is not designed as a flight monitoring system but rather as a training aid.

It is recognised in aviation that provision of OFDM improves safety levels. The Investigation considers that the CVFDR of the PC-9(M) has the ability to provide OFDM through the use of appropriate software. The use of OFDM software to automatically monitor flights for IAC defined exceedences would be more efficient and comprehensive.

The Investigation is aware that this may not be technically feasible on some IAC aircraft types due to the absence of an FDR, nevertheless it recommends that IAC reviews and implements OFDM monitoring on suitable aircraft types. Therefore a Safety Recommendation is issued accordingly.

2.7 Survival

An impact at such a velocity and nose down attitude followed by the rapid deceleration and disintegration of the fuselage, resulted in an accident that was not survivable.

The SPTM recognises that it is possible to lose control and get into an unusual position during an emergency low-level abort. It states to EJECT immediately in that case. Although some of the ejection pyrotechnic cartridges had activated the Investigation is satisfied that this was due to the velocity of the aircraft at impact. As neither ejection seat had been activated it is probable that the rapidity of the final event left insufficient time for either crew member to initiate the ejection sequence.

2.8 Audits

The Investigation reviewed copies of previous Flight Safety Section (FSS) and Operations audits of FTS and ACC. The FSS audit reports stated that they were not Operations or Quality Audits.

It is noted that the FSS Audit Report, dated 16/9/2003, was much more detailed than those following. Subsequent audits did not report on items noted for action in previous audits. In addition the level of detail provided was sparse. It is noted that the audit dated 19/2/2009 did not identify that the OC FTS was not type rated and was operating between two squadrons. Consequently, the audits did not identify any potential deficiency in oversight capability in FTS.

The auditors were members of the IAC. While there can be a tacit acceptance from within an organisation of the status quo, nevertheless an objective overview is required from safety auditors in order to identify hazards and threats to safety.

It is also noted that no FSS audits were provided to the Investigation between 2004 and 2009. The Investigation believes that this level of monitoring is inadequate and recommends that the IAC should review the effectiveness of the FSS auditing processes.

The Investigation believes that all aspects of FTS functionality should be included in the FSS audit process and that an external input to the audit process is recommended.

This should not be taken to infer that other audit processes such as Operations or Quality audits should be discontinued.

2.9 Safety Management Systems (SMS)

In recent years the concept of SMS has been introduced in civil aviation. SMS is a systematic approach to managing safety including the necessary organisational structures, accountabilities, policies and procedures. It is pro-active rather than reactive and includes, at a minimum identification of safety hazards, ensuring that remedial action necessary to mitigate the risks/hazards are implemented and providing for continuous monitoring and regular assessment of the safety levels achieved.

This was introduced by the IAC and Section F, Flight Safety, of the ARM contains the relevant policies and procedures. These processes need to be reviewed at regular intervals in order to ensure best practice is organisationally achieved. In addition, due to the small size and wide operational diversity of IAC activities an external input to this review process is needed to ensure a sufficiently wide overview is achieved. This would ensure that the tacit acceptance of the status quo is avoided.

In view of these considerations a Safety Recommendation is made that the IAC should review the operation of its SMS, the auditing process and that it should consider an external input.

2.10 Summary and Chain of Events

The CVFDR data and information revealed that the Cadet in the front seat was the operating pilot until the Instructor took control. As they crossed the eastern shore of Lough Mask the weather deteriorated. The Cadet made a decision to bypass Maum and route to EICM. However, the Instructor acknowledged this but directed him to continue towards Maum, thus commencing a chain of events that ended in the fatal accident:

Instructor experience: The Instructor was highly regarded and experienced. It is probable that this influenced his decision to press on into deteriorating weather and rising terrain.

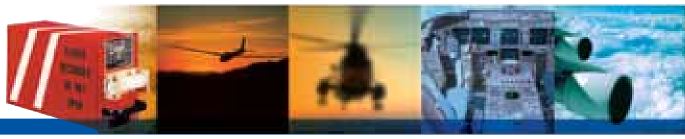
Reducing margins: A reducing cloud base caused a descent from an altitude of 1,500 ft towards 1,000 ft.

Decision making: A route was selected by the Instructor to the northwest through the mountains, via Finny Valley to Maum, at high speed and low height in deteriorating weather. This new route had not been planned and no new limits were set.

Task failure: The new route was abandoned, probably due to deteriorating weather; and a route towards Maum was resumed.

Failure to re-evaluate: After the Instructor briefed his student that their escape route would be a 180° about turn there was no further discussion of an escape strategy. The option of a climb above the MSA of 3,300 ft was not discussed - the focus continued to be on remaining visual and getting to Maum.

Inappropriate speed control: Failure to reduce speed in deteriorating visibility and high terrain resulted in reduced time for decision making. As a result crew workload and stress levels increased significantly.



Non-adherence to SOPs: The Instructor assumed control (at Finny Valley) without announcing it first. F265 later crossed over the ridge into Crumlin Valley below minimum height. (RADALT minimum height was 436 ft while the exercise minimum was 1,000 ft, IAC legal minimum 500 ft). Horizontal visibility in Crumlin Valley was below 5,000 metres.

Loss of Situational Awareness: Unexpectedly seeing a mountain ahead and having to make an evasive manoeuvre.

Recognition of mistake: Instructor said "*Bad decision now*".

Further indicator of loss of Situational Awareness: Not availing of the eastern exit from Crumlin Valley.

Increasing stress and anxiety: Indicated by vigorous handling of the aircraft during the final turn.

Spatial Disorientation onset: The vigorous manoeuvring prior to the attempted Low Level Abort made the onset of spatial disorientation more likely.

Somatogravic Illusion: The Instructor probably succumbed to a somatogravic illusion and pushed the nose down.

The discipline of staying on and following instruments is fundamental to controlled flight in IMC. The indications are that this did not happen following the final pitch up, probably due to overwhelming sensations causing him to disbelieve his instruments. By the time ground was seen there was insufficient height to recover.

The Investigation has concluded that the accident was a CFIT event attributable to Spatial Disorientation primarily due to a Somatogravic Illusion. As a result this accident is classified as an unrecognised disorientation in that the Instructor only became aware of the true state of affairs at a time when the accident was inevitable.

3. CONCLUSIONS

(a) Findings

1. The aircraft was airworthy, serviceable and had been properly maintained according to an appropriate maintenance schedule.

2. There were no relevant aircraft technical defects.

3. The flight crew were appropriately qualified with valid IAC ratings.

4. The daytime VMC navigational exercise was planned and commenced in accordance with FTS procedures.

5. While approaching the Maum checkpoint and high terrain the weather deteriorated as forecast.

6. The Instructor directed the Cadet to continue towards Maum and to look at their options further in.

7. Speed was not reduced in deteriorating weather close to high terrain. This resulted in significantly increased crew workload and stress.

8. An unplanned attempt to route circuitously through Finny Valley to Maum was suggested by the Instructor. This was quickly abandoned by him, probably due to the weather, and he turned the aircraft towards a ridge, in the general direction of Maum without reassessing the situation.

9. Situational Awareness was lost due to poor visibility, low cloud and terrain.

10. The aircraft crossed into the narrow and confined Crumlin Valley at high speed in visual contact with the ground.

11. It is likely that horizontal visibility in Crumlin Valley at that time and altitude was approximately 1,000 m.

12. The Instructor took control, probably when a steep mountain ahead came into view, and commenced a rapid series of steep visual turns.

13. The final turn ended with a rolling pitch-up into cloud when an Emergency Low Level Abort manoeuvre was probably commenced. The vigorous manoeuvring prior to this made the onset of spatial disorientation more likely.

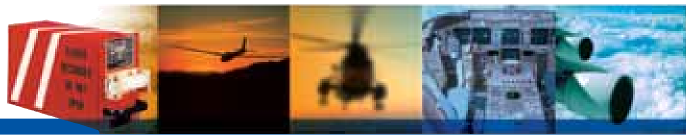
14. The aircraft then commenced a push-over, ultimately reaching -3G, which most likely led to somatogravic sensations causing a False Climb and Inversion Illusion.

15. An attempt was made to recover immediately before impact.

16. The aircraft impacted in a wings level, nose down attitude at high speed while still under control.

17. The aircraft was destroyed and the accident was not survivable.

18. The flight crew did not initiate ejection.



19. OC FTS was not qualified on the PC-9(M). The Investigation considers that this situation was not conducive to optimum oversight of FTS.

20. Self-authorisation by the Instructor (CFI) was found to be the norm in FTS. This reduced supervisory oversight and was not in accordance with good safety practice.

21. Visibility was not assessed in the Sortie Risk Assessment Form.

22. The level and scope of the audits of FTS was limited.

(b) Probable Cause

Controlled Flight Into Terrain (CFIT) attributable to Spatial Disorientation due to a Somatogravic Illusion following the loss of Situational Awareness.

(c) Contributory Factors

1. Continued flight towards high terrain in deteriorating weather.

2. Very changeable weather conditions.

3. High speed in a high terrain area while visibility was reduced.

4. SAFETY RECOMMENDATIONS

It is recommended that:

1. GOC AC should review the provision of information on spatial disorientation to flight crew. **(IRLD2011011)**

2. GOC AC should review the aircraft type qualification and duty requirements for OC FTS. **(IRLD2011012)**

3. GOC AC should review and amend regulations regarding flight authorisation including guidance and procedures for self-authorisation. **(IRLD2011013)**

4. GOC AC should review the Sortie Risk Assessment process. **(IRLD2011014)**

5. GOC AC should review the operation of the Safety Management System within the IAC, including the auditing process, and should consider an external input. **(IRLD2011015)**

6. GOC AC should consider implementation of Flight Data Monitoring. **(IRLD2011016)**

7. GOC AC should review the presentation and dissemination of the limitations associated with visual navigation exercises in the Flying Training School. **(IRLD2011017)**

APPENDIX A

Meteorology

During pre-flight the cadets prepared their domestics which included weather charts and reports for their planned route. The following are copies of some of the documentation.

Probably the most important chart for planning this low level flight was the Low Level Significant Weather chart. The earlier chart for 12.00 hrs (**Figure No. 6**) showed a warm front approaching the West Coast of Ireland.

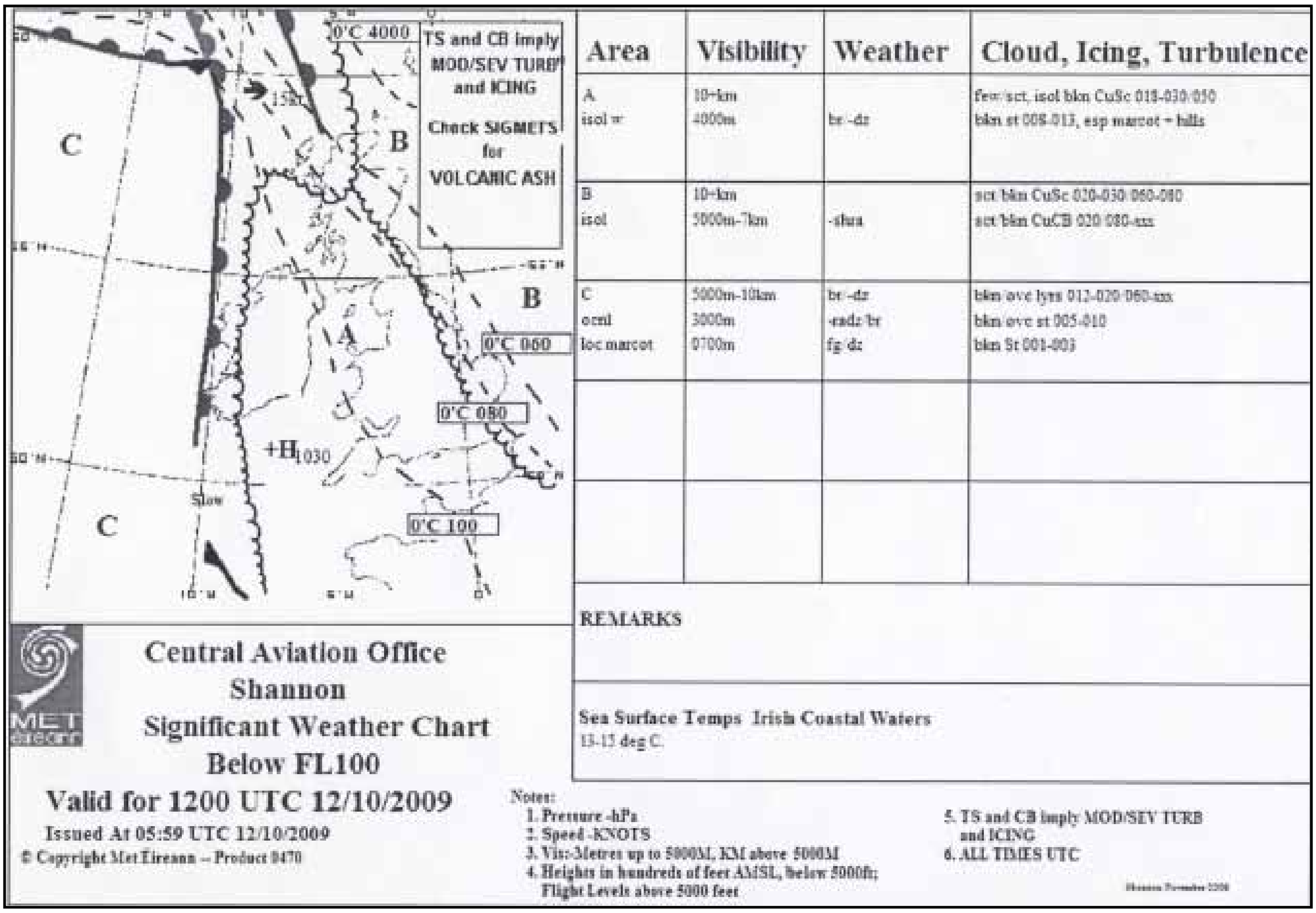


Figure No. 6: 12.00 hrs Low Level Significant Weather Forecast (Met Éireann)

The later low level significant chart for 18.00 hrs (**Figure No. 7)** forecasted that the warm front would have passed the West of Ireland, but the general area (B) still shows a misty aftermath of stratus cloud with light rain or drizzle and little improvement in the general weather conditions.

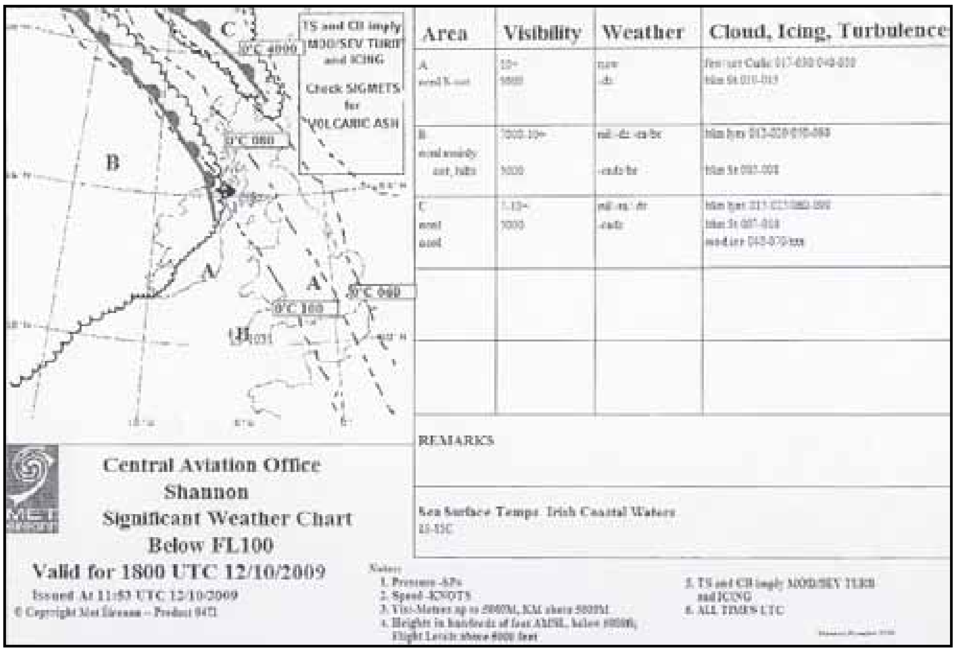


***Figure No. 7:** 18.00 hrs Low Level Significant Weather*
(Met Éireann)

The Synoptic Forecast for 18.00 hrs issued by the UK Met Office shows the front still over the West of Ireland (**Figure No. 8**).

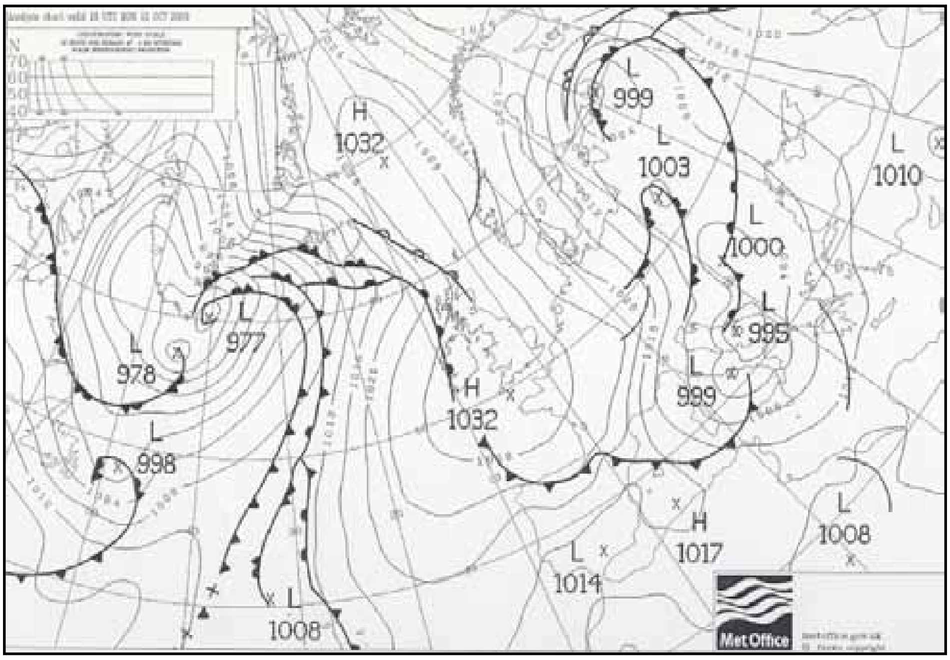


***Figure No. 8:** Synoptic Forecast for 18.00 hrs*
(UK Met Office)

Figure No. 9 contains the forecast for the estimated time of arrival (ETA) at EICM (shortly after 18.00 hrs), which was suitable for VFR operations.

```
     --- LOCAL AREA FORECASTS(LF) ---
(GALWAY (CARNMORE))EICM COR LOCAL AREA FORECAST VALID 121500/122400
     WIND 16007KT VISIBILITY 9999 PROB30 TEMPO 1824 5000 WEATHER
     TEMPO 1524 -DZ -RA CLOUD FEW015 BKN030 TEMPO 1724 BKN015 PROB30
     TEMPO 2024 BKN008 CLOUD HEIGHTS GIVEN ABOVE MSL=
(DONEGAL)EIDL LOCAL AREA FORECAST VALID 121500/122400 WIND 22008KT
     VISIBILITY 9999 TEMPO 2024 5000 WEATHER TEMPO 1824 -RA -DZ
     CLOUD FEW012 BKN030 TEMPO 1824 BKN012 PROB30 TEMPO 2024 BKN006
     CLOUD HEIGHTS GIVEN ABOVE MSL=
(KERRY (FARRANFORE))EIKY LOCAL AREA FORECAST VALID 121500/122400
     WIND 18005KT VISIBILITY 9999 WEATHER NSW CLOUD FEW015 BKN035
     TEMPO 1924 BKN015 CLOUD HEIGHTS GIVEN ABOVE MSL=
(SLIGO)EISG LOCAL AREA FORECAST VALID 122000/130500 WIND 16004KT
     VISIBILITY 9999 TEMPO 2105 3000 WEATHER TEMPO 2105 BR -DZ CLOUD
     SCT020 BKN030 TEMPO 2105 SCT005 BKN010 CLOUD HEIGHTS GIVEN
     ABOVE MSL=
(WATERFORD)EIWF LOCAL AREA FORECAST VALID 122000/130500 WIND 26005KT
     VISIBILITY 9999 TEMPO 0005 5000 PROB30 TEMPO 0305 0700 WEATHER
     TEMPO 0005 BR PROB30 TEMPO 0305 FG CLOUD NSC PROB30 TEMPO 0305
     BKN001 CLOUD HEIGHTS GIVEN ABOVE MSL=
```

***Figure No. 9:** Local Forecasts for 12/10/2009, period 15.00 to 24.00 hrs*

APPENDIX B

Weather Photographs

A photographer taking landscape photographs in the adjacent valley to the north about the time of the accident provided her photographs to the Investigation. The metadata[22] in the photographs showed the timings of the photographs, which were taken in different directions between 16.39 and 17.00 hrs. She had also recorded the location of each photograph. Although the photographer was changing location slightly, she recorded that she was approximately 2 NM northwest of the accident site when these photographs were taken.

The photographs show the weather changing rapidly over the period, with a lowering cloud base affecting the surrounding mountain tops and visibility reducing.

Photo No. 3 was taken 17 minutes before the accident, facing northeast (approximately in the direction from which the aircraft was approaching the area). The terrain shown rises to 1,155 ft AMSL

***Photo No. 3:** Time 16.39 hrs, facing northeast*

(Position N53° 33.076', W009° 33.076')

22 **Metadata:** Data recorded on a digital photo file by a camera providing additional information such as time and exposure information.

Photo No. 4 was taken 4 minutes before the accident, northwest of the accident site facing west. The obscured terrain west of this location rises to 1,900 ft AMSL.

***Photo No. 4:** Time 16.53 hrs, facing west*

(Position N53° 33.076', W009° 32.925')

Photo No. 5 was taken 3 minutes after the accident, northwest of the accident site facing west southwest. The obscured terrain rises to 1,600 ft. This location is approximately 2 NM northwest of the accident site.

***Photo No. 5:** Time 17.00 hrs, facing west southwest*

(Position N53° 33.129', W009° 33.108')

APPENDIX C

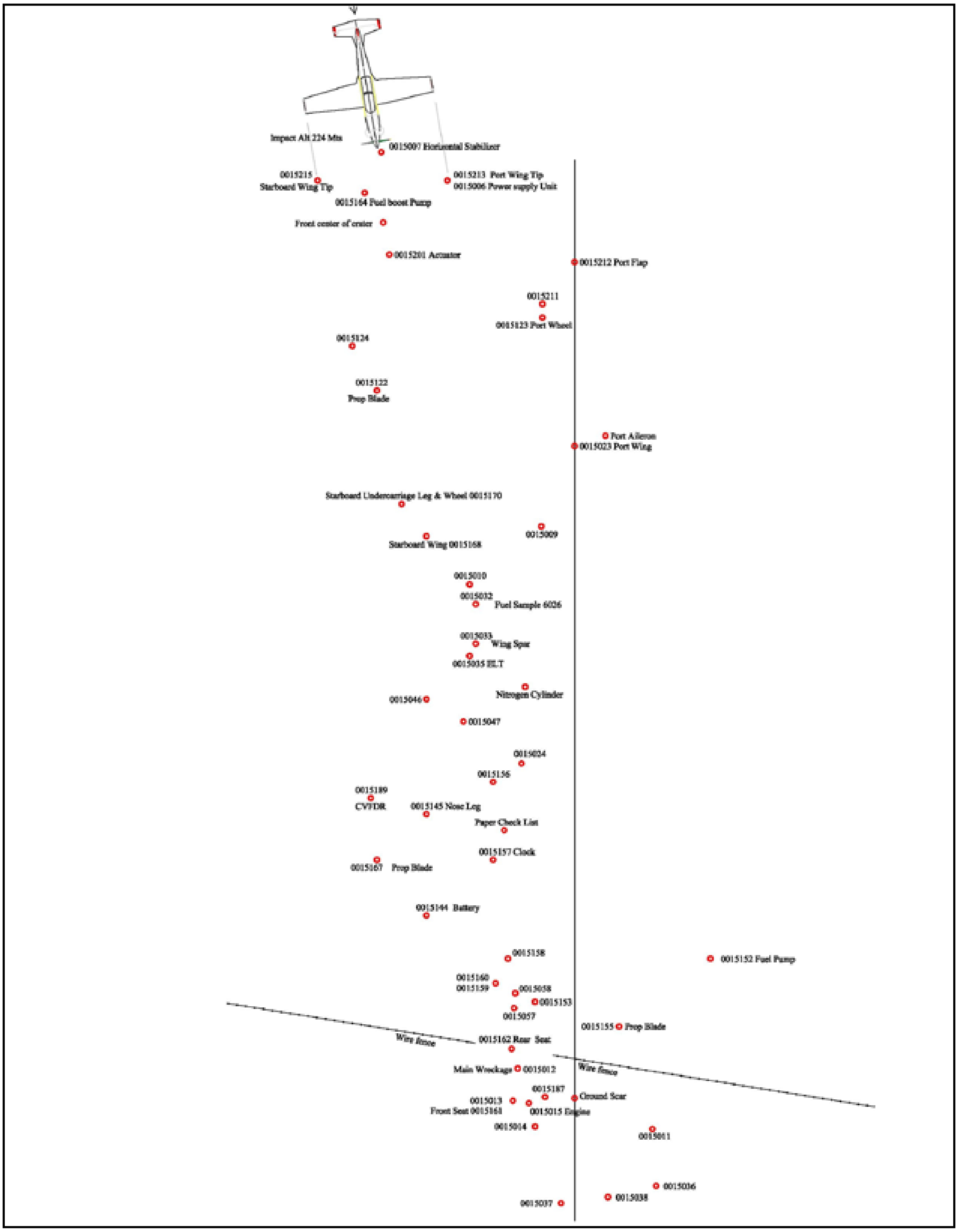
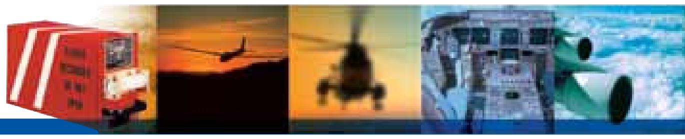


Figure No. 10: *Debris Trail Plot*

(IAC Drawing Office)



APPENDIX D

Spatial Disorientation and Somatogravic Illusions

1 SPATIAL DISORIENTATION

1.1 Background

Previc and Ercoline (2003) define spatial disorientation (SD) as a pilot's inability, "*to sense correctly the position, motion or attitude of the aircraft or of him or herself within the fixed co-ordinate system provided by the surface of the earth and the gravitational vertical*". Building on this definition, Véronneau and Evans (2003) posit, "*…one can reasonably deduce that no CFIT*[23] *accident could occur without the pilot's being unaware of his or her spatial orientation*".

Newman (2007) notes, "*Spatial disorientation is a very common problem … studies show that SD accounts for some six per cent to 32 per cent of major accidents, and some 15 per cent to 69 per cent of fatal accidents*". He further asserts, "*It has been reported that for a given pilot, the career incidence of SD is in the order of 90 to 100 per cent … In other words, if a pilot flies long enough as a career or even a hobby there is almost no chance that he/she will escape experiencing at least one episode of SD. Looked at another way, pilots can be considered to be in one of two groups: those who have been disorientated, and those who will*". He also cautions, "*It [Spatial Disorientation] can affect any pilot, anytime, anywhere, in any aircraft, on any flight, depending on the prevailing circumstances*".

From an analysis of the FDR data the Investigation was satisfied that spatial disorientation in general, and somatogravic illusions in particular, warranted further consideration.

It should be noted that the medical terminology used in this Appendix is explained in the referenced material.

1.2 Accident Involvement of Spatial Disorientation

Benson and Stott (2006) observe that, "*Orientation error poses a difficult problem for accident investigators*". They go on to say that even with information on the aircraft trajectory, control inputs and cockpit voice and flight data recordings, "*it is unlikely that there can be absolute certainty in ascribing the accident to an error in the pilot's perception of aircraft spatial disorientation*".

2 SOMATOGRAVIC ILLUSIONS

2.1 Pilot Perception Mechanism for Acceleration

Pilot perception of accelerations is a physiological process within the vestibular system, in particular the Otolithic Membrane, or as it is more commonly referred to the Otoliths. Benson (2006) provides a detailed description of the vestibular system.

Figure (i): The following is a synopsis of the aspects relevant to this Investigation. It should be noted that the otolithic system is just one component of the human ability to sense acceleration.

---

23 **CFIT or Controlled Flight Into Terrain**, "occurs when an airworthy aircraft, under the control of a qualified pilot, is flown into terrain with inadequate awareness on the part of the pilot of the impending disaster", (Wiener, 1977, cited in Véronneau and Evans, 2003)

In addition to the Otoliths, pressure on the skin of the back and the buttocks when sitting and on the soles of the feet when standing, supplemented by stretch receptors in the muscles of the legs, back and neck all contribute to a largely unconscious awareness of gravitational forces that allows us to maintain posture and prevents us from falling.

The Vestibular System is a pea-sized apparatus, located in the inner ear, with sensory receptors for angular and linear acceleration; semi-circular canals respond to angular acceleration while linear acceleration is sensed by the sac-like utricle and saccule. These sacs are filled with endolymph, a watery fluid, and contain sensory cells (maculae), with many hair-like projections, in plate-like congregations. The maculae in both utricle and saccule are grouped in an irregular, saucer-shaped surface, with a gelatinous covering whose outer surface contains small crystals of calcium carbonate.

In practice, this gelatinous membrane, by virtue of its inertial mass, moves in response to linear acceleration. This movement deflects the sensory cells' cilia, altering their neural activity. The overall effect is that the otoliths behave as multi-axis, linear acceleration transducers for the head. There are two otolith organs on each side of the head. When the head is upright, the utricle is approximately horizontal whilst the saccule is vertical. Whilst it is usually possible to differentiate linear acceleration from head tilt because of the accompanying signals from the semi-circular canals, in an unfamiliar force environment sustained linear acceleration produces otolithic signals that can be misinterpreted as changes in pitch attitude.

2.2 Root Cause

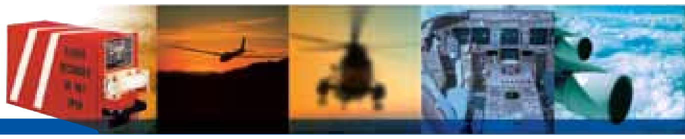
During normal ground-based activities gravitational force is a reliable reference regarding vertical orientation. Gravitational acceleration (from which gravitational force results) is simply a sustained linear acceleration.

In flight, aircrew are exposed to force environments that are significantly different from those experienced during normal ground-based activities. However, just as in everyday life these force environments are a result of being exposed to linear accelerations. The linear accelerations involved are the resultant (vector sum) of normal acceleration (vertically up/down relative to the aircraft) and longitudinal acceleration (forward/backward relative to the aircraft). The force[24] associated with this resultant acceleration is called the Gravitoinertial force. When the resultant acceleration (and associated force) is oscillatory or of short duration, humans can differentiate the Gravitoinertial force from the force due to gravity alone. However, when this acceleration is sustained, the human perception mechanism cannot, without external visual reference, reliably distinguish between the Gravitoinertial force and the force due to gravity, e.g. when an aircraft accelerates in response to a thrust increase. As previously noted the pilot's perception of these accelerations and forces is physiological.

This inability to distinguish Gravitoinertial forces from normal gravity, in the absence of dominant visual cues (e.g. a clear, reliable horizon), is the fundamental cause of a set of illusions called Somatogravic Illusions. Eyewitnesses stated that the accident aircraft pulled up into cloud, prior to the initiation of the final push-over manoeuvre. Consequently, the Investigation is satisfied that the aircraft was operating without dominant visual cues after it entered cloud.

The two Somatogravic Illusions that are relevant to this Investigation are the False Climb illusion and the Inversion illusion.

24 In accordance with Newton's second law, force and acceleration are directly related. The force experienced is calculated by multiplying the acceleration by the mass of the object that is experiencing the acceleration. Both force and acceleration are vector quantities, and resultants are calculated in accordance with the rules for vector addition. The terms force and acceleration are often used interchangeably when discussing Somatogravic effects.



2.3 False Climb Illusion

A pilot in an accelerating aircraft in level flight, experiences the effect of two steady forces, gravity pushing the pilot down into the seat (normal acceleration) and the inertial (longitudinal) force pushing the pilot back into the seat. The combination of these two forces results in the pilot experiencing a single (Gravitoinertial) force acting downwards and backwards --- and this force, "*feels*", the same as gravity.

During normal activities on the surface of the earth, the pilot could only experience these forces under gravity alone if he (and his seat) tilted backwards. Thus, the pilot who is under the influence of Gravitoinertial forces in an accelerating aircraft, may experience a sense of backward tilt which is perceived as a pitch-up attitude of the aircraft. This is termed the False Climb Illusion.

Figure (i) (reproduced in larger format as **Figure (v)**) shows eight successive images of the accident aircraft, at 0.25-second intervals[25]. This sequence is taken from the aircraft's final climb, before the aircraft reaches its apogee. Time-points -8 sec, -7.75 sec and -7.5 sec of **Figure (i)**, show the three (successive) 0.25-second recordings over which the False Climb Illusion emerges. The upper symbol (aircraft) for each time-point shows the aircraft oriented according to the actual recorded pitch angle. Superimposed on the aircraft is a representation of the Gx (blue) & Gz (pink) vectors, along with the resultant Gravitoinertial vector (brown); these are more easily seen in **Figure (v)**. The lower symbol (figure) is orientated to align the resultant Gravitoinertial vector with the normal (expected) direction of the gravity vector.

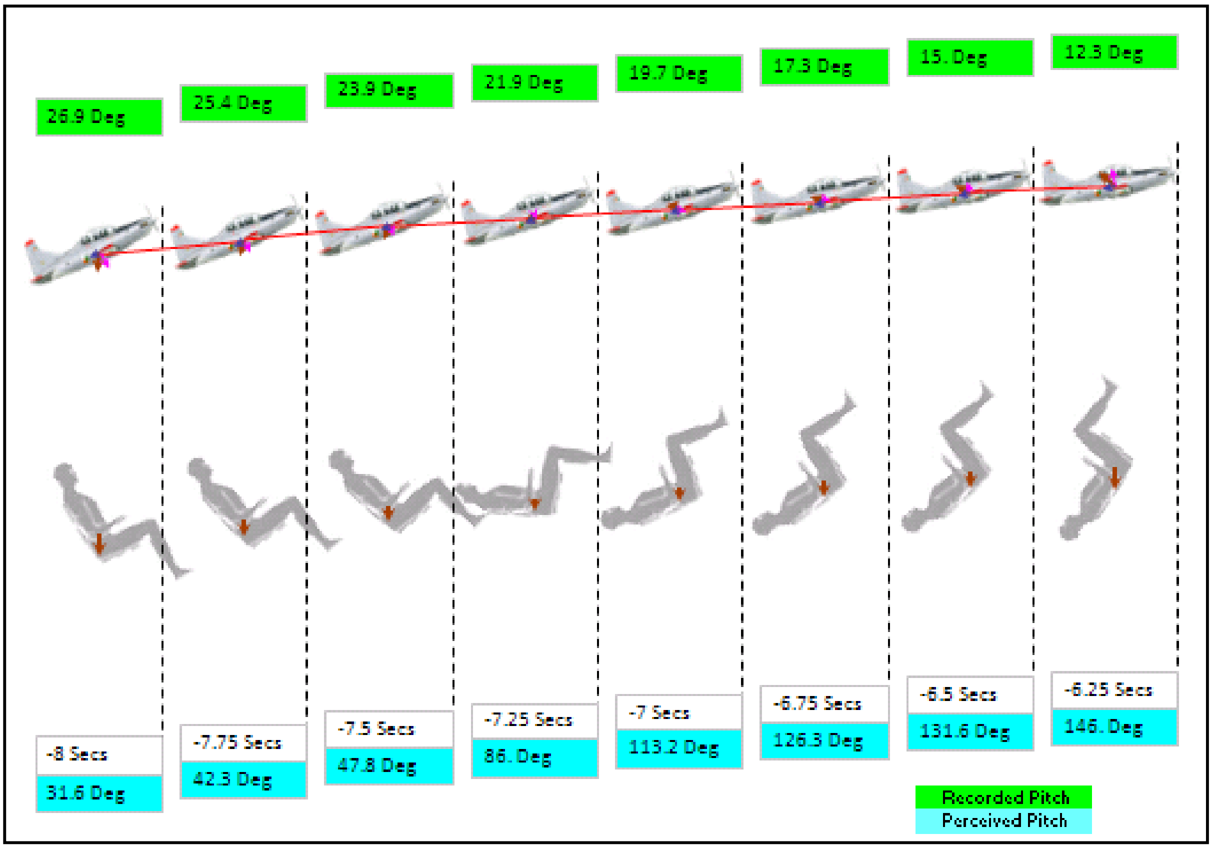


Figure (i): Emergence of False Pitch and Inversion Illusions

25 All Figures in this report use a common time base. This time base treats 0 seconds as the time of the last recorded Gx value and all other times are designated as (negative) numbers of seconds before 0 seconds. As Gx is recorded four times a second the final point (0 second) shown in all Figures is less than 0.25 seconds before the FDR ceased recording.

Thus, it can be seen that if a pilot (in this case the Instructor) confused the Gravitoinertial vector for normal gravity he could have mistakenly believed that his aircraft had adopted a more nose up attitude than it had in reality. Comparison of the pitches of the lower and upper symbols at time-points -8 sec, -7.75 sec and -7.5 sec illustrate this false pitch-up perception.

2.4 The Inversion Illusion

As the Gravitoinertial force is a resultant vector, its magnitude and direction are affected by changes in the magnitudes of either of its component vectors i.e. the longitudinal or normal accelerations. Thus, for a climbing aircraft with constant power setting, forward movement of the control stick to initiate a reduction in pitch, inevitably results in reduced normal acceleration and increased longitudinal acceleration. The effect on the resultant Gravitoinertial vector is that its direction "*swings*", to the rear which, if the pilot mistakes the Gravitoinertial vector for gravity, leads the pilot to believe that the aircraft is pitching up rather than responding to his command to pitch down.

Faced with this apparent contradiction, the pilot may push the stick further forward often to the point that the normal acceleration component becomes negative i.e. points upward. Once the normal acceleration component becomes negative, the resultant Gravitoinertial vector points backwards and upwards; in such a case the pilot believes that the aircraft has now inverted, and the pilot is said to be experiencing an Inversion Illusion. The situation is such that the pilot is caught in a feedback situation whereby the harder he pushes the stick forward i.e. tries to lower the nose of the aircraft, the more severe his illusion of inversion will become.

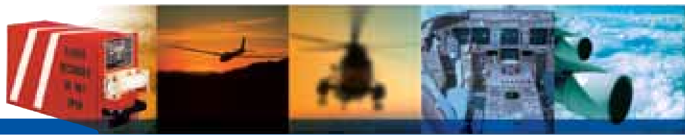
McCarthy and Stott (1994) verified the existence of the Inversion Illusion in flight. Under a controlled and previously briefed scenario, subjects were exposed to push-over manoeuvres up to –1G. They found that, "*3/3 naive non-pilots, 6/8 pilots, and 0/2 test pilots*", experienced the illusion. Of those who experienced the illusion, "*Five subjects felt sudden inversion, two felt feet up rotation to the inverted and one felt a rotation of indeterminate direction*".

Time-points -7.25 sec to -6.25 sec of **Figure (i)** show the five (successive) quarter second recordings over which the False Climb Illusion became an Inversion Illusion. At time-point -7.25 sec the perception was that the aircraft had pitched to vertical and thereafter (points -7 sec to -6.25 sec) that the aircraft had become inverted. **Figure (iv)** shows that these conditions probably persisted until time-point -1.25 sec when recovery was initiated.

It should be noted that in this case the time elapsed from the start of False Climb Illusion to the onset of the Inversion Illusion is approximately one second. Such rapid development is consistent with McCarthy and Stott's finding that onset of the Inversion Illusion may be sudden and that the precursor phase of False Climb may be so rapid and/or transient as to go unnoticed by the pilot. The transient nature of the false climb illusion in this case only happened for a brief period and after the Instructor had initiated the control action to lower the nose. Thus, a false climb illusion did not cause the Instructor to initiate the push-over.

2.5 Environments that Increase Somatogravic Risks

Benson and Stott, writing in Ernsting's Aviation Medicine (2006), identify certain scenarios when particular care must be exercised regarding possible somatogravic effects. They specifically mention take-off into low cloud where transition to Instrument Flying must be anticipated and planned for. Similarly, overshooting a runway to go-around, particularly at night or in poor weather is an increased somatogravic risk. Finally they identify, "*Low-level flight in a military aircraft may have to be aborted on account of deteriorating visual conditions, low cloud or failing light. This manoeuvre involves a rapid climb to a safe altitude with full thrust applied to the engines. The desire to correct for what feels like an excessive pitch angle has to be resisted in favour of what the aircraft instruments are saying*".



The Investigation notes that during the accident flight the aircraft torque was initially increased (by pilot input) from 1.8 psi to 71.6 psi, reflecting the application of full thrust during the final pitch-up.

2.6 Somatogravic Investigation Methodology

The Investigation used the recorded normal (Gz) and longitudinal (Gx) accelerations to calculate the magnitude and direction of the resultant Gravitoinertial vector that the Instructor experienced during the final pull-up/push-over manoeuvre. Using this information the Investigation constructed models of the associated perceived pitch angle of the aircraft and the actual and perceived orientation of the aircraft. Whilst Gz has a recording frequency of 8 Hz (i.e. it is recorded 8 times per second), Gx is only recorded at 4 Hz (i.e. 4 times per second). Consequently, Gravitoinertial calculations could only be carried out at 0.25-second intervals.

The Investigation notes McCarthy and Stott's view that, "*Gy may be ignored in conventional aircraft except in a spin*", and consequently Gy was not considered in the Investigation's analysis as it was satisfied from FDR data that 265 did not spin.

2.7 Results of the Analysis

The Investigation calculated the perceived pitch angle (ArcTan Gx/Gz), and compared this with the actual pitch recorded on the aircraft. This comparison is presented in **Figure (ii)** & **Figure (iii).** For ease of reference, the aircraft altitude was also plotted on the right axis of **Figure (ii)**, while elevator position is plotted on the right axis of **Figure (iii)**. **Figure (ii)** & **Figure (iii)** show the divergence between actual and perceived pitch at time-point -8 sec. This divergence develops rapidly and then persists.

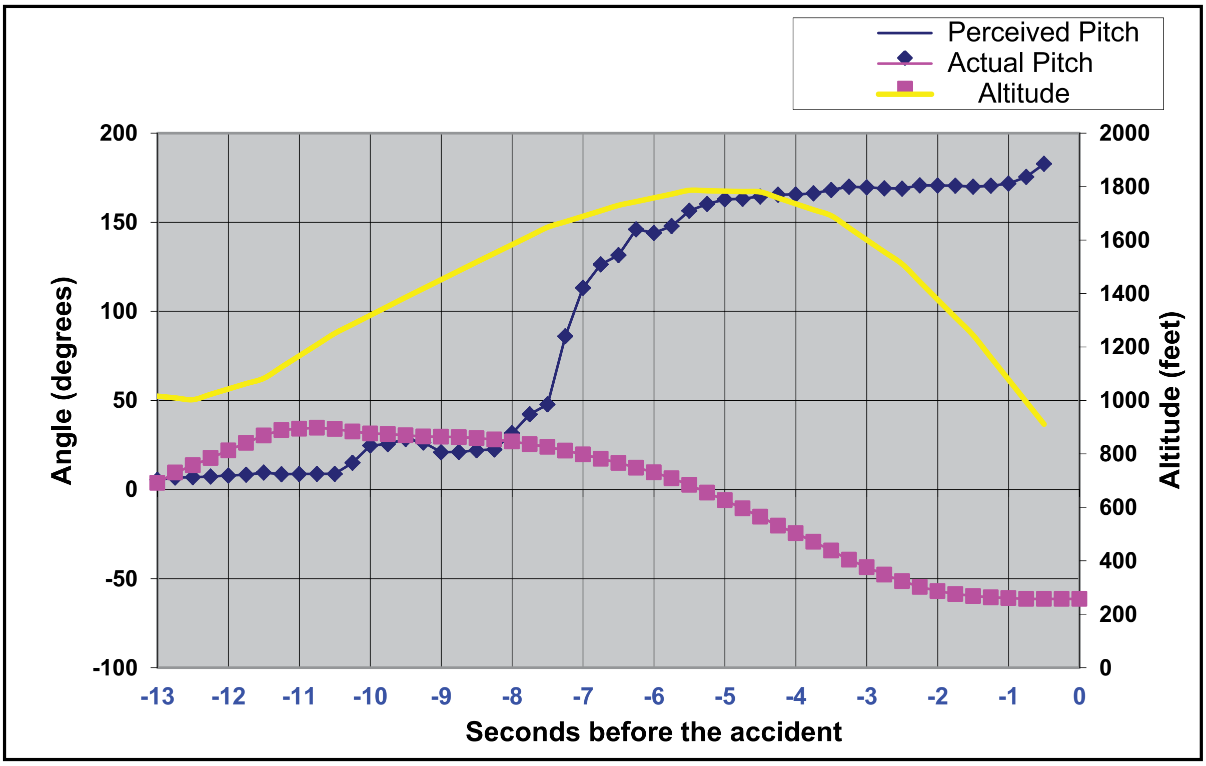


Figure (ii): Perceived versus Actual Pitch, with Altitude

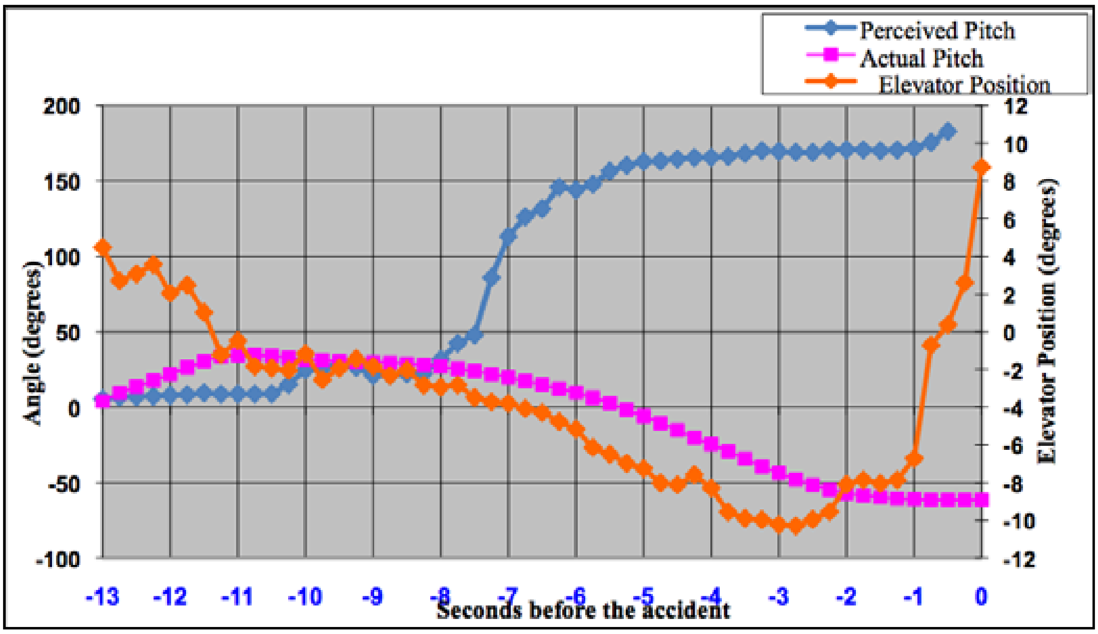


Figure (iii): Perceived versus Actual Pitch, with Elevator Position

The reason for the illusion is that the reduction in the magnitude of Gz relative to Gx causes the direction of Gravitoinertial vector to rotate backwards. The pilot response to the backward swing of the Gravitoinertial vector is to push the stick forward. Pushing the stick forward further increases the magnitude of Gz in the negative direction, causing the Gravitoinertial vector to rotate further backwards resulting in an inversion illusion. The effect can best be appreciated by studying **Figure (i)** & **Figure (iv)**, which are reproduced in larger formats as **Figure (v)** & **Figure (vi)**. Attention should be paid to the change in magnitude and direction of Gz (the pink arrows) and the associated changes in magnitude and direction of the Gravitoinertial vector (the brown arrows). These Figures are representative and no dimensional scaling has been incorporated.

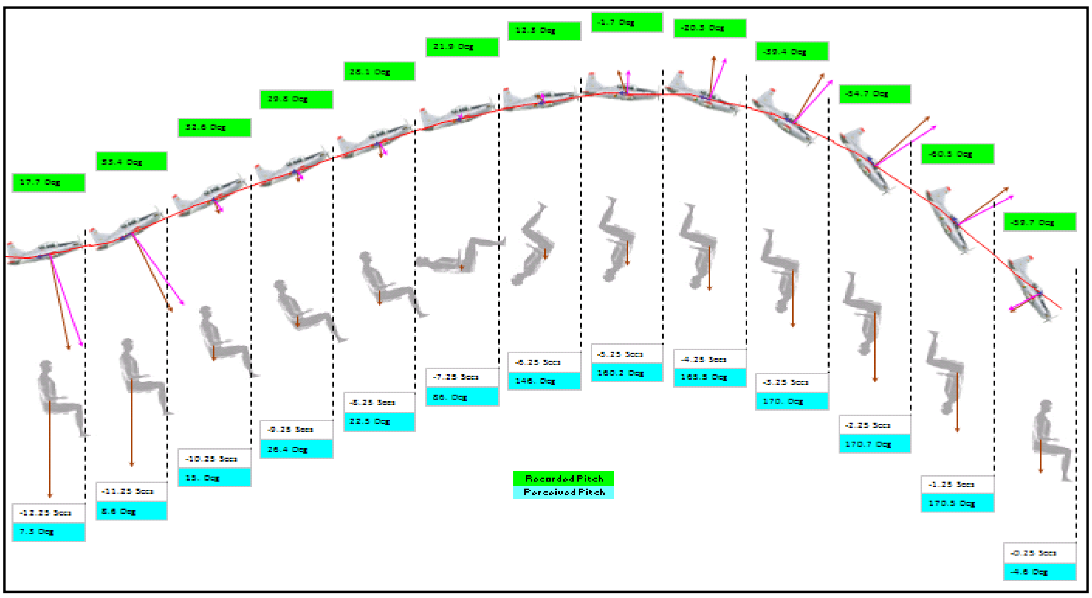


Figure (iv): Aircraft Trajectory with Actual and Perceived Orientation

2.8 Final Correction

The Transportation Safety Board of Canada in a report in 2000 (reference A00O0111) noted, "*Pilots succumbing to…*[Somatogravic illusions] *…characteristically crash in a nose-low attitude … Sometimes, however, they are seen to descend out of the overcast and try belatedly to pull up, as though they suddenly regained correct orientation upon seeing the ground again*".

Examination of the final 4 time-points on the Elevator Position plot (**Figure (iii)**) indicates that there was a rearward stick movement sufficient to produce a change of 7.37G in less than a second, from –3.02G to +4.35G. The FDR confirms that simultaneously a left stick input was made to reduce the aircraft roll angle from 93° right to 18° right, and engine torque reduced from 60.5 psi to 15.6 psi. The aircraft's last recorded pitch angle was 55° nose-down; estimations at the site from the initial ground impact marks site indicated an impact angle of approximately 45° nose-down with wings level. The rapid, significant and simultaneous changes in aircraft stick inputs allied to the sudden reduction of torque suggest that, in the final 1 to 2 seconds of flight the Instructor did acquire and recognise visual cues which restored his perception of aircraft orientation and that he commenced a recovery manoeuvre by levelling the wings, reducing power and pulling-up.

2.9 Other Sensory Inputs

Whilst the Otoliths are the primary apparatus for pitch perception, the Investigation noted that the semi-circular canals should also have provided the Instructor with information regarding his orientation.

At the onset of upward pitch the associated rate of rotation was approximately 16° per second well above the normal sensation threshold, which is typically 2° per second[26]. Consequently the Instructor was likely to have a sense of rotation mediated through the semi-circular canals. Despite the fact that the resultant vector remained within about 5° of the aircraft normal axis while the 30-degree climb was being established, the sense of rotation accompanying the pilot's deliberate control action would have been a sufficient cue to indicate to him that the aircraft had indeed pitched up.

However, the Pilot's stick forward control action that followed indicated that the Pilot felt the need to reduce the climb angle. As has been shown above forward movement of the control stick to reduce the pitch angle was the initiating event for the somatogravic illusions. During approximately 2 seconds the resultant Gravitoinertial vector rapidly reduced in magnitude and rotated backwards and upwards. There would have been no corresponding rotational sense of pitch-up. Indeed the semi-circular canals should actually have correctly indicated the downward pitch of the aircraft. The Pilot resolved these sensations in favour of the erroneous sense of inversion consequent on a resultant vector of 3G that was directed upwards with respect to the aircraft. Such confusions between rotational sensations and the direction of the force vector are common in aviation.

The Investigation also notes that during the final climb/push-over manoeuvre the aircraft rolled progressively to the right to 93° before the final, rapid recovery to 18° roll right. Benson (2006) gives the median threshold for detection of roll as the same as that for pitch, which was noted above as 2° per second. Thus, since the Instructor did not respond to the semi-circular canal stimulation resulting from pitch down, it is not surprising that he did not detect similar stimulation indicating that he was rolling to the right.

26 This figure (32°/sec) is obtained under laboratory conditions with the subject's attention focussed on the task of detecting rotation. This represents the best that can be achieved under ideal conditions. It is quite likely that the presence of a conflicting sensation of rotation of many times this value could be overlooked in the stress of the accident scenario.

2.10 Possible Reason for Initiating the Push-over Manoeuvre

While the analysis of the FDR data presented here indicates why the Pilot may have felt the aircraft to be inverted as a consequence of the vigorous push-over manoeuvre, it does not explain why he initiated the manoeuvre. To investigate the possibility that the energetic pull-up manoeuvre might have led to a perception of having over-pitched the aircraft, the Investigation examined the true and vector-derived pitch rates during the pull-up phase of the low-level abort manoeuvre. This was done by taking the mean of the forward and backward differences at each 0.25 sec time point for the actual aircraft pitch and for the calculated direction of the resultant force vector.

These calculations show that during the 4G phase of pull-up between -13 sec and -11.25 sec the actual pitch rate was of the order of 16 - 20°/s, which brought the aircraft to 34° of pitch-up in about 2 seconds. During this time the resultant force vector only rotated at 2 – 3°/sec. At -11 sec the Pilot abruptly eased off on the stick so that just 1 second later the normal Gz had reduced to 0.4G.

This change was associated with a rapid swing of the resultant force vector for a brief period at around -10.25 sec at a rate of 32°/sec to bring the force vector to within a few degrees of the true pitch attitude.

This abrupt change in the direction of the force vector may have given the Pilot the feeling that the aircraft was continuing to pitch upwards after he had eased off on the stick and at a time when he would have expected it to have stopped doing so (as indeed it had). This may have been the erroneous indication to the Pilot that a further stick forward control was required, leading him to begin to push-over the aircraft some 2 seconds later at -8 sec and by -7 sec the Gz vector had become negative.

This analysis of perceived pitch rates may provide the sensory stimulus to explain the Pilot's initial stick forward action, which then became self-perpetuating for the reasons explained above. This effect can be seen by closely studying **Figure (ii)** and comparing the actual aircraft pitch and the perceived aircraft pitch between -10.5 seconds and -9.75 seconds. **Figure (vii)** shows the actual and perceived pitch along with the Elevator Position (a linear function of stick forward (negative)/aft (positive) position, which further illustrates and supports the hypothesis regarding the stimulus for push-over initiation.

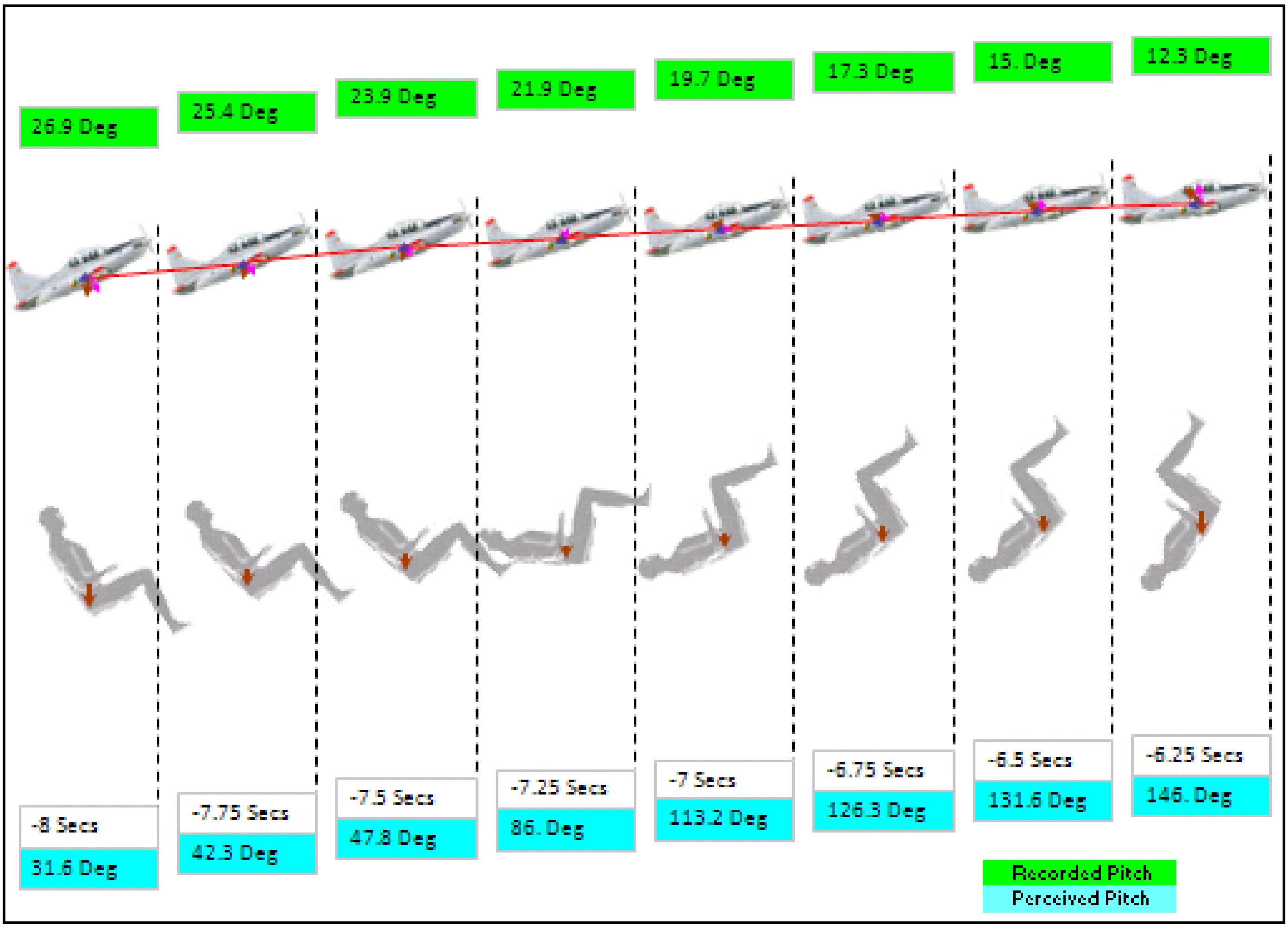


Figure (v): Emergence of False Pitch and Inversion Illusions (Large)

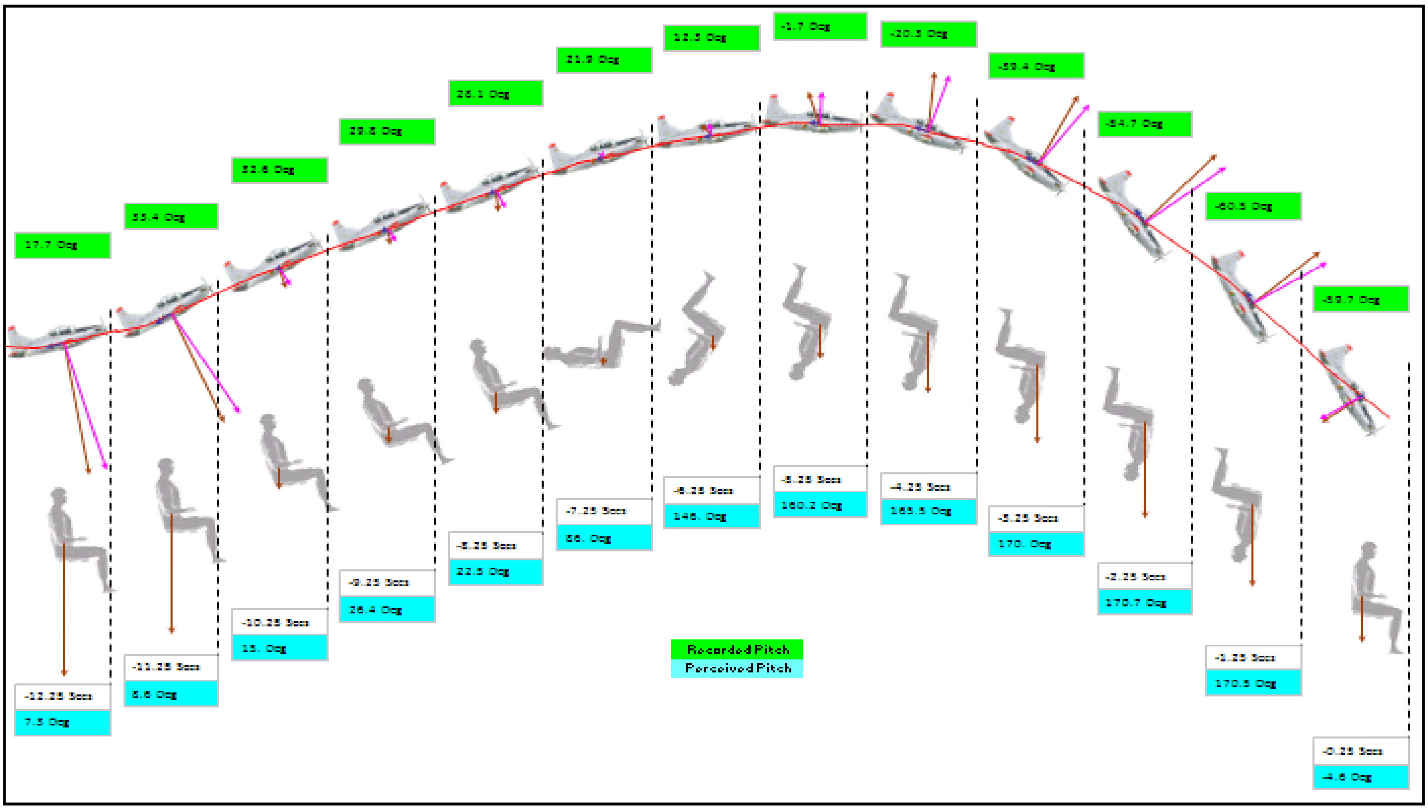
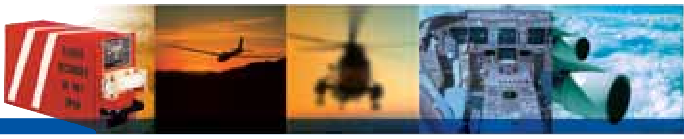


Figure (vi): Trajectory with Actual and Perceived Orientation (Large)



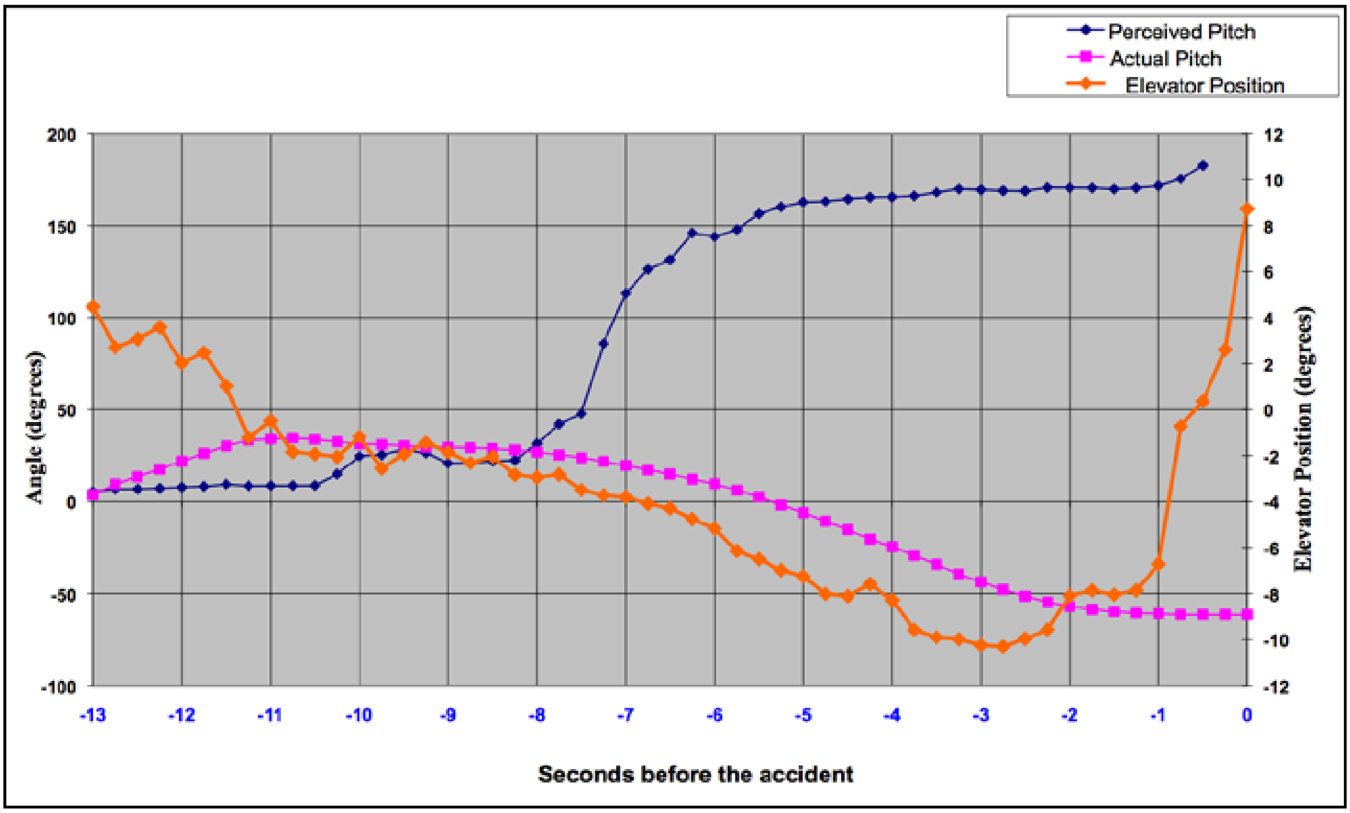


Figure (vii): Actual & Perceived Pitch, with Elevator position

REFERENCES

Benson, A.J. (2006) "*Spatial Orientation in Flight*", Ernsting's Aviation Medicine, Hodder Arnold, UK

Benson, A.J., Stott, J.R.R. (2006) "*Spatial Disorientation in Flight*", Ernsting's Aviation Medicine, Hodder Arnold, UK

Bushby A., Holmes S.R., McGown A., Bunting A., Rakhee P., Stott J.R. (2005) An Assessment of the Influence of Spatial Disorientation upon Military Aircraft Accidents from 1983 to 2002. QinetiQ Report No. QINETIQ/05/00474

McCarthy, G.W., Stott J.R.R. (1994) "I*n Flight Verification of the Inversion Illusion*", Aviation Space and Environmental Medicine, USA

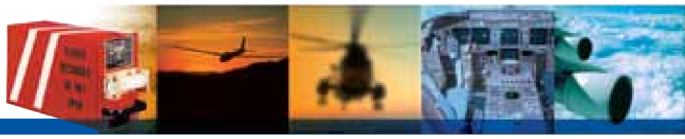
Newman, D.G. (2007) "*An Overview of Spatial Disorientation as a Factor in Aviation Accidents and Incidents*", Australian Transportation Safety Bureau, Australia

Previc, F.H., Ercoline, W.R. (2003) "*Spatial Disorientation in Aviation: Historical Background, Concepts, and Terminology*", Spatial Disorientation in Aviation, American Institute of Astronautics and Aeronautics, USA

Transportation Safety Board of Canada (TSB) (2000) "*Aviation Investigation Report, Controlled Flight into Terrain, Grand Aire Express Inc., Fassault-Breguet Falcon 20E N18GA, Peterborough Airport, Ontario 0.5 nm W, 13 June 2000, Report Number A00O0111*", TSB, Canada

Véronneau, S.J.H., Evans, R.H. (2003) "*Spatial Disorientation Mishap Classification, Data and Investigation*", Spatial Disorientation in Aviation, American Institute of Astronautics and Aeronautics, USA

Wiener, E. L. (1977) "*Controlled Flight into Terrain Accidents: System-Induced Errors*", Human Factors, Vol. 19, pp. 171-181



GLOSSARY

AAIU	Air Accident Investigation Unit
ACC	Air Corps College
ACHQ	Air Corps Headquarters
AFM	Airplane Flight Manual
AGL	Above Ground Level.
Altitude	Elevation above mean sea level
AMSL	Above Mean Sea Level
ARM	Air Regulations Manual
ATC	Air Traffic Control
CAA	Civil Aviation Authority (UK)
CFI	Chief Flying Instructor
CFIT	Controlled Flight Into Terrain
CGI	Chief Ground Instructor
Class G	Uncontrolled airspace
CRM	Crew Resource Management
CSU	Constant Speed Unit
CTR	ATC Control Zone
CVFDR	Cockpit Voice and Flight Data Recorder
CVR	Cockpit Voice Recorder
DR	Dead Reckoning is used to estimate a navigational position.
EGPWS	Enhanced Ground Proximity Warning System
EICM	Galway Airport
EIME	Casement Aerodrome, Baldonnel, Co. Dublin
ELT	Emergency Location Transmitter
ELU	Electronic Limiter Unit
F261	Foxtrot 261, the ATC call sign of the search aircraft
F265	Foxtrot 265, the ATC call sign of the accident aircraft
F266	Foxtrot 266, the ATC call sign of the third aircraft in the sortie
FAR	Federal Aviation Regulation - USA
FDR	Flight Data Recorder
FOCA	Federal Office of Civil Aviation - Switzerland
FTS	Flying Training School
G	The force of acceleration due to gravity
GOC AC	General Officer Commanding Air Corps
GPS	Global Positioning System
Height	Distance of the aircraft above the ground
hPa	Hecto-pascals or measurement of pressure
HQ	Headquarters
HUD	Head Up Display
IAC	Irish Air Corps
IFR	Instrument Flight Rules
IIC	Investigator-in-Charge
IMC	Instrument Meteorological Conditions
IRS	Inertial Reference System
ITM	Instructor Training Manual PC-9(M)

MAA	Military Airworthiness Authority
MDDS	Mission Data De-briefing System
MEL	Minimum Equipment List
Mmo	Maximum Mach operating speed
MRCC	Marine Rescue Coordination Centre
MSA	Minimum Safe Altitude
MTS	Military Training School
NM	Nautical mile
NVM	Non Volatile Memory
OC	Officer Commanding
OLF	Operational Low Flying
P1	Pilot in Command (PIC)
PF	Pilot Flying
PFD	Primary Flight Display
PIC	Pilot in Command
PIN	Pilot Information Notice
PNF	Pilot Non-Flying, also known as Pilot Monitoring (PM).
QNH	Altimeter barometric setting that displays altitude above sea level
RACO	Representative Association of Commissioned Officers
RADALT	Radio Altimeter
RMM	Removable Memory Module
RPM	Revolutions Per Minute
SA	Situational Awareness
SAR	Search and Rescue
SD	Spatial Disorientation
SOP	Standard Operating Procedures
SPTM	Student Pilot Training Manual PC-9(M)
TAD	Trim Aid Device
TTS	Technical Training School
U/S	Unserviceable
UHF	Ultra High Frequency
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VMO	Maximum Operating Speed (kts)
VO	Maximum Manoeuvre Speed

- END -

In accordance with Annex 13 to the International Civil Aviation Organisation Convention, Regulation EU Directive 94/56/EC, and Statutory Instrument No. 205 of 1997, AIR NAVIGATION (NOTIFICATION AND INVESTIGATION OF ACCIDENTS, SERIOUS INCIDENTS AND INCIDENTS) REGULATION, 1997, the sole purpose of these investigations is to prevent aviation accidents and serious incidents. It is not the purpose of any such accident 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.

Produced by the Air Accident Investigation Unit

AAIU Reports are available on the internet **www.aaiu.ie**

An Roinn Iompair
Turasóireachta agus Spóirt

Department of Transport,
Tourism and Sport

A.A.I.U.,
Department of Transport Tourism and Sport,
2nd Floor, Leeson Lane,
Dublin 2, Ireland.
Tel (24x7): *+353 1 604 1293 or*
+353 1 241 1777
Fax: *+353 1 604 1514*
Email: *info@aaiu.ie*
Web: *www.aaiu.ie*