AIRCRAFT CRASHES SHORTLY AFTER TAKE-OFF

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GENERAL INFORMATION

Incident number	2009083
Classification	Accident
Date and time[1] of incident	16 October 2009, 08.24 hours
Place of the accident	Weert, the Netherlands
Registration	PH-RUL
Aircraft type	Pilatus PC-12/47E
Aircraft category	Single-engine propeller aircraft
Flight type	Business flight
Flight phase	Climb
Aircraft damage	Destroyed
Number of crew members	One
Number of passengers	One
Personal injury	Both occupants died
Other damage	Environmental damage to soil (kerosene pollution)
Light conditions	Daylight

SYNOPSIS

After taking off from Runway 21[2] at Budel Airport (Kempen Airport, EHBD), the Netherlands, PH-RUL turned left and started to climb. Shortly afterwards the aircraft turned right followed by a steep descent. Approximately two minutes after take-off the aircraft crashed near a farm. The two occupants did not survive the crash and the aircraft was completely destroyed.

[1] All times in this report are local times unless stated otherwise.

[2] Runway 21 is the take-off runway with a geographic orientation of 210°.

FACTUAL INFORMATION

The flight

PH-RUL was owned by a company and the director of this company was also the aircraft pilot. The aircraft was based at Budel Airport and was used by the owner/pilot for both business and private purposes.

A business flight to Germany was scheduled to take place on 16 October 2009. Budel Airport staff had made the flight preparations, such as filing a flight plan and preparing the aircraft for the flight, the day before. The flight plan shows that the aircraft would take-off at 08.00 hours for a flight to Egelsbach Airport in Germany (EDFE). In the flight plan, 'Y' had been filled in under the section 'Flight Rules', which means that the flight plan would take effect when PH-RUL would commence[3] the IFR segment[4] of the flight. The last segment of the flight to Egelsbach Airport would change to a VFR flight.[5] The planned flight time was 50 minutes. According to the flight plan three persons were on board.

The pilot reported to the airport just after 08.00 hours. He seemed to be more in a hurry as usual, according to the Airport Operations employee. The passenger had already arrived. The aircraft was parked outside and was flight ready. The pilot and the passenger walked to the aircraft and boarded the plane. An airport employee later walked to the aircraft to hand over a number of flight documents to the pilot. The passenger was seated in the cockpit, on the right next to the pilot.

After starting the engine and executing the checklist, PH-RUL taxied to the beginning of Runway 21. While the aircraft was taxiing, an Airport Operations employee radioed the pilot the clearance about the flight route to be followed. Clearance was: after take-off, turn left, direct to navigation point OSGOS, initially VFR, transponder code 7000 and then switch over to Dutch Mil, for control during the IFR flight. This was confirmed by the pilot. PH-RUL took off from Runway 21 at approximately 08.22 hours. A few minutes later another aircraft, PH-DIX, departed from the same runway, initially also in the direction of OSGOS.

Shortly after PH-RUL had taken off, the pilot reported his frequency change to the airport by radio. After some time, the pilot checked in on the Dutch Mil frequency. The Dutch Mil air traffic controller did not respond immediately and when the air traffic controller called the aircraft a little later, the pilot did not respond. The pilot did not respond to the second call either. It emerged a few minutes later that PH-RUL had crashed near Weert, approximately three kilometres east of Budel Airport.

The aircraft had crashed near a farm and had been destroyed. The two occupants did not survive the crash.

[3] Since Budel Airport is located in uncontrolled airspace, the first segment is carried out as a VFR flight, which does not require a flight plan. The IFR flight commences when the aircraft enters controlled airspace.

[4] An IFR flight is a flight to which Instrument Flight Rules apply in addition to general flight rules.

[5] A VFR flight is a flight to which Visual Flight Rules apply in addition to general flight rules.

INVESTIGATION AND ANALYSIS

Investigation

After the accident had been reported, Dutch Safety Board investigators visited the site to commence the investigation. They were assisted by an expert from the National Aerospace Laboratory (NLR) and an investigator from the aircraft manufacturer, Pilatus Aircraft.

Description of the site

The aircraft came down next to a farm. The aircraft first hit the ground in a silage pile, which was located south of the farm. The plastic cover on the silage pile had been torn width-wise and part of the winglet on the right wing was lying where the tear started. The aircraft engine, the propeller hub and two of the four propeller blades were lying right behind the silage pile. The largest section of the aircraft was lying on the road beyond the silage pile. This section was completely destroyed and had burned out. A large number of aircraft parts were lying in the field beyond the road, strewn across a large distance. Viewed from the location in the silage pile where the aircraft had first hit the ground, the wrecked parts were roughly strewn in a 155-degree direction across a length of approximately 90 metres.

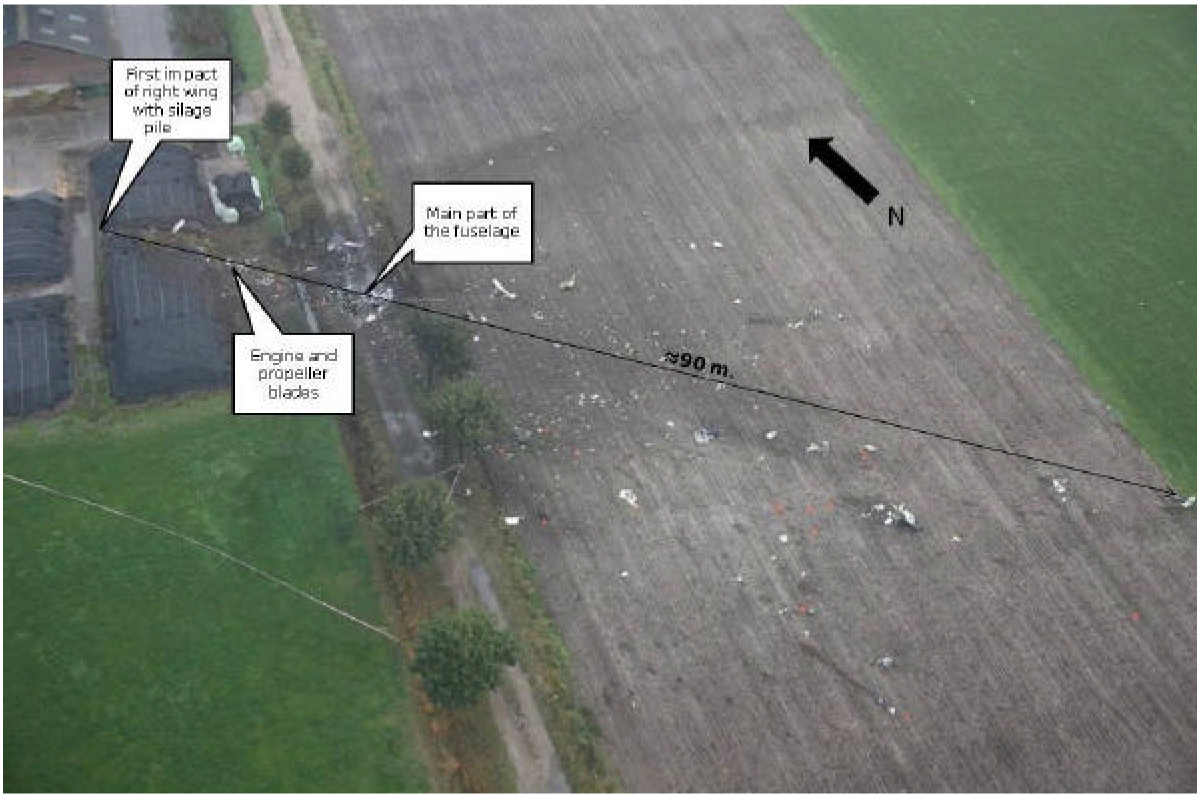

Figure 1: Aerial photograph of the site of the accident (source: Aviation Police, KLPD)

Witnesses

There were no witnesses to the accident. The occupant of the farm had only heard the impact. When he went to take a look, he saw a large fire near the silage pile. He then promptly alerted the emergency services.

The aircraft

PH-RUL was a single-engine propeller aircraft of model and type Pilatus PC-12/47E. The aircraft has retractable landing gear and is designed to carry passengers and/or cargo. The aircraft has a pressurised cabin and is capable of operating at an altitude of 30,000 feet. The propeller is powered by a turbine engine of model and type Pratt & Whitney Canada PT6A-67P. The aircraft has a maximum take-off weight of 4,740 kg. It provides seating for two pilots in the cockpit, and in the PH-RUL configuration seats six passengers in the cabin. The aircraft is certified for single-pilot operation. The aircraft is permitted to be flown in VFR and IFR conditions in day and night circumstances. The accident airplane was not equipped or required to be equipped with a cockpit voice recorder (CVR) or flight data recorder (FDR).

Figure 2: Pilatus PC-12/47E (source: Pilatus Aircraft)

The instrument panel is divided into a 'T layout'. Two screens, the primary flight displays (PFDs), are located directly in front of both seats. The PFDs display essential flight information for the pilot/pilots, such as altitude, speed, heading, the position of the aircraft, engine performance and selected radio frequencies. Two Multi-Function Displays (MFDs) are located in the centre, one beneath the other. The information displayed on the top screen includes navigation and position information in relation to the ground. The lower screen mainly displays information about the aircraft systems. The centre console, under the lower MFD, contains the multi-functional control panel for entering all the necessary flight data. The propulsion controls are located under the console.

The Electronic Standby Instrument System (ESIS) is located on the left, in front of the pilot. The ESIS provides the most essential flight information as shown on the PFD. The ESIS works independently from the system that controls the PFD monitors and has its own electrical power supply. In addition, the Multi Mode Digital Radios panel and Automatic Flight Control System panel are located above the screens. The circuit breaker panels are located at the side panels next to the two seats and the overhead panel contains, among other system panels, the operating and control panels for fuel, electric and lighting.

Figure 3: Pilatus PC-12/47E cockpit (source: Pilatus Aircraft)

After manufacture, the first flight in the flight test program was carried out with the PC-12/47E, serial number 1130, under registration HB-FRD, on 25 May 2009. The aircraft was entered in the Dutch Civil Aircraft Register on 17 June 2009 as PH-RUL. The aircraft had accumulated 95.30 hours of flight time until the accident on 16 October 2009.

Technical state

- A hydraulic failure warning showed up during the flight on 18 September 2009. Examination after the flight revealed that the warning could not be reproduced. The warning and the examination were not mentioned in the technical administration of the aircraft.
- The left hand and right hand angle of attack transmitters were renewed on 28 September 2009 because the electrical heating was switched on when the covers were still applied causing the covers to melt.
- The mandatory 100-hour inspection was performed on 9 October 2009. No serious defects were established during the inspection. Additional work was carried out during this inspection:
  - The bearing of the right hand aileron was cleaned and lubricated.
  - Two exceedings were found; an engine exceeding caused by low power after start up and an exceeding identified as flap over speed.

  These exceedings were handled in accordance with the Pilatus maintenance manual.

  Two findings were deferred:
  - The right hand main landing gear shock strut scraper ring was found de-formed
  - The fuel bowl drain had to be replaced due to a damaged lock wire hole. These findings would be carried out when the parts were delivered by the manufacturer.

The test flight made after the inspection was without abnormalities.

- The right hand audio panel was replaced by a new one due to technical malfunction on 15 October 2009.
- According to the aircraft records, all Airworthiness Directives (AD's) and Service Bulletins (SB's) were met.

Airworthiness directives

On 11 February 2009 the European Aviation Safety Agency, EASA, issued an Airworthiness Directive (AD) for Pilatus aircraft type PC-12/47E, serial no. 545 and from serial number 1001. The AD was amended on 3 April 2009 and on 20 November 2009. AD2009-0800-E dated 3 April 2009 was in force at the time of the accident. The AD describes a potential problem that arises if an accelerated turn onto the runway is performed immediately followed by take-off. At that time, both PFD's could indicate a roll attitude offset of up to 10 degrees in the same direction. The wrong indication would correct itself after several minutes.

To avoid this problem the AD required a revision of the operating procedures and requested that the aircraft had to hold stationary for a minimum of 60 seconds prior to line up and for a minimum of 15 seconds while lined up on the runway centre line.
The AD issued on 20 November 2009 stated that the problem can be solved by a software update. It emerged from the investigation that the updated software had already been installed on PH-RUL prior to delivery.

High Performance aircraft

The Pilatus PC-12/47E is designated as a High-Performance Aircraft. According to JAR-FCL1.251 these aircraft "*...are certified for single pilot operation but have similar performances, systems and navigation capabilities to those more usually associated with multi-pilot types of aircraft, and regularly operate within the same airspace. The level of knowledge required to operate safely in this environment is not part of, or not included to the necessary depth of knowledge in the training syllabi for the PPI, CPL or IR(A) but these license holders may fly as pilot-in-command of such aircraft."*

For that reason, JAR-FCL stipulates that an additional theoretical training course must be followed and that the pilot must pass the examination in order to operate these type of aircraft. To attain an equivalent rating, pilots must pass a 'type rating skill test'.

Investigation of the aircraft

An investigation of the remains of the aircraft commenced at the site of the accident. The relevant parts of the aircraft were then transported to a hangar where further examination took place. The engine was sent to the manufacturer in Canada for investigation. The engine was examined by manufacturing plant experts, under the supervision of Transportation Safety Board of Canada (TSB) investigators. The propeller manufacturer assessed the propeller damage.

The aircraft investigation revealed the following:

- The landing gear was retracted at the time of the accident.
- The flaps were retracted at the time of the accident.
- All flight control surfaces were found near the aircraft.
- Flight control continuity was established for the rudder and the elevator from the surfaces to the cockpit area.
- Due to the disintegration of the wing and the damage caused by impact fire in the fuselage, the flight control continuity for the aileron could not be established.
- Due to the extensive damage it was not possible to establish flight control continuity in the cockpit area.
- The stabilizer trim was within the green take off range.
- The aileron trim was slightly left wing down. The trim tab had been set within the limits applicable to take-off.
- The rudder trim was slightly to the right.
- All doors were most probably closed at the time of impact.

The investigation was severely hampered by the enormous damage the engine had sustained from the impact. The examination of the engine performed at the manufacturer's premises revealed that the engine showed marks indicating that the engine was running on power at the time of the impact. There were no indications suggesting that the engine had been defective prior to the accident.

The propeller manufacturer's expert was of the opinion that in the light of the propeller blade damage it was highly likely that the engine had been running on medium to high power and that the impact had occurred at high speed.

According to the Budel Airport records the aircraft had been refuelled at the airport on 9 October 2009. The amount of fuel in the tanks at that time is unknown. The tanks were refuelled with 997 litres of fuel. According to the aircraft logbook, no flights were carried out with the aircraft after that date. The next flight due to take place was the flight involved in the accident on 16 October 2009.

The calculation made of the estimated weight of the occupants and the amount of fuel shows that the take-off weight of the aircraft was around 3,926kg. The centre of gravity was approximately 5.86 metres from the datum.

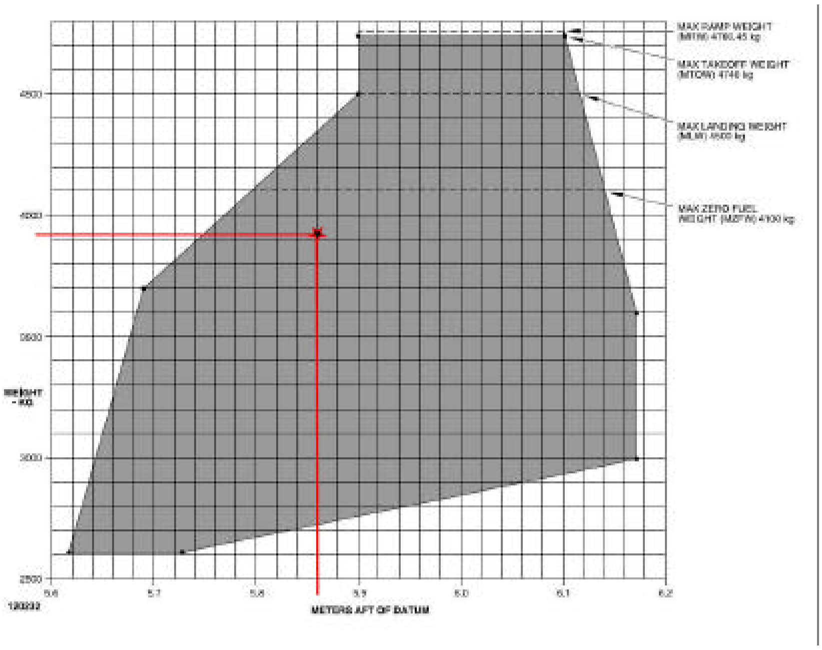

Figure 4: graph of weight and balance

As stated, PH-RUL did not feature any equipment for recording flight data or audio data and sounds coming from the cockpit. The aircraft was equipped with a modular avionics unit (MAU). The MAU controls the digital instruments and stores their data. Error messages and failures of these instruments are also stored. The MAU is also used for maintenance purposes but is not crashworthy. The MAU was found among the remains of the aircraft and was very heavily damaged and partly burned. All modules were removed from the MAU and sent to the manufacturer in the USA for examination. The modules were examined in the presence of a Dutch Safety Board investigator and all relevant memory chips were collected and examined to find out whether they might possibly contain any information. The investigation revealed that nearly all the chips were damaged. The damage was so severe that no information could be obtained from the chips. Only one chip contained some information that could be downloaded. The information indicated that 6.34 minutes had elapsed between the time the engine was started and the time at which the aircraft took off. That was the only information obtainable from the MAU.

The pilot

The pilot was a 57 year old male. He held a valid Dutch and US Private Pilot's Licence (PPL) for fixed-wing aircraft and a valid Dutch Private Pilot's Licence for helicopters.

Fixed-wing aircraft

Type of licence	PPL(A) issued 10 July 2007
Type rating	PC12, pilot in command, VFR, valid until 1 July 2010; Aerospatiale SET, valid until 1 July 2010; MLA, valid until 1 January 2010
Ratings	RT/VFR flights only, LPE English level 4
No. of flight hours in total	783.41 hours
Number of flight hours based on type	84.45 hours
No. of flight hours based on type during the last three months	62.30 hours

Helicopters

Type of licence	PPL(A) effective 28 April 2009
Type rating	EC120, pilot in command, VFR, valid until 1 October 2010; R44, pilot in command, VFR, valid until 1 October 2010;
Ratings	RT, LPE English level 4

US licence

Type of licence	US PPL(A) effective 25 April 2008
Aircraft class	SEP(A), land
Ratings	Instrument airplane

Table 1: Overview of the pilot's licences and aeronautical experience

The information in the pilot's logbook was examined. The pilot's flying hours as a helicopter and an MLA pilot were not taken into account. He started his training as a private pilot on fixed-wing aircraft in December 2006. The PPL for single-engine, fixed-wing aircraft was issued on 10 July 2007. Until the examination, he had accumulated 84.58 hours of flight time operating both a Cessna 172 and a TBM850. The pilot owned the TBM850 aircraft. A rating is required in order to operate this aircraft type.

Based on the nature of the flights operated with a Cessna 172, it may be concluded that these were instruction flights. Both dual control and solo training flights were carried out. He had accumulated 72.13 hours of flight time on dual control training flights until the examination.

All TBM850 flights are recorded in the logbook as dual control training flights. This means that the pilot in command was a qualified instructor and that the aircraft pilot flew the aircraft as a student. Based on the routes which the aircraft operated, it may be concluded that the aircraft was mainly used for business purposes.

The majority of the flights operated by the pilot from January 2008 were written down as flights in instrument meteorological conditions (IMC). These flights were recorded as 'DBO (dual received)' in the logbook.

The pilot was issued a US Private Pilot's Certificate on 25 April 2008 with ratings for single-engine land aircraft and instrument airplane.

The pilot attained the 'Aerospatiale SET'[6] type rating on 10 June 2008. He had completed 269:33 flying hours with an instructor and 20.20 flying hours as pilot in command until 26 June 2008. All flights operated by the pilot from 26 June 2008 were recorded as flights in IMC conditions in the logbook, with the pilot serving as the pilot in command.

[6] Aircraft type TBM850 falls under the Aerospatiale Single-Engine Turbine type rating.

The pilot followed a simulator training course for aircraft type Pilatus PC-12NG in the USA from 16 through 22 March 2009. The course involved both theory and practical instruction with 20.05 flying hours in the simulator. The topics covered included VFR and IFR procedures, systems and using the autopilot.

He followed a theoretical training course held by Pilatus, the manufacturer, in Switzerland from 25 to 29 May 2009 and a practical training course on aircraft type Pilatus PC-12NG immediately after, from 29 May 2009. He had accumulated a total of 14.18 hours flying with an instructor, 1.40 hours of which involved instrument flight training. The topics covered in the course included preparing the flight by programming the Flight Management System (FMS) and flying in VMC conditions using PC-12 instruments. In addition, he received training on the principles of an automatic flight in VMC conditions using FMS. No training was provided on using the IFR section of the FMS.

On 9 June 2009 the pilot passed the 'type rating skill test' for VFR flights operated with aircraft type PC-12NG. On the basis of the test the pilot attained type rating 'PC12, VFR PIC'[7]in his Dutch pilot's licence on 24 June 2009.

The last flight was recorded in the pilot's logbook on 14 July 2009. According to the logbook, he had accumulated 721.11 hours of flight time operating fixed-wing aircraft, 475.11 hours of which comprised flights in IMC conditions and 435.26 hours as pilot in command.

The aircraft logbook shows that the pilot had accumulated a further 62.30 hours of flight time after that date operating PH-RUL. It is not known whether these flights were carried out as flights in VMC or IMC conditions.

Sample surveys turned out that some flights were recorded in the logbook as flight under IMC-conditions whereas the weather met the VFR-requirements.

The logbook furthermore showed that the pilot had carried out the flight from Budel Airport to Egelsbach Airport more than 40 times. By far the majority of these flights had been carried out with an instructor.

It emerged from the interviews that the pilot wanted to attain the Dutch instrument flight rating on the basis of his US licence. In order to attain an equivalent instrument rating private pilots must meet the following requirements: accumulate a minimum of 500 instrument flight hours as pilot in command and pass the Dutch practical examination.

On 2nd July 2010 the Dutch CAA issued a statement that the pilot met the requirements for validation of his foreign licence. His US/PPL/IR could be validated into a Dutch PPL(A) with IR(A) after having passed the following conditions:

- He should have been found fit for medical class II at a JAA approved medical centre;
- He should pass a JAR-FCL[8] skill test on a single pilot aeroplane in IFR-conditions.

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[7] VFR PIC: Pilot in command in VFR conditions.

[8] Joint Aviation Regulation-Flight Crew Licensing

Interviewed flight instructors had different opinions about the flying capabilities of the pilot. Some stated that he was able to fly the aircraft safely in both VMC and IMC conditions, others stated that his capabilities in IMC conditions were below standard and that the pilot sometimes overestimated his flying skills. Also during the practical type training in Switzerland it turned out that skills of the pilot did not met the standard for IMC-flights. Flight instructors on Budel Airport told him to operate this advanced aircraft conscientiously and the staff of the airport offered him to hire a safety pilot whenever he wanted.

Autopsy
An autopsy was performed on the bodies of both occupants. No matters were found that might explain the accident. The autopsy showed that the occupants had deceased as a result of the impact and that there most probably was no fire on board the aircraft during the flight.

Weather
Various sources were used to obtain weather information: KNMI (the Royal Netherlands Meteorological Institute), Eindhoven Air Base and the Kleine Brogel Air Base in Belgium. In addition, cloud information was provided by another aircraft.

According to the KNMI weather report, the weather conditions near Budel Airport were as follows at the time of the accident:

Wind	On the ground: 270 degrees 8 knots 500 feet: 320 degrees 25 knots 1,000 feet: 330 degrees 30 knots 1,500 feet: 330 degrees 10 knots 3,000 feet: 340 degrees 40 knots
Weather	Periods of rain / drizzle
Visibility	3,000-5,000 metres, in drizzle temporarily 2,000-3,000 metres
Cloud	Broken/overcast (5-8/8) at 300-400 feet, top above 10,000 feet
Temperature	10°C
Ice accretion	Not below 7,000 feet

The weather at Eindhoven Air Base

Wind	On the ground: 250 degrees 8 knots
Weather	Drizzle
Visibility	5,000 metres
Cloud	Overcast (8/8) at 400 feet
Temperature/ dew point	10°C/9°C

The weather at the nearby Kleine Brogel Air Base in Belgium

Wind	On the ground: 240 degrees 8 knots
Weather	Drizzle
Visibility	3,000 metres
Cloud	Scattered (3-4/8) at 600 feet; overcast (8/8 level of cloud) at 800 feet
Temperature/ dew point	8°C/7°C

Table 2: Overview of weather conditions at the various locations

At the request of Airport Operations, the pilot flying PH-DIX, which had taken off shortly after PH-RUL, reported that the cloud base was located at 750 feet and the cloud tops at around 3,000 feet.

Budel Airport

Budel Airport is an airport that does not have any Air Traffic Control but where flight information is provided solely by Airport Operations. The airport is open to VFR traffic during the uniform daylight period and for IFR traffic outside the uniform daylight period to the extent this falls outside 06.00 and 22.00 hours. The airport has a 1,199-metre paved runway oriented on a 030°-210° heading. Runway 21 was in use at the time of the accident.

The airspace surrounding Budel Airport where PH-RUL flew is uncontrolled airspace up to an altitude of 1,200 feet, Class G airspace. The minimum conditions for VFR flights in Class G airspace below 3,000 feet are: horizontal visibility 1,500 metres, clear of clouds with the surface in sight. The AIP[9] describes the flight procedures at Budel Airport. The rules relevant to this investigation are as follows (summarised):

– The en route clearance will be issued by the appropriate ATC unit to Budel Aerodrome Information and will be relayed by Budel Aerodrome Information as soon as possible to departing aircraft after taxi permission has been given. An en route clearance contains:

    - Clearance limit: airport of destination.
    - Standard instrument departure (SID).
    - SSR code.
    - ATC unit and frequency on which the aircraft shall report as soon as possible after take-off.
    - Departure instructions if applicable.

- Pilots of departing aircraft shall contact the ATC unit, as indicated in the en route clearance, as soon as possible after take-off but not later than passing 1000 ft AMSL. Normally departing aircraft will be transferred to Dutch MIL.

On Budel Airport aircraft maintenance, airport operations and flight instruction is available. One organization has been managing all these activities. The aircraft was stored and maintained on Budel Airport. The training organization on Budel Airport provided flying instruction and training to the pilot and provided type rated pilots to the owner of the PH-RUL during the time he did not hold a type rating or when he needed co-pilot for a flight. In addition, flight preparations, such as refueling, weather forecast and filing the flight plan were done by Budel Airport staff.

Interviews revealed that the pilot, when he had the intention to make a flight, informed airport operations about his intentions and about the details of the flight. Airport operations took care of refuelling of the aircraft, catering, flight preparations, filling the flight plan, printing the latest weather forecast and all other information, relevant to the flight.

[9] Aeronautical Information Publication

The pilot informed Budel Airport operations about the flight of 16 October in advance. Staff of the airport prepared the flight as usual; the aircraft was parked outside, the flight plan was filed and the weather forecast and Notams[10] were printed. According to the operations employee the weather was marginal but it met the requirements for the first VFR-part of the flight. He also acquainted with the flying abilities of the pilot and he had no reason to advise him to cancel the flight. It was the pilots own discretion to decide to execute or cancel the flight. The employee was also aware that the pilot did not possess an instrument rating in his Dutch license but hold an American PPL with an instrument rating. According to the employee, this covered the execution of this flight because it was an IFR-pick up. According to the employee, the pilot was aware that he always could ask for a co-pilot of the training organisation to accompany him. The pilot did not ask for a co-pilot for this flight.

Communication[11]

The Airport Operations employee at Budel Airport contacted Dutch Mil by telephone prior to the flight to obtain clearance for the IFR segment of the flight for both PH-RUL and PH-DIX.

It emerged from the conversations held by Airport Operations at Budel Airport via Budel Radio that PH-RUL had been issued clearance to turn left and fly direct in the direction of navigation point OSGOS after take-off. The Airport operations employee issued PH-RUL the relevant clearance at 08.20 hours by radio. The pilot of PH-RUL correctly read back the above clearance. PH-RUL took off at approximately 08.22 hours after the Airport Operations employee had communicated the prevailing wind conditions. PH-RUL checked out Budel Radio at 08.23:17 hours stating “And switching over to Dutch Mil, bye”. During the radio transmission a warning signal can be heard in the background. The Airport Operations employee replied: “Have a good flight”, to which PH-RUL again replied: “Thank you”. The same warning signal can be heard during the last transmission. The total communication lasted approximately five seconds.

PH-RUL called Dutch Mil Air Traffic Control at 08.24:27 hours. The call was not answered immediately because the air traffic controller was dealing with a telephone call. At 08.24:41 hours the air traffic controller asked who had called Dutch Mil. No response was received. Dutch Mil called PH-RUL at 08.24:52 hours but PH-RUL did not respond to the call. No background noise could be heard during PH-RUL's first call to Dutch Mil.

The warning signal audible in the background was the sound that is emitted when disengaging the autopilot. The pilot can manually disengage the autopilot; in that case an aural warning made up of three consecutive tones called the cavalry charge is emitted once. The autopilot can also be automatically disengaged by the aircraft system; in that case the same sound of three consecutive tones is emitted and repeated until the pilot manually mutes off the warning signal.

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[10] Notice to airmen, daily relevant information for pilots.

[11] During the course of the investigation it emerged that there was a time difference between the various data-recording systems, namely the radar system and the equipment that records communication at Budel Airport. For the purpose of the investigation, all times were synchronised with the time used by the radar system, and converted to local time, if applicable.

Radar[12]

The radar images obtained showed the following:

- After take-off, PH-RUL first appeared on the radar screen at 06.23.:26 UTC radar time.
- At that time the aircraft was flying at an altitude of 688 feet at a ground speed of 136 (103)[13] knots, south of Budel Airport with a heading of 132°.
- The aircraft made a left turn of approximately 180º in relation to the direction in which it had taken off.
- At 06.24:09 hours PH-RUL was flying west of Budel Airport at an altitude of 1,888 feet at a speed of 156 (189) knots with a heading of 350º.
- PH-RUL then turned slightly further left and then made a sharp right turn.
- The last radar image was taken at 06.24:29 hours. PH-RUL was then flying with a heading of 024º at an altitude of 2,188 feet at a speed of 134 (157) knots.

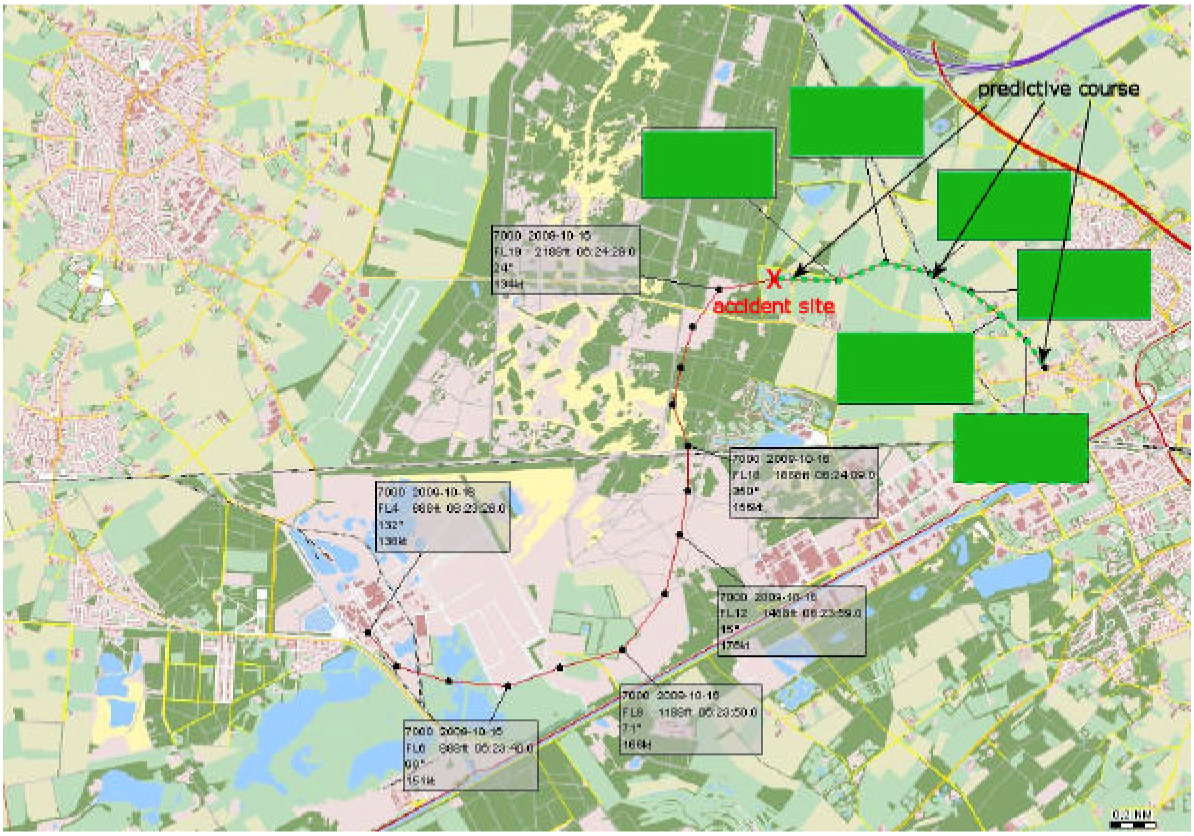


Figure 5: Radar plot of the heading flown by PH-RUL[14] *(source: Air Traffic Control Netherlands, (LVNL))*

[12] Radar times are stated in UTC (Coordinated Universal Time). Local time is UTC + 2 hours.

[13] The speeds referred to were calculated by the radar and are ground speeds. The conversion to air speed, which calculates the effect of the wind, is stated in brackets.

[14] The radar system also calculates the predicted course, altitude and speed of the aircraft. The 'predictive course' and corresponding labels are shown in green on the radar plot.

A vertical profile was also obtained. According to this profile PH-RUL was climbing at 06.24:19 hours. The next radar image showed PH-RUL flying at an altitude of 1,888 ft at 06.24:33 hours and the aircraft was descending.

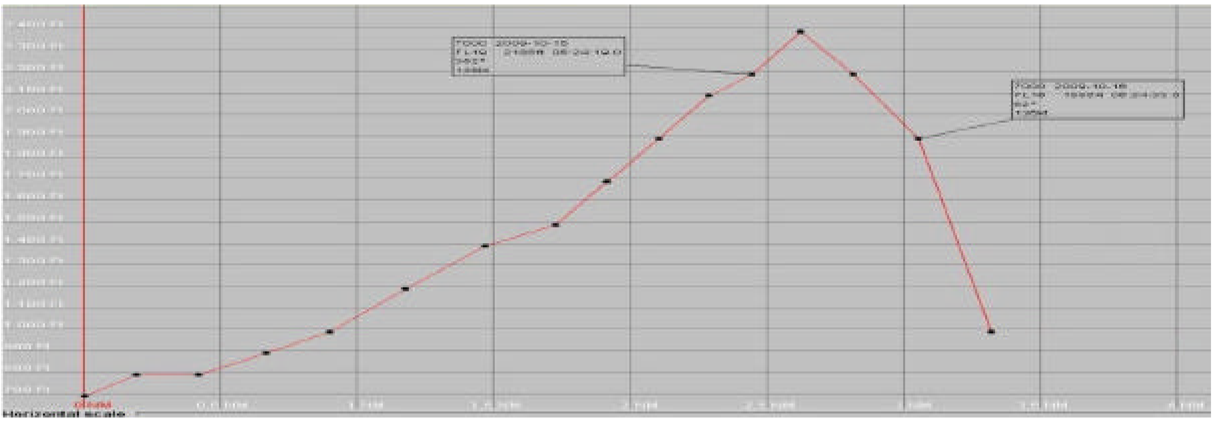


Figure 6: Radar plot of the vertical profile of PH-RUL

A comparison of the radar images of PH-RUL and PH-DIX shows that the two aircraft followed a different route although they had both received clearance to fly to navigation point OSGOS.

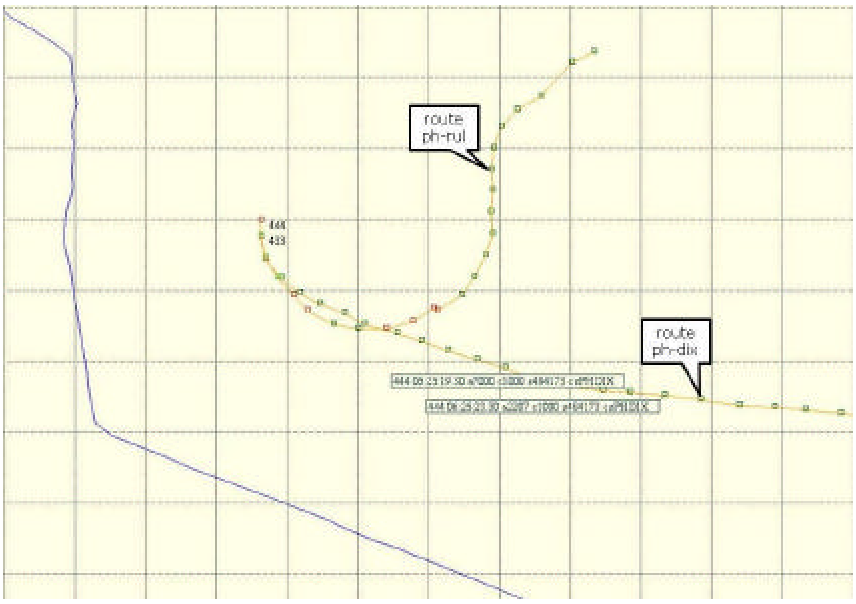


Figure 7: Radar plot of the headings flown by PH-RUL and PH-DIX (source: Dutch Mil)

Procedures on board the aircraft

The Pilatus PC-12/47E can be operated by the pilot manually, as well as by using the autopilot. If the route or a segment of the route will be flown using the autopilot , the route must be entered in the FMS and the FMS must be linked to the autopilot. The route is entered by selecting the waypoints or beacons en route. The FMS contains a library which stores a large number of fixed departure routes. The system also provides the option of storing previous flights carried out so that these can again be used at a later date. These routes can be selected via the MFD input panel and after pressing the autopilot button the aircraft will follow the selected route without the pilot himself steering the aircraft.

The aircraft flight manual states that the autopilot may be engaged at 400 feet above ground and the aircraft is fully configured after take off climb

Analysis

The following factors hampered the analysis of the information and the tracing of the probable cause of the accident:

- The aircraft did not feature flight data recording equipment.
- As a result of the extensive damage, the technical investigation of the aircraft was limited.
- There were no witnesses to the accident.

The aircraft

The aircraft was in a good technical condition, to the extent this can be verified. The aircraft was five months old and had accumulated 95.30 hours of flight time. The required 100-hour inspection had been performed, and the aircraft complied with the AD in force. No aspects were found during the inspection that might have had a bearing on the cause of the accident.

The weight and centre of gravity of the aircraft were within the limits stipulated in the aircraft flight manual. Although the exact amount of fuel could not be established, the 997 litres of fuel with which the aircraft had been refuelled was sufficient for the Budel to Egelsbach flight.

It may be concluded from the examination of the aircraft, engine and propeller that the aircraft struck the ground with the engine running and a rotating propeller. There is every indication that power had been selected at the time of impact. There are no indications suggesting that engine problems had occurred.

It may be concluded from the marks found in the silage pile that the aircraft first struck the ground with its right wing. The engine and propeller hit the ground behind the silage pile and the aircraft overturned. On the basis of the tracks, it emerged that PH-RUL was flying a 155° heading just before the accident. In the light of the tracks on the ground, the aircraft was flying at a high horizontal speed and banked to the right.

The landing gear and flaps of the aircraft were retracted at the time of the impact. This rules out that the pilot wanted to make an emergency landing.

No indications were found suggesting that the accident was caused by a technical failure of the aircraft.

Test flight

A test flight with a similar PC-12/47E was carried out with the assistance of the manufacturer. Two Dutch Safety Board investigators were present during the flight. The purpose of the flight was as follows:

1. To find out how much time elapses between the moment the pilot starts to complete the checklist until the moment the aircraft is ready to taxi to the take-off runway.
2. To find out under which circumstances the autopilot is disengaged by the system, and the same warning signal sounds as the signal that can be heard on the sound-recording.
3. To find out which actions are needed to re-engage the autopilot.
4. To find out how the system responds if the route that has been entered in the FMS is changed in the intervening period.
5. To find out what the pilot's workload is under normal circumstances and what his workload is in the event a failure occurs.

The test flight revealed the following:

Re 1 Starting from the moment at which the testpilot started completing the checklist and entering information into the FMS until the moment the aircraft was ready to taxi to the take-off runway, the time measured was eight minutes and 40 seconds.

Re 2 The system automatically disengages the autopilot if:

a) The speed decreases to such an extent that the stick shaker activates.
b) The pilot changes heading with the yoke such that it no longer corresponds with the heading entered in the autopilot.
c) Failures occur in the avionic systems, the flight director, the pitot-static system, the inertial measurement unit (the inertial reference system) or the autopilot servos.

In addition, the autopilot can be disengaged by the pilot. As stated earlier, the three-tone cavalry charge warning signal is sounded but once only.

Re 3 If the cavalry charge is sounded continuously, it must first be switched off by pressing in the autopilot disconnect button on the yoke, after which the autopilot can be re-engaged by pressing the A/P button on the panel. Reengagement of the autopilot is not possible if situations as mentioned in 2 continue.

Re 4 If the route entered in the FMS is changed in the intervening period, the autopilot will follow the new route and will remain switched on.

Re 5 If the pilot intends to fly the aircraft in fully automatic flight, all relevant information must be entered in the FMS. If this is carried out correctly and the autopilot is engaged after take-off, the pilot's workload will be low. After performing the required actions shortly after take-off, the work involves monitoring the different instruments and looking out for other traffic outside if flying in Visual Flight Rules.

If the information has not been entered in the FMS correctly or if it is incomplete, the system will give an error message during the flight and will disengage the autopilot. In that case the pilot's workload will be higher than before. The pilot is required to steer the aircraft manually, maintain its level and position, identify and possibly resolve the failure and return the aircraft to its original position once again, if necessary.

The test flight showed that a well-trained pilot who has the required knowledge and skills to operate the aircraft, is capable of performing these tasks proficiently. The following should be noted in this context:

- The pilot initiated the abnormalities himself;
- The aircraft did not fly through clouds during the flight.

While resolving the failures and resetting the autopilot system, it emerged that the pilot moved his head many times to look at the screens and enter new information via the data entry panel.

In addition, the situation in which one or more screens failed was also simulated during the flight. The system software is programmed such that the screen displaying the most elementary PFD flight data is always displayed on one of the screens that is still working. In the event of the failure of all four screens, the relevant information can still be read on the Electronic Stand-by Instrument System (ESIS) located in front of the pilot on the left.

The pilot

The pilot had held a valid Dutch Private Pilot's Licence with a single-engine land aircraft rating since July 2007.

He attained the US Private Pilot's License with single-engine land aircraft and instrument airplane rating on 25 April 2008.

Virtually all flights he had operated after attaining his Dutch Private Pilot's Licence until the date on which he took the examination for the Aerospatiale SET type rating on 10 June 2008 were carried out together with instructors. After 26 June 2008, all flights were recorded in his logbook as flights in IMC conditions, with his name being recorded as the pilot in command.

Given the fact that all flights he operated after 26 June 2008 were recorded as flights in IMC conditions in his logbook, the pilot appears to have wanted to comply with the requirement of having accumulated 500 instrument flight hours as soon as possible. After having accumulated the required number of flight hours he would be eligible for an equivalent Dutch rating on the basis of his US licence. According the statement of the Dutch CAA, he fulfilled the 500-hour requirement prior to the accident; however, he had not yet fulfilled the other requirements: found fit for medical class II and pass a JAR-FCL[15] skill test on a single pilot airplane in IFR-conditions.

[15] Joint Aviation Regulation-Flight Crew Licensing

It must be mentioned that it is uncertain that the flights which were operated as IFR-flight, actually were flown under IMC-conditions. According to random checks the weather during some flights met the VFR-requirements. One can make an IFR-flight while no clouds are present and sight is more than ten kilometres. Therefore it may be concluded that the amount of IFR flight hours in the pilot's logbook is not equivalent to the flight hours actually flown under IMC-conditions.

Although US licenses including instrument airplane ratings are invalid for Dutch registered aircraft, it may be assumed that the pilot indeed had knowledge of instrument flights; after all he had passed the US examination. He had also followed a theoretical and practical training course in the Pilatus PC-12NG flight simulator in the USA, which involved basic instrument flight training.

The pilot had attained his PC-12/47E VFR type rating from the aircraft manufacturer in Switzerland; he therefore had sufficient knowledge to enable him to operate the aircraft proficiently in visual flight conditions. The PC-12/47E is designated as a High-Performance Aircraft. In order to operate such an aircraft, a pilot with a Private Pilot's Licence is required to follow further training. The pilot fulfilled this requirement in attaining the type rating.

This means that the pilot should be deemed capable of operating the aircraft proficiently during VFR flights with and without the autopilot engaged. He also passed the FAA-examination for the instrument rating in his American license and he followed a simulator training course for aircraft type Pilatus PC-12NG, including VFR and IFR procedures, systems and use of the autopilot. That is why he should have had the knowledge to operate the PC-12/47E during IFR-flights.

The work load on a pilot increases considerably if an unexpected situation arises in which the system disengages the autopilot during a flight in instrument meteorological conditions. The pilot must steer the aircraft manually without any visual references and he also must navigate and, if desirable, re-engage the autopilot. Proper training and experience in the above situation is indispensable to coordinate all tasks in the right manner. To the extent this could be checked, the pilot, however, had had no training in or experience of flying an aircraft in IMC conditions in which the work load had risen due to deviating circumstances, where it is vital to ensure that one's attention and tasks are properly coordinated.

The role of the airport staff
The staff of Budel Airport knew the pilot; they trained him, maintained the aircraft, accompanied him during flights and took check flights with him. On the accident day the employee of Operations fulfilled the flight preparations. Although the weather was marginal, he did not advise the pilot to cancel the flight. The employee did not have the authority to cancel the flight; Budel Airport is an uncontrolled airport; pilots depart and land on their own discretion. Because this employee was also flight instructor, he could have advised the pilot about the flight in relation to the weather. He saw no reason to do so; he was of the opinion that the pilot was able to fly solo in IMC conditions, he also knew that the pilot often flew the route and he knew the aircraft was fully IFR-equipped. The fact that the pilot did not hold a Dutch instrument rating did not worry him because he knew the pilot held an US instrument rating. It remained unclear why the airport staff filed the flight plan mentioning "three persons on board." The employee could not remember the reason for this.

The flight

The pilot had carried out the flight from Budel Airport to Egelsbach Airport in Germany more than 40 times. All of these flights were recorded as flights in IMC conditions in the logbook. Although he had by far the majority of cases flown the route with an instructor who acted as co-pilot, he clearly knew the route and the procedures. Under normal circumstances the flight was a matter of routine to him.

According to the flight plan the aircraft would take off at 08.00 hours. The pilot, however, only arrived at Budel Airport after 08.00 hours. He then boarded the aircraft with the passenger and commenced the start-up procedure. The time between aircraft start-up and take-off was six minutes and 34 seconds.

The test flight revealed that a highly experienced pilot takes more than eight minutes to fully complete the checklists, enter the required flight data and start up the engine. The pilot must then still taxi the aircraft to the take-off runway and take-off.

The pilot’s late arrival at the airport, the fact that he seemed to be in a hurry and the short period of time between starting up the system and take-off suggest that the pilot wanted to make up for the time he was running behind schedule.

If an aircraft is to be fully flown in automatic flight, a route must either be entered in the FMS or a route stored in the aircraft’s database must be selected. In both cases, it takes some time to feed all information into the FMS system.

Clearance for the flight was issued while the aircraft was taxiing. As a consequence, the pilot either still had to enter additional information in the FMS while taxiing or he deferred this until after takeoff. The latter seems to be unlikely because the autopilot was engaged shortly after takeoff and therefore all data had to be put in into the FMS already.

Overall, it is clear that the flight was not prepared thoroughly and that the start-up procedure was not performed in a relaxed manner.

The weather information obtained from the various neighbouring airfields and statements show that the weather in Budel was marginal. In other words, while the weather did indeed meet the VFR criteria (visibility of more than 1.5 km, free of cloud, and ground and water visibility) the cloud base and visibility, however, were no more than minimum. Since the cloud base was located between 600 and 800 feet, the IFR part of the flight would need to commence at this altitude.

The reconstruction shows that the pilot of PH-RUL had contacted Airport Operations at Budel Airport and changed frequency before reaching an altitude of 688 feet.

The cavalry charge warning signal is audible during the communication between PH-RUL and Airport Operations at Budel Airport. It is audible in two transmissions during the communication, which took approximately five seconds. It may be concluded from the above that the warning signal is the signal indicating that the system has disengaged the autopilot. The pilot’s voice sounds calm during the transmissions. The radar plot shows that the aircraft was starting to turn left at that time. The aircraft was not yet visible on the radar at that time and was therefore flying at an altitude of less than 688 feet above the ground (the altitude at which the aircraft was first seen on the radar). The autopilot had therefore already been engaged shortly after take-off and disengaged a while later again.

According to the Pilot Operating Handbook the autopilot should only be engaged at 400 feet above ground and the aircraft is fully configured after takeoff climb. This means that after takeoff a certain workload might have been present because the pilot had to perform several tasks. After connection of the autopilot the pilot's workload reduced and he was able to concentrate on the communication. However, shortly afterwards the autopilot disengaged and the pilot had to steer the aircraft manually.

The pilot called Dutch Mil approximately 70 seconds after he had signed off at Budel Airport. The aircraft was flying at an altitude of approximately 2,000 feet in the clouds at that time. The pilot's voice sounded calm and the warning signal was no longer audible. The pilot had evidently switched off the signal and he did not feel that the situation was threatening. Dutch Mil did not respond immediately but called PH-RUL for the first time, 14 seconds later, and another ten seconds later made a second call. PH-RUL, however, did not respond. PH-RUL crashed around that time.

No clarity has been obtained on what caused the autopilot to disengage. It is possible that the system detected a condition, which caused the disconnection or that the pilot himself steered the aircraft along another heading, countering the autopilot. The third possibility, a stalling situation, should be considered unlikely, because the aircraft was flown in automatic flight at that time and the aircraft system prevents the aircraft from reaching a stalling situation. Moreover, the air speed calculated was well over the aircraft stalling speed (approximately 86 knots with a roll angle of 0 degrees and approximately 100 knots with a roll angle of 40 degrees).

The radar images show that PH-RUL started to turn left after take-off as set out in the Budel Airport procedures. After the disengagement of the autopilot, the aircraft continued the left turn until having turned almost 180 degrees and it was flying a northerly heading. This is not the heading that leads to navigation point OSGOS. Also the time between signing off at Budel Airport and calling Dutch Mil was longer as usual and did not take place before reaching 1,000 ft as required. It may be concluded from the above that the pilot's attention must have been diverted from following the correct route to navigation point OSGOS and changing to Dutch Mil frequency during this phase of the flight.

After PH-RUL had flown a small distance straight ahead, the aircraft made a sharp right turn, during which it rapidly lost height. This pattern means that it is likely that the autopilot was still disengaged. Moreover, the whole route deviates considerably from the planned route to navigation point OSGOS. This becomes clear when comparing the route flown by PH-RUL with the route followed by PH-DIX, which was also heading towards OSGOS (see image 6).

All of the above shows that after the cavalry charge the autopilot was no longer engaged and the pilot was steering the aircraft manually.

There were approximately 14 seconds between the last radio contact in which everything sounded normal and the time at which the pilot failed to respond to a call made by Dutch Mil. It is therefore likely that during this brief period PH-RUL reached a situation that was not recognized by the pilot. The fact that the pilot called Dutch Mil at 08.24:27 hours with a calm voice while the aircraft was already descending, as shown in the radar plot (see figure 5). This moment was probably short before impact. Furthermore, the pilot did not make an emergency call and the engine was running on power at the time the aircraft struck the ground. If the pilot had indeed been aware of the situation, one of his first actions would have been to make an emergency call and to reduce power.

Due to the low cloud base, 400 to 600 ft, the pilot would have had visual references outside the cockpit in the very last moment. Considering the speed and the rate of descend of the aircraft, this altitude was too low to recover the position of the aircraft.

A timeline showing all main events has been included in Appendix B to this report.

Spatial disorientation
It is likely that after the disconnection by the system of the autopilot, the pilot of PH-RUL first switched off the warning signal and then attempted to trace or eliminate the cause of the disconnection, or re-engage the autopilot. He also had to read the heading, speed, altitude and position of the aircraft by looking on both the PFD and MFD. In these instances, he inevitably had to move his head. During the test flight it emerged that when entering information or operating the FMS for other purposes, the pilot of a PC-12/47E needs to move his head to look at the centre console where the information is entered.

The risk of spatial disorientation is recognised in aviation. The results of several international studies show that spatial disorientation accounts for some six to 32 percent of major accidents, and some 15 to 26 percent of fatal accidents. The true prevalence of spatial disorientation is almost certainly underestimated. It is vitally important that pilots are aware that none of them is immune for spatial disorientation. It can affect any pilot, anytime, anywhere in any aircraft, on any flight, depending on the prevailing circumstances.[16]

At the request of the Dutch Safety Board, physiologists from the Royal Netherlands Air Force Centre for Man and Aviation (*Centrum voor Mens en Luchtvaart*) provided a description of the balance organ and how spatial disorientation arises. The description can be found in Appendix A to this report.

The reconstruction revealed that circumstances arose during the flight which increased the risk of spatial disorientation:

- The aircraft was flying through clouds at the time the system disengaged the autopilot.
- The aircraft was flying a left turn which took approximately one minute.
- The aircraft was climbing.
- When looking at the centre console in order to enter information or to find out the cause of the autopilot being disengaged, the pilot had to move his head.

[16] ATSB transport safety investigation report B2007/0063: “An overview of spatial disorientation as a factor in aviation accidents and incidents”

The aircraft was flying through clouds, as a result of which the pilot had no external visual references. Since the aircraft was making a left turn for around one minute, his vestibular system will have lost its sensation of turning. This is a situation in which spatial disorientation (vertigo) may occur.

The report on spatial disorientation reveals that after around 10-15 seconds a human being no longer perceives rotation but is under the illusion that a straight-line flight is being made. The aircraft was climbing and therefore must have had a relatively high nose position. Moving one's head while rotating combined with the aircraft's high nose position provides false information about the position and direction of the aircraft.

All of the above requires that the pilot be disciplined in relying solely on the information provided by flight instruments and not to follow the sensations of his body. His success in doing so greatly depends on the knowledge, experience, training and capacities of the pilot in continuing to fly an aircraft in such situations proficiently and to rectify any abnormal conditions without the assistance of a co-pilot.

As mentioned High Performance Aircraft have similar performances, systems and navigation capabilities to those more usually associated with multi-pilot types of aircraft. Inmulti-pilot types of aircraft a proper division of tasks between the two pilots is essential in dealing with abnormal conditions or emergencies. The actual pilot focuses solely on steering the aircraft while the other pilot is primarily engaged in 'monitoring' the actual pilot, identifying and resolving the failure, ensuring the required communication and other necessary activities. Pilots of civil aircraft are trained and regularly undergo the relevant skills tests. The mentioned report states that single pilot operations, particularly where an autopilot is not available, face additional risks and the need to identify and manage SD events. It is advisable for pilot to undertake regular instrument flight exposures, preferably with an experienced instructor.
In this case one pilot had to fulfill all tasks and furthermore this was pilot was not well trained on a regular base for this kind of situations. All this enlarged the possibility of spatial disorientation.

Flight recorder equipment
As stated at the beginning of the chapter, the investigation was hampered because there was no flight recorder equipment on board the aircraft. This is not legally required either. On the basis of ICAO Annex 6, European Regulation L254/141 (EU-OPS) stipulates in Section 1.700 onward that this obligation applies to, inter alia, aircraft that are used for commercial transportation first issued with an Individual Certificate of Airworthiness on or after 1 April 1998 and:

- are multi-engine turbine-powered and have a maximum permissible passenger configuration of more than nine; or
- have a maximum certified take-off mass over 5,700kg.

Although the Pilatus PC-12/47E has

- a single turbine engine;
- a maximum permissible passenger configuration of nine;
- a maximum certified take-off mass of 4,740 kg;

the aircraft's performance and use options are such that it is comparable with aircraft that are indeed required to comply with the flight recorder equipment obligation. This is also set out in the additional requirements with which pilots of High Performance Aircraft are required to comply.

As a result of this and other accidents, the manufacturer Pilatus Aircraft has decided to equip the new PC-12/47E aircraft as standard with equipment that records flight data, conversations and cockpit sounds for the purpose of accident investigation.

The Dutch Safety Board therefore recommends that this aircraft category too features mandatory flight recorder equipment for the purpose of accident investigation.

Résumé

The disconnection of the autopilot shortly after takeoff must have been a complete surprise to the pilot. In a short space of time he was confronted with a higher workload which he alone had to handle; he had to steer the aircraft manually without having any external visual references and he had to have the discipline to concentrate only on the instruments. He had to continue the flight to its destination and lastly he had to ensure communication with Dutch Mil.

The pilot was confronted with a build-up of actions and tasks, the majority of which he probably had never encountered in the given circumstances and had not been trained in either. Moreover, the relatively low number of accumulated flight hours operating the PC-12/47E solely did not help him maintain control of the situation. The fact that the aircraft flew quite another heading than the intended heading to navigation point OSGOS indicates that the pilot was unaware or no longer aware of his position and heading at that time.

In view of the sparse information available to help trace the cause of the accident, the investigation focused on all possible causes: a technical failure, a medical failure, meteorological conditions and human factors. None of these causes can be ruled out completely. A technical cause, however, is unlikely because the aircraft was six months old, had just undergone the 100-hour inspection, the engine was running on power at the time of the impact and there were no indications suggesting fire during the flight. In the case that one or more displays had failed, the ESIS always continues to provide information about the attitude, heading and speed of the aircraft, which made the pilot able to continue the flight safely.

A medical cause is also unlikely: the pilot had passed a medical test, was healthy and the autopsy showed that he had died as a result of the accident. There were also no meteorological conditions, such as turbulence, ice accretion or a thunderstorm that could have directly caused the accident. The low cloud base most probably did play a role in the accident because the pilot did not have visual references shortly after takeoff, neither during the steep descent to compare the attitude of the aircraft with the horizon.

Taking all of the above into the equation, after the disconnection of the autopilot the pilot most probably found himself in a situation in which he became disoriented and lost control of steering the aircraft due to the high workload and his lack of training and experience.

CONCLUSION

Although no technical or medical cause can quite ruled out, it is most likely that the accident was caused by the pilot losing control of steering the aircraft as a result of spatial disorientation while flying through clouds.

The following factors played a role in the above:

- The disconnection of the autopilot shortly after take-off.
- The higher workload after the disconnection of the autopilot, mainly because the pilot was the only pilot on board the aircraft.
- The pilot's lack of training and experience in manually steering an advanced aircraft, such as the PC-12/47E, in a non-standard situation, in IMC conditions.

RECOMMENDATIONS

It is recommended to EASA to make flight recorder equipment mandatory for High Performance Aircraft, designed for carrying persons and/or cargo for the purpose of accident investigation.

Note: The draft report, without recommendations, was submitted for inspection of factual inaccuracies to the parties or persons directly involved in accordance with the Dutch Safety Board Act: Pilatus Aircraft and the wife of the pilot. In so far factual inaccuracies are concerned, the Safety Board has incorporated the comments received into the final report. This type of comment is not mentioned separately. The comments that have not been incorporated are mentioned in a table that can be found on the website of the Dutch Safety Board: www.safetyboard.nl.

APPENDIX A

Spatial disorientation

The inner ear contains the balance organ, which consists of two distinct parts: the semicircular canals and the otolith organs. The semicircular canals detect angular or turning acceleration and the otolith organs detect linear acceleration. In normal conditions, with two feet flat on the ground and your head straight above your knees when moving no faster than 5km/h, the balance organ provides correct information. In other conditions, for instance while flying, the information provided by the balance organ is sometimes unreliable.

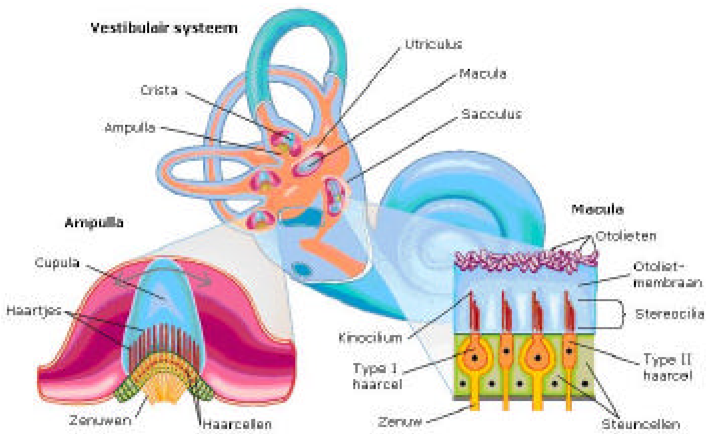


Image 6: The inner ear

Semicircular canals

The semicircular canals consist of three hollow tubes located perpendicular to each other. The canals are interconnected and are filled with a fluid of a specific viscosity. The direction of the imaginary plane where a canal is located more or less corresponds to the three known motions of an aircraft. One canal lies in the pitch plane, another in the yaw plane and the third in the roll plane. Since measurements can be made in three canals located perpendicular to each other, provided certain conditions are met, each rotation the aircraft undergoes will be detected.

The effect is similar to the principle of making fluid rotate in a glass. When the glass is turned, the fluid will initially continue to remain stationary relative to the environment while the glass rotates. The fluid will also gradually start to rotate as a result of resistance with the glass until it rotates as fast as the glass. The semicircular canal is comparable to the glass and the fluid inside it.

Each canal contains a motion sensor with tiny hairs that are attached to the canal wall. The degree of displacement of the hairs indicates a degree of angular or rotational acceleration to the brain. Take the roll canal, for instance. If the canal is rolled anticlockwise, the fluid would seem to turn clockwise relative to the canal while it in actual fact remains stationary. The difference in movement between the canal and the fluid causes the hairs to change direction and this sends an angular acceleration signal to our brain. If a certain angular velocity is reached after a time (rotation per unit of time) at a certain point in time the fluid will turn as fast as the canal as a result of the friction between the fluid and the canal wall. The hairs will move to the centre and an angular acceleration signal will no longer be sent. If a person has no visual reference, the sensation of turning will also be removed. In other words: you will rotate at a certain speed without noticing.

If the rotational speed is subsequently reduced (negative angular acceleration), the fluid will continue to flow for a while due to its mass inertia and will want to maintain its speed while the canal rotates more slowly. The fluid is now turning in the same direction as the canal, both in anticlockwise direction but at a different speed. The hairs are tilted in the opposite direction and consequently actually register angular acceleration and thus rotation in the opposite direction. In other words: you are still turning anticlockwise but the balance organ says that it is clockwise.

Incidentally a condition known as the threshold value is attached to registering angular acceleration. If a person rotates very slowly, i.e. when the angular acceleration is below the threshold value, nothing is registered. This creates the leans phenomenon. If no visual inputs are present, when flying through clouds or flying at night, a pilot will initially not notice that the aircraft has banked. When cross-checking the instruments the pilot will see an artificial horizon showing that the aircraft has banked 15 degrees, for instance. In the pilot's mind, however, the aircraft will still be flying at wings level. A logical and impulsive reaction will follow and the pilot will position the aircraft horizontally on the artificial horizon at wings level. While the roll canal does register this movement, it will be based on the incorrectly registered wings-level flight and thus registered as banking.

The pilot will now see that he is flying at wings level but feels as if he has banked. Since he knows that he can rely on his instruments, he also knows that he is flying at wings level yet in response to this illusion he will lean towards an imaginary vertical position, known as 'leans'.

Another phenomenon that relates to the semicircular canals is called the Coriolis illusion.
The registration of angular acceleration by a certain canal depends on the position of the canal in relation to the earth's surface. In other words, if you keep your head upright, the canals will correspond to the roll, pitch and yaw planes. If you tilt your head downward, for instance, the roll canal will become a yaw canal and the yaw canal will become a roll canal. If a rolling movement occurs, it will therefore be registered by the original yaw canal. It will consequently feel like a yaw movement. In aviation terms, this means that a pilot should preferably not move his head during angular acceleration. If the pilot indeed moves his head and experiences a pitch-up sensation in a horizontal turn for instance, a logical impulsive reaction will be to lower the nose of the aircraft.

The otolith organs
The otolith organs make up the other part of the balance organ. They detect linear acceleration. The otolith organs send a signal indicating linear acceleration when the accelerating force (in fact the reaction force to the latter) causes a number of crystals to move in a gelatinous layer. The otolith organs are positioned both vertically and horizontally in the balance organ.

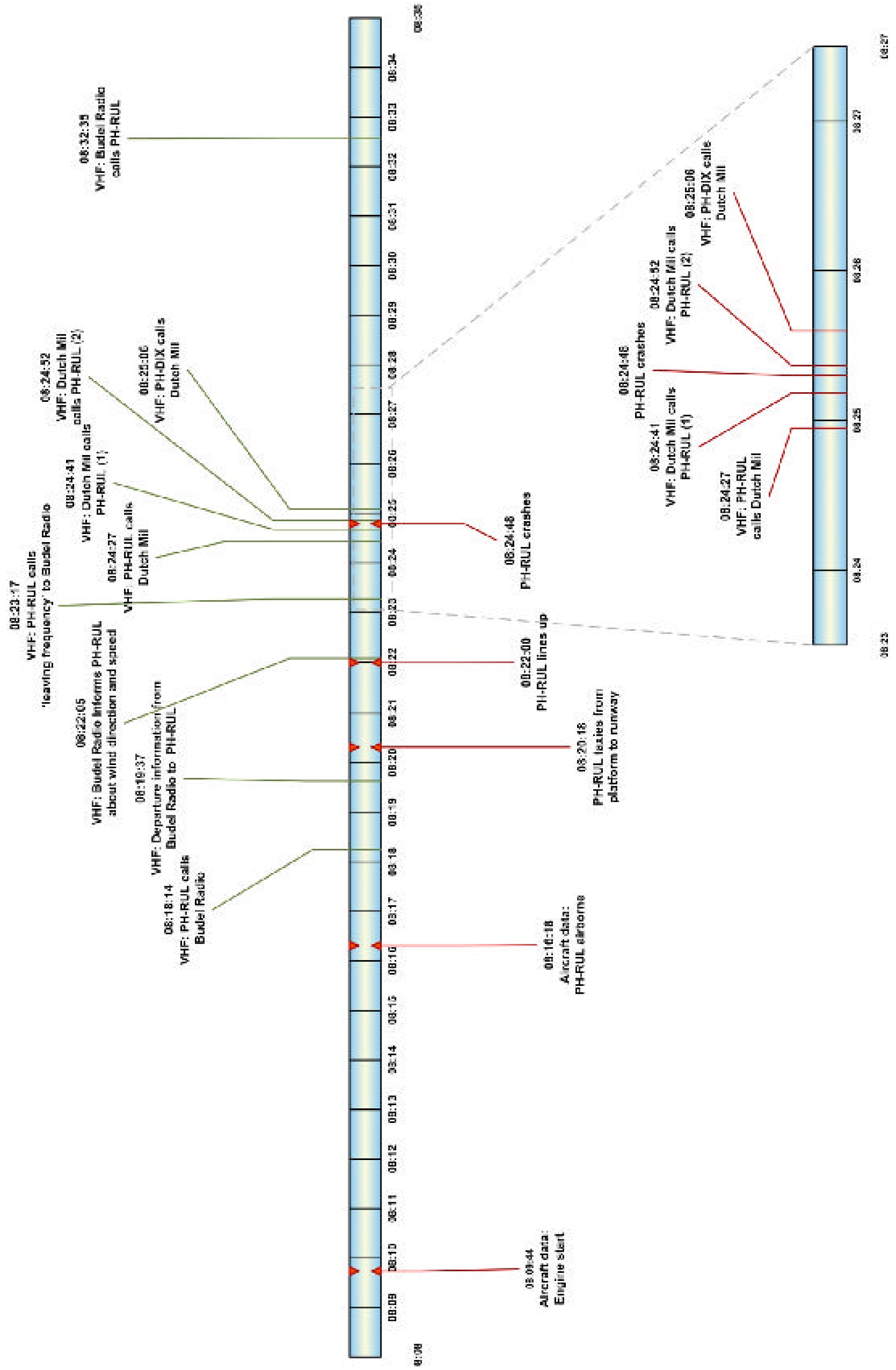
If your head is held upright the force of gravity will pull the crystals. The crystals will not move and this therefore means that your head is in an upright position. If you tilt your head forward or backward, the force of gravity will continue to point downward and will cause the crystals in the gelatinous layer to move. The degree of movement is a measure for the position of the head relative to gravity. The position of the head is also confirmed by the activation of the groups of muscles during such head movements, such as the neck muscles. When bending forward or backward from the hips the otolith organs will move as well but other groups of muscles will be engaged.

Interaction usually occurs between the balance organ, muscular sensation and the eyes. For example, the semicircular canals also control eye movements. If a person turns around a few times and then stops, the yaw canal will continue to control the eyes for a while. These involuntary eye movements are also referred to as 'nystagmus'.

In aviation, other accelerating forces are at work in addition to the usual acceleration caused by the force of gravity. An example is acceleration during a take-off or a touch-and-go landing. An accelerating force pushes the aircraft forward. The opposite reaction force pushes you backward into the seat, causing the crystals in the otolith organs to move backward as well. The position of the crystals during acceleration is the same as when the head is tilted backward. The big difference is that no muscular activity takes place. This is therefore interpreted as a backward movement of the whole body, in other words as a high aircraft nose position. This therefore means that horizontal linear acceleration gives the illusion of a high nose position, whereas a horizontal delay which will create the illusion of a low nose position. This is referred to as the 'G excess' illusion.

A particular form of the G excess illusion and the resulting 'overbank' (too much slope) may occur if the head is held at right angles to the direction of the aircraft in a turn and the pilot looks at the centre of the turn flown. The G force that occurs in the turn will more or less follow the otolith organs and the crystals will consequently move backward. This causes a pitch-up sensation in relation to the head. Because the head is positioned at right angles to the direction of the aircraft, this sensation is interpreted as a rollout sensation (so, a pitch-up illusion for the head). Because the pilot does not want to roll out (which in reality the aircraft is not doing anyway), he is inclined to compensate for the false illusion of rollout by banking the aircraft. The pilot in fact overbanks the aircraft but fails to assume the accompanying higher nose position of the aircraft. The aerodynamic forces on the aircraft are no longer in equilibrium. The aircraft will soon point its nose downward as a result and will rapidly lose height.

Appendix B


08:08:44
Aircraft data:
Engine start
08:16:18
Aircraft data:
PH-RUL airborne
08:18:14
VHF: PH-RUL calls
Budel Radio
08:19:37
VHF: Departure information from
Budel Radio to PH-RUL
08:20:18
PH-RUL taxies from
platform to runway
08:22:00
PH-RUL lines up
08:22:05
VHF: Budel Radio informs PH-RUL
about wind direction and speed
08:23:17
VHF: PH-RUL calls
'leaving frequency' to Budel Radio
08:24:27
VHF: PH-RUL calls
Dutch Mil
08:24:41
VHF: Dutch Mil calls
PH-RUL (1)
08:24:48
PH-RUL crashes
08:24:52
VHF: Dutch Mil
calls PH-RUL (2)
08:25:06
VHF: PH-DIX calls
Dutch Mil
08:32:35
VHF: Budel Radio
calls PH-RUL

Appendix C

Remarks that have not been amended.

The draft report was sent to Pilatus Aircraft and the relatives of the pilot to check the draft report for any inaccuracies or ambiguities. Their remarks are incorporated in the report, remarks which were not adopted are listed below including the Boards considerations.

Pilatus		
Page	*Remark*	*Consideration of the Safety Board*
10, paragraph 2	Pilatus would like to add the following statement regarding the pilot's training at Pilatus: "Due to the absence of a JAR/FCL instrument rating in the pilot's Dutch license and his lack of skill in flying under IMC conditions, his PC-12/47E training was limited to "VFR only"."	The contents of the training are described sufficiently in the paragraph. The reason why items whether or not are trained, is less relevant.
12, paragraph 2	Pilatus questions whether the considerable amount of 38 different publicized departure procedures (SID's) for Budel Airport should be mentioned in this section of the report, as they could also contribute to the workload of the pilot.	The amount of standard instrument departures of Budel Airport is considered less relevant in relation to this accident. The pilot was instructed to fly direct to OSGOS.
13, paragraph 3	Considering the marginal weather condition at the time of the takeoff Pilatus proposes to change the sentence "The flight would initially commence as a VFR flight." to "The flight would initially commence as a VFR flight, which actually was not feasible considering the weather conditions.	This remark does not belong in the communication paragraph. Besides, according to the weather information, the weather was marginal but met the VFR-criteria. (See page 20)
16, paragraph 6	Considering the small track in the silage pile the bank angle appeared to be quite high. Pilatus proposes to state this accordingly.	It is obvious that the aircraft banked to the right. The extent of the bank angle is not to be determined by means of the track in the silage pile.
19, paragraph 3	Again it should be highlighted here that this further training was only done for VFR conditions and not on IFR/IMC, which were the actual condition at the time of the accident. Therefore it should be stated that the pilot did not fulfill those additional requirements for IFR/IMC. Propose the state this in the report accordingly.	It is described sufficiently in the report that the pilot was trained for his VFR-rating. However, the pilots had some experience in flying in IMC-conditions.
20, paragraph 5	The large amount of SID's for Budel airport could also contribute to an incorrect FMS programming. Pilatus proposes to address this in the report.	See the reaction on the remark of page 11.
20, paragraph 8	Considering the short time and the resulting workload at this point Pilatus would like to propose that most likely no proper transition from VMC to IMC took place.	It is described sufficiently on page 20 and 21 that the transition from VFR to IFR took place on a higher altitude as required and that the ircraft was already flying in the clouds when the call to Dutch Mil was made.

25, three bullits	An average trained pilot would have managed this situation and the resulting workload without a problem and without the need of a second pilot. Therefore Pilatus proposes to reconsider or delete this statement as the training is covered in the following bullet point in the report. Alternatively the following wording could be used: "Inability of the pilot to cope with the increased workload." Pilatus would like to highlight that all certification flying of the Pilatus PC-12 aircraft was performed considering single pilot operation and a switched-off autopilot. This included flying in IMC and natural icing conditions. The workload was always within acceptable limits.	According to the Safety Board it is likely that the disengagement of the auto pilot causes a higher workload for the pilot. This workload can be handled better by two pilots than by one pilot.

Relatives of the pilot (text summarized)		
	Only the exclusion of a medical cause can be proved, the other two possibilities, technical and human factors, are based on hypothesis and are not proved by evidence since the aircraft was destroyed and data was almost not usable.	The conclusion that no univocal cause could be found is correct and nothing could be excluded. However, the Safety Board is of the opinion that spatial disorientation is the most likely cause in relation to the factual information.
	The conclusion that a technical cause was not likely because the aircraft was quite new, is wrong.	Considering the fact that the aircraft was quite new; the required 100-hour inspection had been performed and the fact that the technical administration showed that the performed actions had no relation with the steering or navigation of the aircraft, a technical cause is not likely. However, it can not be ruled out completely.
	Also human failing as cause is not proved in the report. Nobody can tell what happened in the cockpit just before impact, only assumptions are made.	See the first item. Besides, in the report it is called human factors and not human failing.
	Mentioning spatial disorientation as main cause, is also an assumption. The mentioned contributing factors are also assumptions: • It can not be proved why the auto pilot was disengaged by the system; • Also the high workload is an assumption because the pilot sounded cal and in control; • The lack of training and experience. The TBM is also a complex aircraft and the Eurocopter and Robinson helicopters too. Unusual situations happened during flights in these aircraft too. Besides the pilot had complementary training for the PC-12 at Simcom in the USA. The pilots flying hours in helicopters were not mentioned in the report.	The most important finding was that the auto pilot was desengaged by the system shortly after take off. The reason why remained unclear but was less relevant. The voice of the pilot sounded calm and no emergecy call was made, that could be an indication that the pilot was not aware of his situation. As stated in the report, the pilot received several training in flying the aircraft. Investigation revealed that he had a lack of experience in flying the aircraft single pilot in actual IMC conditions. The report stated that his experience as helicopter and MLA-pilot were not take into account because these hours were not known by the investigators and the operation of these type of aircraft is quite different that the operation of a Pilatus PC-12.