Norwegian Safety Investigation Authority

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REPORT AVIATION 2023/02

Air accident 8 km west-northwest of Larvik in Vestfold og Telemark County, Norway on 23 November 2021 involving a Diamond DA 42 NG, LN-PFM, operated by Pilot Flight Academy

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The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving aviation safety.

The object of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to issue safety recommendations if relevant. It is not the NSIA's task to apportion blame or liability under criminal or civil law.

This report should not be used for purposes other than preventive aviation safety work.

Photo: Pilot Flight Academy

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Aviation accident report

Table 1: Data

Type of aircraft:	Diamond Aircraft Industries GmbH DA 42 NG
Nationality and registration:	Norwegian, LN-PFM
Owner:	Sky Management AS, Notodden, Norway
Operator:	Pilot Flight Academy, Sandefjord, Norway
Crew:	2 (instructor/pilot in command and student)
Passengers:	1
Location:	Woodland area in Askedalsåsane 8 km west-northwest of Larvik in Vestfold og Telemark county (N 59.063 E 009.888)
Time of accident:	Tuesday 23 November 2021, estimated time 09:10:26

All times given in this report are local times (UTC + 1 hour) unless otherwise stated.

Notification

At 0927 hrs on Tuesday 23 November 2021, the Norwegian Safety Investigation Authority (NSIA) was notified by the air traffic service at Sandefjord Airport Torp of an accident involving one of Pilot Flight Academy's training aircraft. Smoke had been observed rising from an area near Bommestad, close to where the E18 road crosses the Numedalslågen river at Larvik. The observation proved to be unrelated to the accident. The scene of the accident was later described as being in the vicinity of Tvedalen in the Helgeroa 1 training area. It was established that three people had died and three accident investigators travelled to the site of the accident, arriving slightly before 1400 hrs on the same day.

In accordance with ICAO Annex 13 Aircraft Accident and Incident Investigation, the NSIA informed the investigating authorities in the state of manufacture of the airplane and propellers, respectively: the Federal Investigation Authority in Austria and the Federal Bureau of Aircraft Accidents Investigation (Bundesstelle für Flugunfalluntersuchung – BFU) in Germany. The investigating authorities appointed accredited representatives who assisted during the investigation. The European Aviation Safety Agency (EASA) and the Civil Aviation Authority (CAA) Norway were also notified.

Summary

On Tuesday 23 November 2021, the airplane LN-PFM went out of control and crashed in hilly woodland in Askedalsåsane in Larvik community, Norway. All three on board died instantly.

The accident occurred during instructions on multi-engine piston aircraft (MEP). A student from Pilot Flight Academy had his first instruction flight in a twin-engine DA 42 NG-type airplane.

Airwork training was conducted at an altitude of about 3,600 ft above ground level (AGL) in the Helgeroa 1 training area. Besides the instructor and the student, a fellow student was seated in the back seat. Approximately 32 minutes into the flight, while practising slow-speed flight with the landing gear and flaps extended (landing configuration), the airplane went out of control and spun into the ground.

The airplane was destroyed during impact and an intense fire broke out. The wreckage was almost completely consumed by the fire or destroyed by the heat, and it was not possible to extract stored electronic data from the wreckage. One witness saw a segment of the accident sequense. The investigation has largely been based on available radar data, information from the flight school and examination of the wreckage and the accident site. The NSIA has found no failures with the aircraft that could explain why the airplane went out of control. However, technical failures cannot be excluded.

The airplane type was approved for training purposes and the school’s training program was approved by CAA Norway. The instructor held valid licenses to act as an instructor during the flight. The weather was well-suited for the instruction flight in question and is therefore not a factor in the accident.

The NSIA has investigated several possible scenarios, but it has not been possible to establish an unequivocal explanation as to why the airplane went out of control and started to spin. Like other multi-engine aircraft, the aircraft type is not approved for spins. In general, multi-engine aircraft could be difficult to get out of a spin if they inadvertently entered a spin.

After the accident, the flight school has taken several steps to improve safety.

Based on the investigation, the NSIA issues one safety recommendation.

1. Factual information

1. Factual information

1.1 History of the flight

1.1.1 INTRODUCTION

The accident occurred during an instruction flight. The student had completed phases 1–3 of his integrated Airline Transport Pilot (ATP (A)) training in the USA and had started phase 4[1] at Pilot Flight Academy (PFA) in Norway. Between 8 October and 1 November 2021, the student had completed a total of 18 hours of instruction in a Diamond DA 42 NG simulator.[2] The student passed a scheduled progress check on 1 November and was ready to start flying the DA 42 NG.

PFA did not record students' times of arrival at the flight school. At what time in the morning the student arrived on the day of the accident is therefore unknown. A fellow student arriving early in the morning reported meeting the student at 0630 hrs. The fellow student described the student as being excited and a little stressed. The student was to fly lesson 4.1, and this was his first flight in a twin-engine airplane and his first flight in Norway. Even if he had flown the airplane type in a simulator, there were some new factors to consider in preparing for a real flight. The two of them ended up sitting next to each other during the planning. The fellow student, who had completed more of the training programme, answered some questions, including about how to check the airplane's fuel level and how to complete the operational flight plan.

After half an hour, the student had to leave to meet up with the instructor to review the planned flight. What the two of them talked about in preparation for the flight remains unknown, but, after a while, the instructor and student proceeded to the hangar and conducted a pre-flight check of LN-PFM together. At the same time, the fellow student was conducting a pre-flight check of LN-PFN, another airplane of the same type. In order to avoid opening the hangar doors several times and letting in cold air unnecessarily, both aircraft were moved outside at the same time. Video recordings from the hangar show that LN-PFM was taken out of the hangar at 0744 hrs.

Before each flight, the crew are required to leave three documents behind on a shelf at the school: a weight and balance form, an operational flight plan and a checklist. The checklist comprises items to be checked during preparation for a flight, and it must be signed by both the student and the instructor. None of these documents were found on the shelf. The NSIA assumes that the documents were brought into the airplane and consumed by fire at the accident site.

Because of a high number of instruction flights at Sandefjord Airport Torp (ENTO), the air traffic service and the flight school had jointly developed a system for allocating departure times. For the relevant LN-PFM flight, the instructor initially requested departure at 0800 hrs. When it became clear that they would have to delay their departure, he requested that departure be postponed until 0820 hrs. According to PFA, a standard preparation time of one hour was set aside before each flight. In addition, an extra 30 minutes were to be spent on preparations before the first flight of the day. Among other things, this was meant to cover the time it took to pull the airplane out of the hangar. The extra 30 minutes were mistakenly not included for the accident flight, and, according to PFA, this may have been the cause of the delay.

The student got into the left seat in the cockpit, which is normally occupied by the pilot in command. The instructor settled in the right seat. The instructor was the pilot in command during

[1] The phase that allows the student to fly multi-engine aircraft (ME Class Rating). See also chapter 1.17.2.21.17.2.1
[2] The simulator is not a full-flight simulator.

the flight. Another fellow student, who had attended the flight school in the USA together with the student flying, was next in line to fly lesson 4.1. He was allowed to join the flight, so as to be better prepared for what would be required of him. The fellow student settled in the passenger seat at the rear and is referred to as the passenger in the rest of this report.

The instructor and student probably carried one flight bag each, and these are likely to have been placed in the rear seat and rear luggage space, respectively. They also brought with them a bag containing flight operating manuals and a quick reference handbook (QRH), among other things.

1.1.2 THE FLIGHT

The following information is based on radar data and radio communication data from Avinor, Automatic Dependent Surveillance-Broadcast (ADS-B) data from Flightradar24 and Avinor, and Enhanced Surveillance (EHS) data from Avinor (see Figure 1 and Figure 2). LN-PFM used the call sign P71M, but the airplane's ADS-B transmitter was not set accordingly; it incorrectly transmitted the call sign P620M.

P71M took off from runway 18 at Torp at 0837 hrs, heading southwest towards the Helgeroa 1 training area. The airplane climbed to 2,000 ft, whereafter the student requested clearance from the air traffic service (Farris Approach on frequency 134,050 MHz) to enter Farris TMA.[3] The air traffic service granted clearance to fly to Helgeroa 1 up to 5,000 ft.[4] The student acknowledged receipt of the clearance at 0842 hrs.

On entering Helgeroa 1, P71M first flew towards the periphery of the area. The airplane then made several turns, using both moderate bank angles and bank angles of up to 60°. Two slow flight sequences were also completed.

During the period that P71M was in Helgeroa 1, the air traffic service made contact to inform of two other aircraft passing through the area. The student responded clearly and accurately to these calls. The final communication about these aircraft took place at 0852 hrs, which was the last time that anybody was in contact with P71M.

After completing a ninth turn, the airplane continued on a heading of approximately 200°. During the next 30 seconds, the speed dropped gradually from 123 to 65 knots indicated airspeed (KIAS). The aircraft descended marginally, from 4,010 to 3,960 ft, during the same period. The airplane then rolled 7° to the left at the same time as the rate of descend increased.

Because of a limited amount of available data, it is not possible to describe accurately what happened next. Available data show that the airplane descended rapidly. After 8 seconds, the descent stabilized at approximately 8,000 ft/min (40 m/sec). Records show that the airspeed was almost stable at 100 KIAS. Data were registered down to an altitude of approximately 775 ft AMSL, corresponding to approximately 127 m above ground level (AGL).

At 0913 hrs, when another aircraft requested clearance to enter Farris TMA, the air traffic controller realised that P71M had disappeared from the radar. The traffic controller called P71M asking '*Pilot71M,…. your position?'*. When P71M failed to respond to repeated calls, the traffic controller checked with other air traffic service units and asked other aircraft in the area to look out for P71M. At approximately 0922 hrs, it was believed that P71M had probably crashed. A helicopter approaching the area was asked to check the observation of smoke near Tvedalen. At 0945 hrs, the helicopter crew confirmed that they were flying over the crash site. At that time, one of the

[3] TMA – terminal manoeuvring area
[4] AMSL – above mean sea level

Royal Norwegian Air Force's Sea King SAR helicopters (Saver 60) was already on its way to the crash site passing Tønsberg.

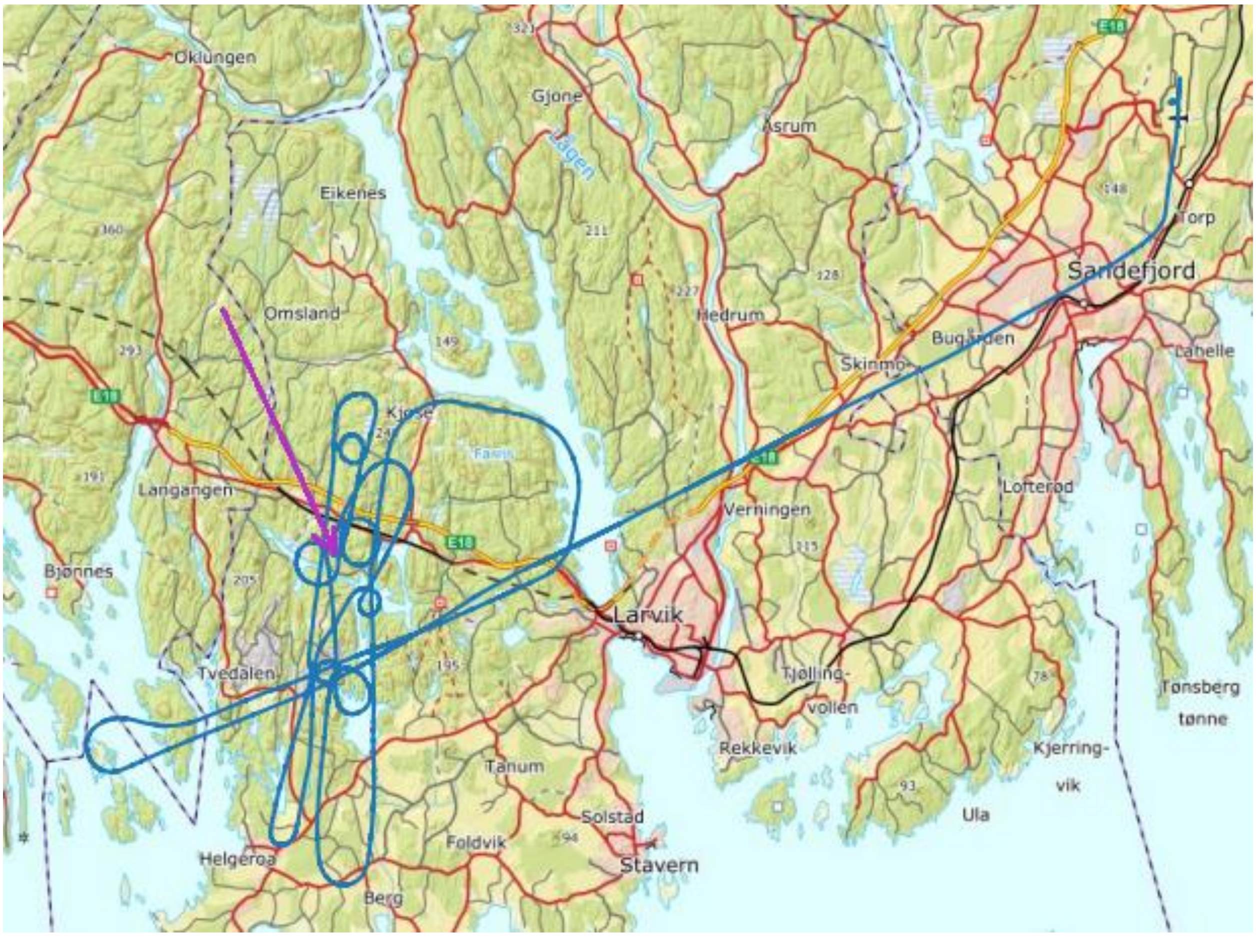

Figure 1: LN-PFM's entire flight from Sandefjord Airport Torp to the crash site. The magenta arrow points towards the accident site. Source: Avinor/Flightradar24/© The Norwegian Mapping Authority/NSIA

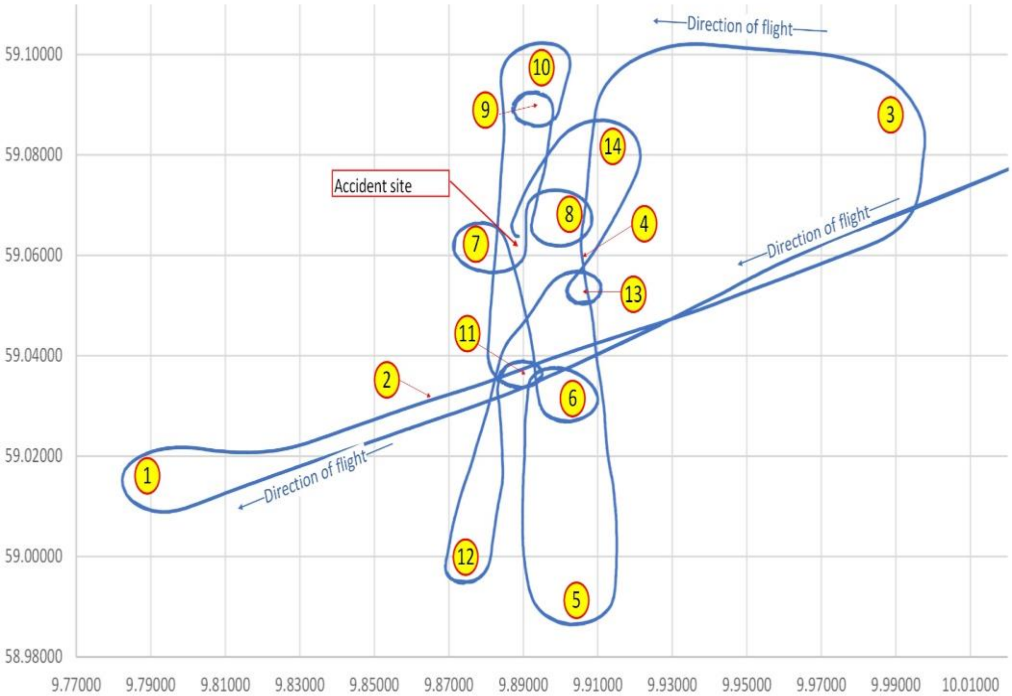

Figure 2: The airplane's manoeuvres during the final 28 minutes or so of the flight in the Helgeroa 1 training area. Manoeuvres marked with a yellow circle are explained below. The red rectangle indicates the accident site. Source: Avinor/Flightradar24/NSIA

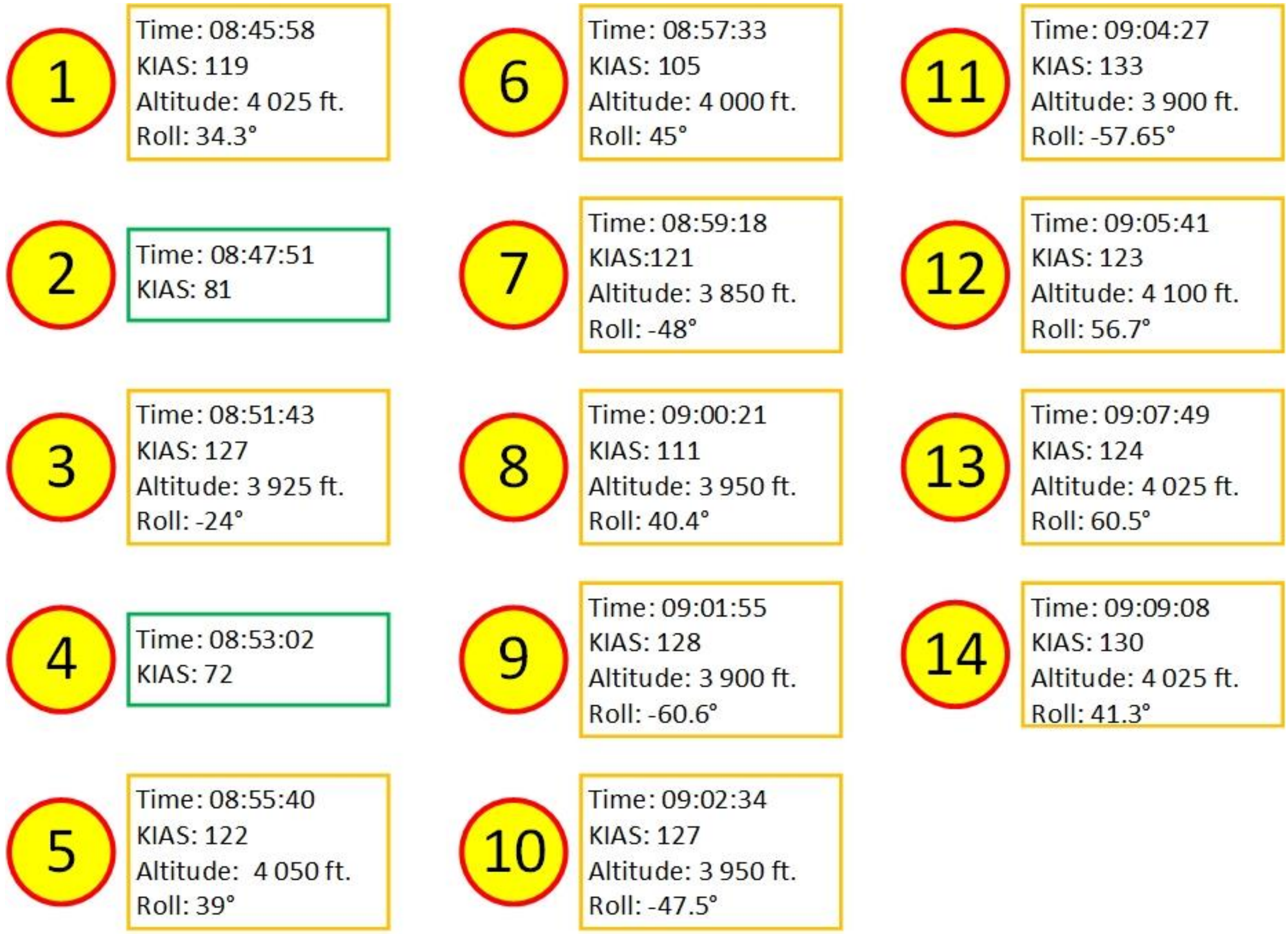

Figure 3: Indicated airspeed (KIAS), altitude above mean sea level (AMSL) and roll angle (positive values indicate rolling to the left while negative values indicate rolling to the right) at the points presented graphically in the previous figure. Source: Avinor/Flightradar24/NSIA

1.1.3 WITNESS

A witness sat waiting inside a dump truck at a quarry 2 km southwest of the crash site. He was looking towards the northeast and suddenly saw an airplane heading straight towards the ground. It was rotating in a spiral-like pattern and, at first, he thought the pilot must be very fearless to be flying an airplane in such a way. When the airplane disappeared behind a pile of gravel, he kept looking to see whether it would reappear. He then drove higher up to get a better view. From there, he observed a column of smoke rising from a position that could be related to where he had last observed the airplane. According to the witness's phone log, he called the 112 emergency number at 0919 hrs and reported the accident.

The witness has explained to the NSIA that he observed the airplane for an estimated 4–5 seconds and that it probably rotated 4–5 times. When he used a model airplane to demonstrate the rotational movement to the NSIA, he indicated a somewhat slower rate of rotation. When asked directly by the NSIA, he thought that the airplane descended in a spiral-like pattern and that it did not roll around its longitudinal axis. He found exact recollection difficult, but believed that it rotated clockwise viewed from above.

The NSIA accompanied the witness into the dump truck at the place from which he had seen the airplane. From there, the place on the sky where he estimated having first seen the airplane and the place where it had disappeared from view were documented using an inclinometer. He first saw the airplane approximately 15° above the horizon and it had disappeared from view 5.4° above the horizon. The witness had observed the airplane from a position approximately 125 AMSL. That was 16 metres higher than the crash site, and it means that he first saw the airplane approximately 533 metres (1,749 ft) above the crash site and that he lost sight of it approximately 205 metres (673 ft) above the crash site.

1.2 Injuries to persons

Table 2: Personal injuries

Injuries	Crew	Passengers	Others
Fatal	2	1	
Serious			
Minor/none			

1.3 Damage to aircraft

The aircraft was destroyed; see chapter 1.12.2 for a more detailed description.

1.4 Other damage

Damage to some small trees and fire damage to the ground over a limited area (see Figure 12).

1.5 Personnel information

1.5.1 FLIGHT COMMANDER/INSTRUCTOR

The 30-year-old male commander started his aviation career by attending a bachelor programme at the University of Tromsø during the period 2014–2017. The commander was issued a commercial pilot licence (CPL(A)) on 1 July 2017. He then gained temporary employment at Pilot Flight Academy on 16 April 2018. At the school, he received full training to become an instructor at PFA including one hour of theoretical instruction in spins[5] and completed a 45-minute instruction flight in an American Champion 8KCAB. The instruction was given on 30 June 2018 and consisted of slow flight, stalling, spinning and recovery after a fully developed spin. The commander received further standardization- and safety training as a flight instructor in August 2018.

The flight commander passed a skill test for privileges to fly multi-engine aircraft in connection with his studies at the University of Tromsø. He renewed these privileges by performing a Proficiency Check (PC) on the Diamond DA 42 NG on 21 March 2019. The multi-engine airplane and instrument flying privileges were further renewed on 12 March 2020 and 29 March 2021 (expiring on 31 March 2022). Examination for privileges to carry out instruction on multi-engine aircraft was passed on 24 May 2021. Examination for privileges to conduct instruction for instrument ratings was passed 15 July 2021. The last two privileges were valid until 30 September 2024.

The commander held a Class 1 medical certificate without restrictions, valid until 28 May 2022.

According to Pilot Flight Academy, the flight commander had given a total of 408 hours of in-flight instruction and 135 hours of simulator instruction. This included 61:20 hours of instruction on the DA 42. The day before the accident he had given 2:35 hours of instruction on the DA 42 NG. The flight school's internal investigation team interviewed four students whom the flight commander had instructed in lessons 4.1–4.3. It was concluded that he was considered skilled and knowledgeable. No information emerged to indicate that he had breached any procedures in the school's training

[5] *Spinning is described in more detail in chapter 1.18.3.*

manual. Experience differed, however, as to whether the commander demonstrated a manoeuvrer before he let the student try, or let the student attempt the manoeuvrer as soon as he had described how it should be done. According to PFA, the flight commander had participated in the mandatory standardisation meetings arranged by the flight school.

The flight commander's work schedule consisted of five consecutive working days followed by four days off. He was on the second working day of the schedule when the accident occurred.

None of those who spoke with the flight commander in the morning before the accident noticed anything out of the ordinary.

Table 3: Flying experience, commander

Flight time (hours)	**All types**	**On type**
Last 24 hours	03:10	03:10
Last 3 days	03:10	03:10
Last 30 days	11:20	08:00
Last 90 days	79:50	48:25
Total	750:25	85:30

1.5.2 THE STUDENT

The student, a 21 year-old male, was admitted to the integrated Aline Transport Pilot (ATP(A)) training course at Pilot Flight Academy in spring 2019. Pilot Flight Academy had signed an agreement with US Aviation Academy (USAA) in Denton, Texas, where the first three phases of the training programme had been completed. On completing the training at USAA, the student had flown a total of 91:15 hours in a Cessna 152[6] and he had qualifications that closely resembled what is required for a European private pilot licence (PPL(A)). The student belonged to the fifth group of students at Pilot Flight Academy who had completed the three first phases of their training at USAA.

On his return to Norway, the student started on the fourth phase of the training programme at Pilot Flight Academy. Initially, he had 18 hours of instruction in a DA 42 NG simulator between 14 and 27 October 2021. The student had eight different instructors during these lessons (4.4–4.11). According to the programme, this included "*Upset recoveries and Recognition"* and "*Recovery from incipient and full stalls"*. On 1 November, the student passed a scheduled progress check (lesson 4.11) and was ready to start flying the DA-42 NG (lessons 4.1–4.3). PFA's internal investigation team has interviewed four of the flight instructors who instructed the student. None of them spoke of the student in negative terms, and he had shown normal progression.

The student held a Class 1 medical certificate valid until 16 June 2022. The medical certificate contained the restriction *'VDL Valid only with correction for defective distant vision'.*[7]

To people who spoke with the student in the morning before departure, he came across as excited and a little stressed, but hardly more so than could be expected before a first flight on a new airplane type.

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[6] *A single-engine airplane.*
[7] *Required use of glasses or contact lenses.*

Table 4: Flying experience, student

Flight time (hours)	All types	On type
Last 24 hours	0:33	0:33
Last 3 days	0:33	0:33
Last 30 days	0:33	0:33
Last 90 days	29:25	0:33
Total	91:48	0:33[8]

1.6 Aircraft information

1.6.1 IN GENERAL

Diamond DA 42 is a light twin-engine airplane with four seats. It is a low wing airplane mainly made of carbon composite, with retractable landing gear and a T-tail. The type was developed by Diamond Aircraft Industries in Austria. DA 42 Twin Star, the first version of the airplane, was granted type approval by EASA in July 2005. Initially, the DA 42 had two diesel engines manufactured by Thielert, but when that company went bankrupt, the airplane type was equipped with two Austro Engine E4 diesel engines and designated DA 42 NG. The airplane type is equipped with a Garmin G1000 NXi avionic system and a 3-axis autopilot.

More than 1,000 DA 42 airplanes have been manufactured and it has become a popular training aircraft at many flight schools.

CAA Norway approved Pilot Flight Academy's use of DA 42 NG as a training aircraft in 2014.

1.6.2 DATA FOR LN-PFM

Type:	Diamond DA 42 NG
Serial number:	42 N255
Year of manufacture:	2020
First registered in Norway:	22 October 2020
Put into service by PFA:	November 2020
ARC[9]:	Valid until 26 October 2022
Aircraft total time:	1,381:28 hours
Length:	8.56 metres
Wing span:	13.55 metres
Maximum take-off mass:	1,999 kg

[8] *Additionally, the student had 18 hours instruction in a DA 42 NG simulator.*
[9] *Airworthiness Review Certificate, review of the airplane's maintenance documentation.*

Engines:	2 Austro Engine E4-C
Serial number, left engine:	05055
Serial number, right engine:	05036
Propellers:	2 MT-Propeller MTV-6-R-C-F/CF190-69
Serial number, left propeller:	200093
Serial number, right propeller:	200094
Types of fuel:	Jet A-1

1.6.3 TYPE CERTIFICATION

Diamond DA 42 NG was granted type certification by EASA on 17 January 2008 in accordance with the design provisions in JAR 23 Amendment 1. The certification is documented in TCDS No EASA.A.005.

The certification requirements in JAR/CS 23.201 concern airplane stall characteristics. According to the manufacturer Diamond Aircraft Industries, the DA 42's stall characteristics have proved to be in line with those general requirements on test flights during type certification. The DA 42's stall characteristics were tested in relation to the requirements in JAR/CS 23.201 as well as JAR/CS 23.203. The following results were achieved in tests with the centre of gravity at the aft limit:

- Wings level stall: maximum roll 5–12°
- Turning flight stall: on standard entry, the airplane showed little roll variations
- Stall with loads exceeding 1 G: the airplane tended to recover (wings level) in right turns and sometimes ended up rolling left.

Diamond Aircraft Industries has furthermore stated that, at no time during the test flights did the airplane tend towards unsafe flight characteristics or spinning (see chapter 1.6.4.3). When testing the stall characteristics, the airplane gained a pitch-up attitude of 25° at 75% power from the engines. Furthermore, all the tests were conducted in coordinated flight, that is without skidding or slipping. No notable loss of altitude was recorded in connection with stalls.

1.6.4 FLIGHT CHARACTERISTICS

1.6.4.1 In general

Pilots interviewed by the NSIA have emphasised that the airplane's flight characteristics were generally good and predictable. It was explained, however, that the airplane type could bank steeply left if engine power was increased too abruptly during slow flight. It was therefore important to push both power levers forward slowly and simultaneously completing a slow flight sequence. When asked about the use of rudder trim, the chief flight instructor informed the NSIA that the airplane type often had to be flown with some left trim. Several instructors stated that they had to apply a lot of force to the rudder pedals, particularly if the airplane type was flown with asymmetric engine power.

1.6.4.2 Stalling

During slow flight, it is necessary to have a high angle of attack so as not to lose altitude. Stalling occurs if the angle of attack becomes too steep[10] so that the air flow over the wings separates and the lift is sharply reduced. Stall speed is the lowest speed at which the aircraft can maintain altitude without exceeding the critical angle of attack.

Airplanes are often equipped with a stall warning system, which issues an audio warning when a stall is imminent. The warning can also be referred to as a first indication. In most airplane types, a further increase in the angle of attack will give rise to aerodynamic vibrations/buffeting in the flight controls. This constitutes the final warning before the airplane stalls. Different airplane types have different stall characteristics, for example with respect to how abruptly the stall occurs, the degree of rudder authority and the tendency for wingdrop.

Diamond Aircraft's chief test pilot has informed the NSIA that the airplane's stall characteristics are generally good and predictable. The stall characteristics are milder when the centre of gravity is located close to the forward limit, and more demanding when the centre of gravity is close to the aft limit. The difference is less with a high take-off mass. A high mass will normally give milder stall characteristics. The use of flaps has a slight negative effect on the stall characteristics, while the position of the landing gear has little effect on the stall characteristics. In an accelerated stall, the airplane may abruptly roll the opposite way, but will regain normal flight if the stick pressure is relieved (the stick moved forward again).

According to the Airplane Flight Manual DA 42 NG section 5.3.4, an airplane with a mass of 1,900 kg at the forward centre of gravity limit will have the following stall speeds:

- 68 KIAS with flaps and landing gear retracted
- 62 KIAS with flaps and landing gear extended

Section 2.9 of the flight manual contains the following caution:

CAUTION

Aerobatics, spinning and flight maneuvers with more than 60° of bank are not permitted in the Normal Category. Stalling with asymmetric power or one engine inoperative is not permitted.

1.6.4.3 Spinning

The airplane is not certified for spins, as this is not required for multi-engine airplanes in the normal category (CS-23). According to the certification requirements (JAR/CS 23.221(a)), demonstration of spin characteristics is only required for single-engine airplanes. Diamond Aircraft Industries has not performed spins with the DA 42 and therefore has no data regarding the airplane's spin characteristics. Knowledge of the airplane type's spin characteristics is therefore largely based on theoretical calculations.

Diamond Aircraft Industries' chief test pilot stated that he believed the spin characteristics of DA 40 and DA 42 to be somewhat similar. These airplanes have a lot in common even though the DA 40 has only one engine. Unless a stall with the DA 40 is interrupted, the airplane will often start to spin and, at the same time, oscillate (pitch up and down), possibly pitching up above the horizon before entering a stable spin after 2–3 revolutions. The NSIA forwarded data from the accident flight (see Figure 3 and Figure 25) to Diamond Aircraft. The test pilot believed that the wide variations in sink

[10] *Critical angle of attack*

rate, observed initially in the case of LN-PFM (see Figure 31), may have been such oscillations before the airplane entered a flat spin.

The procedure for spin recovery is described in section 3.12.6 of the flight manual:

CAUTION

Spin recovery has NOT been shown during certification as it is NOT required for this airplane category. The given recovery method is based on general experience!

CAUTION

Intentional spins are prohibited in this airplane. In the event a spin is encountered unintentionally, immediate recovery actions must be taken.
Single-engine stalling is not permitted.

CAUTION

Steps 1 to 4 must be carried out **immediately** and **simultaneously**.

1. POWER lever . . . . IDLE
2. Rudder . . . . full deflection against direction of spin
3. Elevator (control stick) . . . . fully forward
4. Ailerons . . . . neutral
5. FLAPS . . . . UP

When rotation has stopped:

6. Rudder . . . . neutral
7. Elevator (control stick) . . . . pull carefully
8. Return the airplane from a descending into a normal flight attitude. Do not exceed the 'never exceed speed', V_{NE} = 188 KIAS.

END OF CHECKLIST

A spin may occur so fast that there is no time to read a checklist. The content of the checklist must therefore be studied and learnt by heart. The flight school's Standard Operation Procedures (SOP) do not list this checklist as a memory item (see chapter 1.17.2.1). The management at Pilot Flight Academy was not sure how much emphasis individual instructors gave to studying the spin recovery checklist and to what extent the students were tested to demonstrate that they had learnt the checklist by heart.

1.6.4.4 Test flights with LN-PFM by Diamond Aircraft Industries

LN-PFM was test flown by Diamond Aircraft Industries on 27 April 2020 before it was approved and sold. On carrying out stall tests, the aircraft had a mass of 1,687 kg and the centre of gravity moment arm was 2.398 metres.[11] A level flight stall test with the landing gear fully extended, flaps in landing configuration (full flaps deployed – F2) and engines on idle resulted in a stall warning at 68 kt and stalling at 60 kt. During the test, control of the aircraft was maintained at a bank angle of 15°.

With a corresponding landing configuration, 30° banking (roll) and 75% engine power, the following values were recorded:

- A left turn resulted in a stall warning at 70 kt and stalling at 62 kt.

[11] *Low mass, with the centre of gravity close to the forward limit. The test flight thus represents a situation that was different from the one that prevailed when control of LN-PFM was lost.*

- A right turn resulted in a stall warning at 71 kt and stalling at 60 kt.

According to the test report, the airplane did not show tendencies to drop a wing (bank) during these tests. LN-PFM passed all stall tests without remarks.

1.6.5 FLIGHT CONTROLS

The airplane type has conventional control surfaces and can be operated from both sides of the cockpit. The elevator and ailerons are operated via steel rods. The rudder is operated via steel cables. The elevator has a variable elevator stop, which limits the angle to 13° up if engine power from both engines exceeds 20%. If the output from one engine is less than 20%, the elevator is limited to 15.5° up. The variable elevator stop was introduced on the basis of experience gathered during test flights in connection with certification of the airplane type. The system was designed to prevent the airplane from exceeding the recommended roll limit during an accelerated stall (at cruising speed) and was not designed to prevent deep stalling.

The airplane type is equipped with an audio stall warning system.

LN-PFM was equipped with an Electronic Stability and Protection System (ESP) offered as an optional part of the Garmin G1000 and autopilot installation. The system uses the autopilot servos to discourage the pilot from exceeding pitch, roll and speed when the autopilot is turned off. When the ESP is active, the system will provide progressive force feedback via the control stick should the airplane for example bank more than 45°. The system can be disabled via a menu on the airplane's multi-function displays (MDFs), but it will automatically activate the next time the Garmin G1000 is powered up. Alternately, the system can also temporarily be disabled by depressing the Control Wheel Steering (CWS) switch on the left stick or via the Autopilot Disconnect (AP DISC) on both sticks. According to PFA, it was not common practice to disable the ESP via the multi-function displays before slow flight sequences. This was not a standard operating procedure either (see chapter 1.17.2.1).

1.6.6 ENGINES

The engines were built by Austro Engine on the basis of a 2-litre four-cylinder diesel engine from Mercedes. Each engine is liquid-cooled with dual overhead camshafts and common rail fuel injection. The engine is also equipped with a turbocharger and intercooler. Each engine is controlled via an electronic engine control unit (EECU). Each EECU is operated by means of a switch (ENGINE MASTER) on the lower left side of the instrument panel. Each engine can output 123.5 kW (168 hp) at 3,880 rpm. An integrated gearbox reduces at a ratio of 1.69:1, resulting in a propeller speed of 2,300 rpm.

1.6.7 PROPELLERS

1.6.7.1 Introduction

The DA 42 NG is fitted out with two three-blade propellers manufactured by MT-Propeller Entwicklung GmbH. The propellers are connected to the engines via a gearbox. Blade angle is hydraulically controlled by oil pressure from the gearbox. Control is automatic via the engine's EECU and a governor connected to the gearbox (constant speed propeller system).

1.6.7.2 Detailed description

A section drawing of one of DA-42 NG's propellers is shown in Figure 4. The propeller consists of a hub (highlighted in blue in the drawing) and three blades retained in the hub using roller ball bearings. The blades are made of fibreglass-coated wood, and blade angle (pitch) is controlled by oil pressure. A pump in the reduction gearbox delivers a system pressure of 22 bar (320 psi). The pressure is controlled by the governor and acts on a piston (highlighted in green in the drawing). High oil pressure pushes the piston to the left in the drawing, which leads to a low blade angle (high rpm). A spring (2.9) installed in the front housing (2.1) tries to push the piston in the opposite direction (to the right in the drawing). This leads to a high blade angle (low rpm). The centrifugal twisting moment will tend to lower the blade angle. This effect increases with rotational speed. Weights fitted to the blades (6.0–6.6) counteract the centrifugal twisting moment, resulting in a higher blade angle (low rotational speed) if the rpm is increased.

When flying, the forces affecting blade angle will be balanced by the oil pressure resulting in the desired rpm. This is achieved in that the EECU controls the governor, which, in turn, controls the oil pressure. In the case of engine problems, the engine can be stopped and the propellers can be feathered. This can only be done if the ENGINE MASTER switch is turned off. That will stop the engine, the oil pressure will drop and the spring will push the piston to the right so that the propeller feathers to a blade angle of 80° ± 1°. Feathering reduces propeller drag to a minimum, enabling the airplane to continue the flight with one engine. Without feathering, the airplane will be very difficult to handle with only one engine in operation.

If power output and speed are low, the oil pressure can push the piston all the way to the left. A sleeve around the piston extension (2.5) will then stop against a collar in the front housing. This is referred to as ‘low pitch stop’ and corresponds to a blade angle of 13° ± 0.2°.

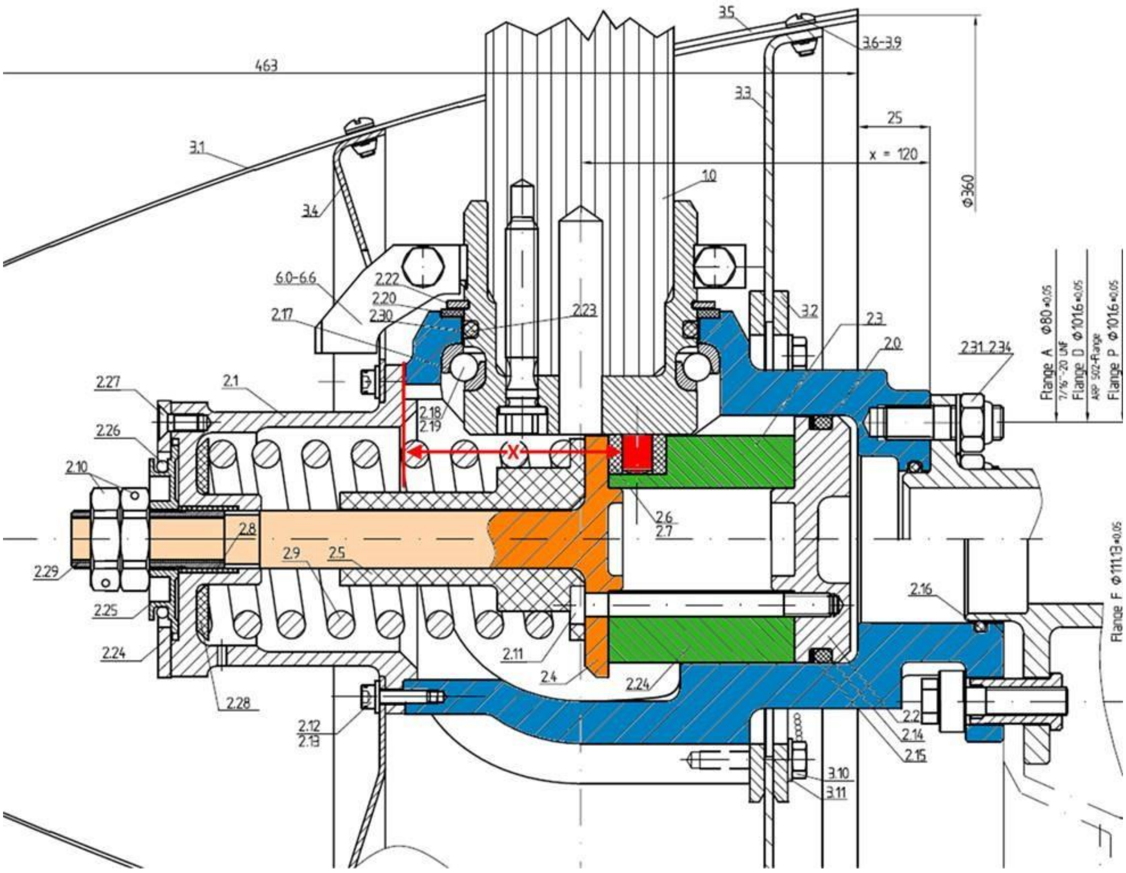

Figure 4: Section drawing of propeller. Source: MT-Propeller/NSIA

1.6.8 FUEL SYSTEM

As standard the airplane type has 98.4-litre of fuel in tanks in each wing. The fuel tanks are immediately outside the engines and normally feed the nearest engine. Tubes and valves between the tanks enable fuel transfer between the tanks and cross-feeding of fuel, for example from the left tank to the right engine. LN-PFM also had a 52-litre auxiliary tank in the space behind each engine. The auxiliary tanks do not have direct feed lines to the engines. An electric pump is used to transfer fuel from the auxiliary to the wing tanks. LN-PFM had a total fuel capacity of 300.8 litres, which includes the auxiliary tanks. A difference in fuel volume of up to 18.9 litres is allowed between the wing tanks. No limit has been defined for differences in content between the auxiliary tanks.

1.6.9 ICING PROTECTION

The aircraft was equipped with an anti-icing system, among other things to protect against icing on wing and tail surfaces. The system uses a fluid that is pressed out through small holes at the leading edge of the wing and tail surfaces. The fluid is stored in a tank in the forward luggage compartment. The tank can hold 30 litres. PFA's procedures state that the tank shall contain at least 22 litres at departure. The pilot who flew LN-PFM before the flight on which the accident occurred has told PFA that no anti-icing fluid was used on that flight and that the tank was full.

1.6.10 MAINTENANCE

1.6.10.1 Completed maintenance

The most recent maintenance inspection of the airplane was a 100-hour inspection carried out on 8 November 2021 when the aircraft total time was 1,296:20 hours. Such inspections largely consist of opening covers and conducting visual inspections. The inspection was carried out and signed for without remarks.

On 10 November 2021, it was entered in the maintenance log that a heating element in the stall warning sensor did not work. The whole sensor was replaced. The aircraft total time was then 1,304:25 hours.

On 16 November 2021, it was entered in the maintenance log that the right fuel probe[12] showed incorrect values. Troubleshooting made it clear that the probe had to be replaced. In order to do so, the right wing had to be removed. A new probe was installed and the wing reinstalled. On 19 November 2021, a licensed aircraft technician from Flyteknisk Notodden AS signed for completion of the work (WO21-689). The aircraft total time was then 1,347:15 hours. On completion of the work, the airplane was test flown on 19 November 2021 with reference to section 05-28-92 of the aircraft maintenance manual (AMM). The flight, which lasted for 10 minutes, included two landings.

Between the maintenance work on 19 November and 23 November 2021, LN-PFM made 18 flights. No more failures were entered in the aircraft log during that period, and maintenance was limited to daily pre-flight checks. The aircraft log was routinely carried on board during flight and relevant pages were copied following the last flight of the day. No formal documentation is therefore available of the pre-flight check, or of fuel and oil levels. PFA has stated, however, that they were not aware of any faults in the aircraft prior to departure on the morning of 23 November.

1.6.10.2 Reliability of stall warning system

When asked by the NSIA, Pilot Flight Academy reported having had nine instances of faults in the DA 42 NG's stall warning system between 2017 and spring 2022. Four of these instances involved a faulty heating element in the stall sensor. A faulty heating element does not mean that the sensor stops working, but it can freeze up when flying in icing conditions.

1.6.11 MASS AND BALANCE

The NSIA has calculated the mass and centre of gravity of LN-PFM at the time of the accident. The calculations are based on information from the flight manual, the aircraft weight report, and

[12] *Fuel Probe P/N D60-2827-13-00_1*

estimated fuel mass. The fuel mass was estimated based on a fuel consumption of 25 litres of fuel during the 44 minutes that passed from departure until it crashed. The weight of the three occupants is based on weights as recorded in connection with regular aero-medical examinations. The mass of the luggage and position of various standard equipment inside the airplane have been calculated on the basis of information from the flight school and next of kin. It is assumed that there were two pilot bags on board, placed in the rear seat and aft luggage compartment, respectively.

Table 5: Data for mass and balance calculations

	Mass (kg)	Arm (m)	Moment (kgm)
Empty mass of LN-PFM	1,469	2.421	3,556.449
Cockpit crew (including clothes and headsets)	168	2.3	386.4
Passenger (including clothes and headset)	86	3.25	279.5
Luggage in passenger seat	10	3.25	32.5
Luggage in forward luggage compartment	2	0.6	1.2
Luggage in aft luggage compartment	9	3.89	35.01
Estimated fuel in main tanks (0.84 kg/l)	96	2.63	251.84
Fuel in auxiliary tank (0.84 kg/l)	84	3.2	268.8
Anti-icing fluid (1.1 kg/l)	33	1	33
	1,957	2.476	4,844.699

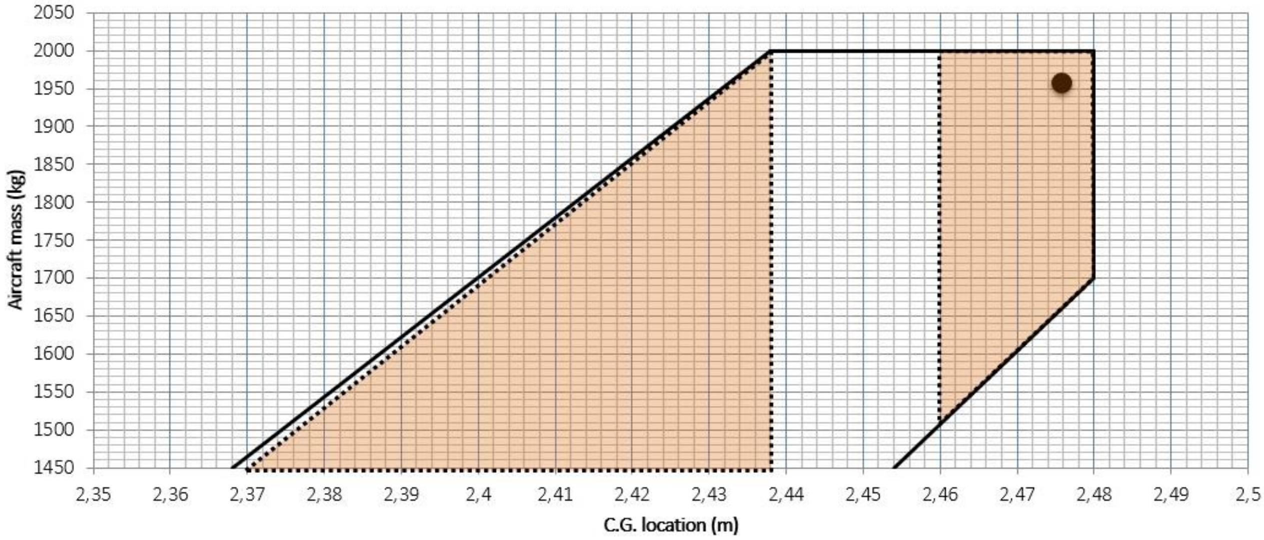

Figure 5: The figure shows the estimated centre of gravity at the time of the accident (black circle). Following the accident, the flight school has decided that certain exercises, including slow flight demonstrations (V_{MCA}) and full stalls, may only be conducted if the centre of gravity lies in the unhighlighted area between the dashed lines. Source: Pilot Flight Academy/NSIA

The calculations show that, at the time of the accident, the airplane's mass was 42 kg below the maximum take-off weight and that the centre of gravity was at 2.476 metres (arm). Given such a mass, the forward and aft centre of gravity limits were 2.434 metres (arm) and 2.48 metres (arm), respectively. This means that the aircraft was within its mass and balance limits when the accident occurred.

DA 42 NG has a relatively limited span between the forward and aft limit. During instruction flights without passengers in the rear seat, it may therefore be necessary to carry weights in the aft luggage compartment. According to PFA, the weights are collected and counted every day, so that nobody carries weights on a flight without being aware of it (see chapter 1.12.2).

1.7 Meteorological information[13]

1.7.1 REPORT FROM THE NORWEGIAN METEOROLOGICAL INSTITUTE[14]

The NSIA has obtained a report from the Norwegian Meteorological Institute concerning the weather situation in the Helgeroa/Tvedalen area on 23 November 2021. Some excerpts from the report are copied in below:

> ***The weather situation in general***
>
> *A low-pressure area in the Norwegian Sea with associated low-pressure fronts brought heavy precipitation to Trøndelag on the day. In combination with a high-pressure system near the British Isles, this pressure area generated a west-northwesterly wind field over southern Norway. This wind direction usually brings good weather to the East of Norway (leeward of the wind).*

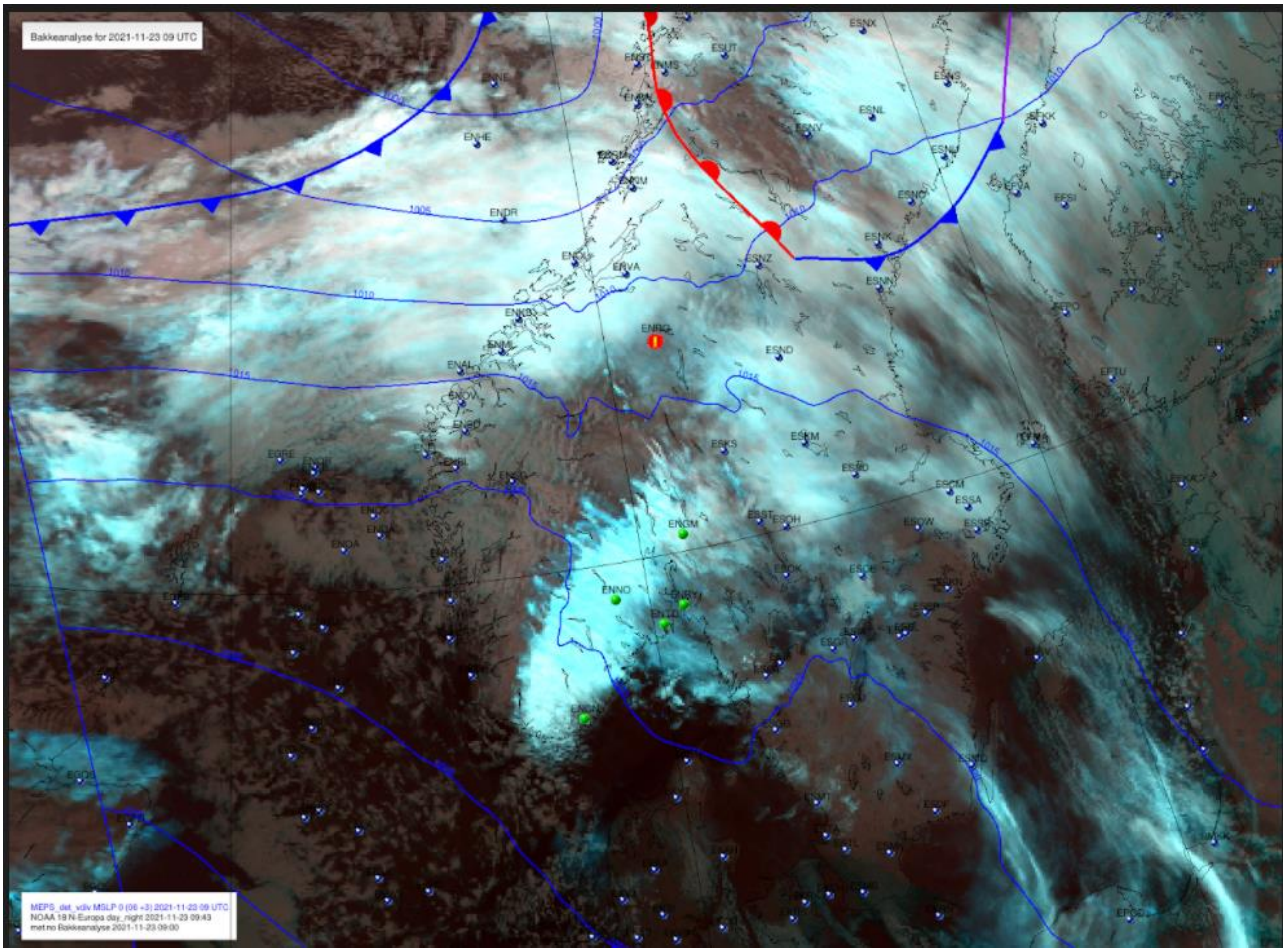

Figure 6: Ground analysis and satellite photo at 1000 hrs local time on Tuesday 23 November 2021. Illustration: Norwegian Meteorological Institute/NSIA

[13] See https://www.ippc.no/ippc/index.jsp for an explanation of meteorological abbreviations.
[14] Translated by the NSIA

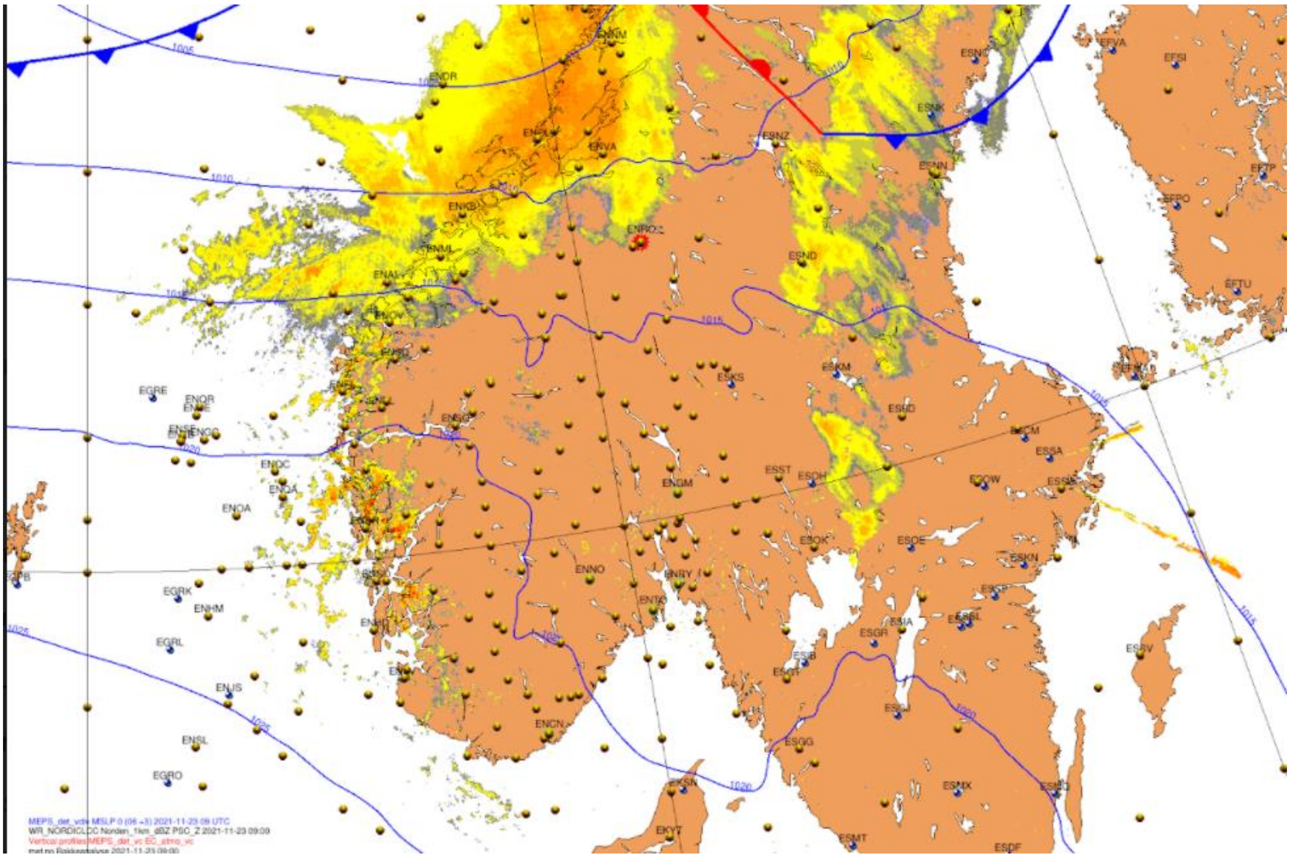

Figure 7: Ground analysis and satellite photo at 1000 hrs local time (09UTC) on Tuesday 23 November 2021. Illustration: Norwegian Meteorological Institute/NSIA

Local weather conditions

At around 0900 hrs local time, the area had fair weather with a high cloud ceiling and good visibility (CAVOK conditions) – see webcam photos from Langesund below. The main cloud ceiling was around FL180–240 (some lenticular clouds). Torp reported CAVOK conditions, +3 degrees C and southerly winds around 3 m/s between 08 and 09 local time. From the vertical profiles ['…] we can see that the area experienced a shallow temperature inversion (warmer higher up), with approximately -1 to +2 degrees near ground level and +5 to +7 degrees at 500–1,000 ft. Above that altitude, there were west-northwesterly winds (more wind details in the following section).

[…]

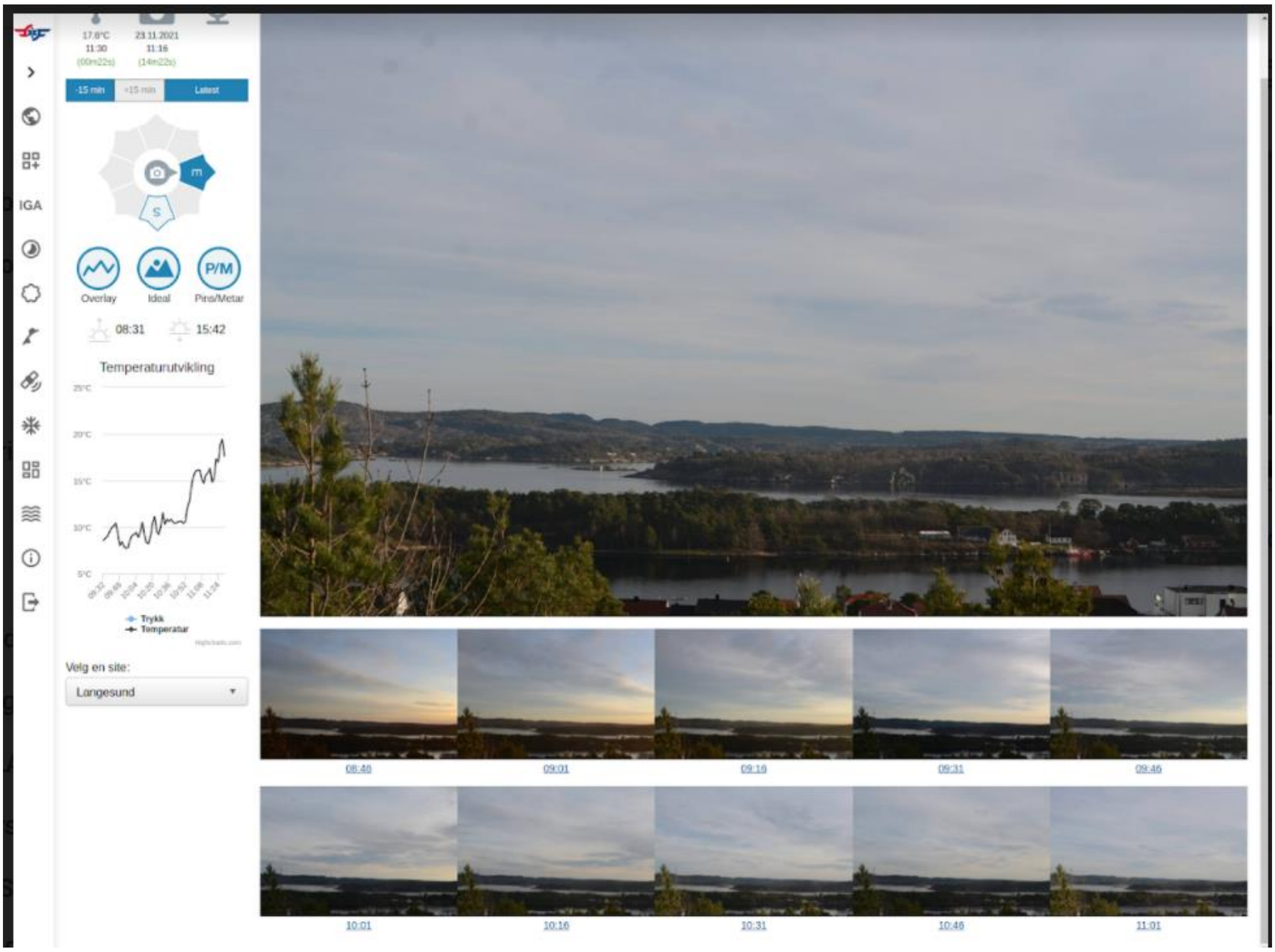

Figure 8: HEMSWX webcam photos (E) from Langesund, 0830–1000 hrs local time on Tuesday 23 November 2021. The crash site is near the horizon on the far left. Source: Norwegian Air Ambulance Foundation/NSIA

[…]

Wind and turbulence

At an altitude of 10 metres, the forecasts and observations indicate southwesterly to westerly winds with a speed of around 5–10 KT (2.5–5 m/s) in the relevant area (observations from Sandefjord Airport Torp and Svenner Lighthouse in the table below). Above the temperature inversion (up to 500–1,000 ft), the data model indicates even wind conditions from around west-northwest at speeds of around 10–20 KT at 2,500 ft and 15–30 KT at 5,000 ft (see Figure 9).

No turbulence warnings were issued for the relevant period. Our data models showed some moderate (MOD) turbulence significantly further westwards (in the area of the Hardangervidda plateau), but none above the relevant area. Our assessment is that there may intermittently have been local light (FBL) turbulence in the relevant area, given the terrain and west-northwesterly winds.

Table 6: Automatic weather observations from Sandefjord Airport Torp. The observations are recorded every hour, including temperature (2 min), mean wind speed (10 min) and prevailing wind direction. Source: Norwegian Meteorological Institute/NSIA

Time (local)	***Temperature***	***Mean wind speed (m/s)***	***Wind direction (degrees)***
0700	*3.4*	*2.6*	*180*
0800	*3.2*	*2.6*	*220*
0900	*4.3*	*3.1*	*240*
1000	*5.0*	*3.6*	*25*

Table 7: Automatic weather observations from Svenner Lighthouse. The observations are recorded every hour, including temperature (2 min), mean wind speed (10 min), strongest gust and prevailing wind direction. Source: Norwegian Meteorological Institute/NSIA

Time (local)	***Temperature***	***Mean wind speed (m/s)***	***Strongest gust (m/s)***	***Wind direction (degrees)***
0700	*7.2*	*3.5*	*4.5*	*250*
0800	*6.6*	*4.0*	*5.0*	*270*
0900	*6.6*	*3.0*	*3.5*	*240*
1000	*6.8*	*4.0*	*4.5*	*260*

[…]

Summary

During the relevant time period, the weather in the area was fair, with good cloud and visibility conditions (CAVOK). Southwest to westerly winds of 5–10 KT blew near the ground while above the temperature inversion (at 500–1,000 ft), wind speeds increased with altitude to 10–20 kt at 2,500 ft and 15–30 kt at 5,000 ft, with a west-northwesterly wind direction. Our assessment is that there may intermittently have been local light (FBL) turbulence in the relevant area.

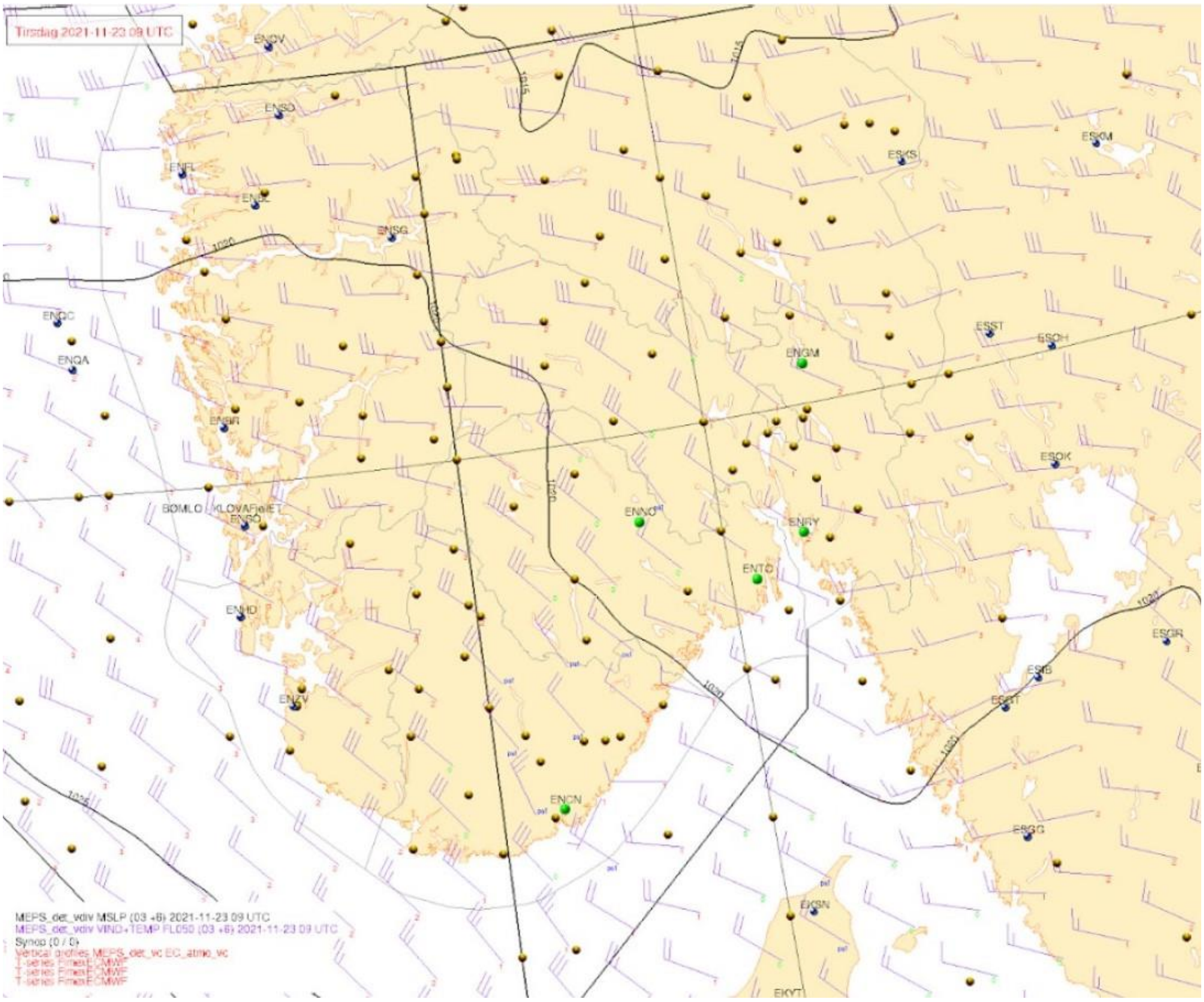

Figure 9: Wind conditions at 5,000 ft at 1000 hrs – prognosis. Illustration: Norwegian Meteorological Institute/NSIA

1.7.2 TAF FOR SANDEFJORD AIRPORT TORP (ENTO)[15]

ENTO 222300Z 2300/2324 VRB05KT CAVOK BECMG 2310/2313 23010KT=

ENTO 230500Z 2306/2406 VRB03KT CAVOK BECMG 2310/2312 23010KT=

1.7.3 METAR FOR SANDEFJORD AIRPORT TORP (ENTO)[16]

ENTO 230720Z 22005KT CAVOK 03/M02 Q1018 NOSIG=

ENTO 230750Z 23006KT CAVOK 03/M01 Q1018 NOSIG=

ENTO 230820Z 25006KT CAVOK 05/M01 Q1018 NOSIG=

[15] Times are stated as UTC
[16] Times are stated as UTC

1.7.4 IGA PROGNOSIS (LOCAL FORECAST) 0600–1600 HRS (0500–1500 UTC)

```
 ZCZC
 FBNO41 ENMI 230500
 IGA PROG 230500-231500 UTC Nov 2021 NORWAY FIR SE PART COAST AND LOWLAND AREAS E OF
E00730 AND S OF N6100


WIND SFC.......: VRB/00-05KT, LCA W-NW/10-15KT. BECMG SW-W/05-10KT, COT 10-20KT
WIND 2000FT....: NW/20-25KT AFTERNOON INCR 30KT SW-PART
WIND/TEMP FL050: 300-350/10-20KT, MORNING BECMG 300-330/25-35KT / MS03-PS03
WIND/TEMP FL100: 300-330/25-35KT OCNL 40KT SW-PART / MS08-MS04
WX.............: NIL. SLIGHT RISK LCA FZFG BEFORE NOON, MAINLY SE-MOST PART
VIS............: +10KM, RISK LCA 0.1-1KM IN FZFG
CLD............: MAINLY SKY CLEAR, RISK LCA BKN/VV 0100-0300FT IN FZFG
0-ISOTHERM.....: 4000FT-FL080, EARLY LCA SFC (GROUND INVERSION)
ICE............: NIL, RISK LCA FBL/MOD IN FZFG
TURB...........: FBL
```

1.8 Aids to navigation

The airplane was equipped with a Garmin G1000 NXi type integrated navigation system. The unit has two multifunction displays that enable communication with several of the airplane's systems, including GPS navigation and Moving Map.

1.9 Communications

Initially, LN-PFM communicated with the control tower at Sandefjord Airport Torp on frequency 118.650 MHz. The airplane was then transferred to Farris Approach on frequency 134.050 MHz. No problems were reported relating to these communication lines during the relevant period.

The NSIA has listened to the communication that took place and gained the impression that the student communicated clearly and accurately, and without any indication of a high stress level.

At the time of the accident, the traffic controller at Farris Approach was communicating with another aircraft. At 09:10:21, that communication was interrupted by noise for a duration of about 3 seconds. The time of the accident is estimated at 09:10:26. The noise may have been the result of another aircraft in the area double-transmitting on the same frequency. It has not been possible to determine whether it was due to a radio call from LN-PFM.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The airplane was not equipped with a flight recorder, and this was not mandatory. However, Garmin G1000 stores a series of data. Data is also stored in the engine control unit (EECU). All these units were destroyed by fire in the accident, making it impossible to retrieve any of the data. Nor was there any external backup of data from these units.

1.12 Wreckage and impact information

1.12.1 THE ACCIDENT SITE

The accident occurred in the training area Helgeroa 1. The crash site was in a hilly woodland area in Askedalsåsane, 8 km west-northwest of Larvik and 1.3 km south of Hobekkseter tunnel on the E18 road in Vestfold og Telemark County. The nearest buildings at Gardsveg were approximately 300 metres south-west of the crash site. Several of the hills are around 150 metres high, with the highest being around 200 metres.

The airplane first hit a rocky outcrop at 109 m (358 ft) AMSL. It then skid 10–12 metres down a steep rock slope and came to rest at the bottom of the slope. There are bushes and trees in the area, and several trees verging on the point of impact were not hit by the airplane.

Figure 10: Overview photo looking north-northeast, taken from a helicopter that was above the crash site a few minutes after the accident. The aircraft is outlined in red at the point of impact with the ground. Photo: Private/NSIA


Figure 11: Photo of the crash site looking east, shortly before 1400 hrs. Photo: NSIA

Figure 12: The crash site looking east-southeast, after the area was cleared. The point of impact was the rocky outcrop near the top edge of the photo. Photo: NSIA

1.12.2 THE WRECKAGE

On top of the rocky outcrop, an approximately 5-metre long straight imprint was found in the vegetation – running in the 15°/195° direction. Some of the wing skin, with remnants of blue tape, was found near the middle of the line. Only the underside of the left wing was marked with registration letters in blue tape. The left winglet was found slightly to the east of the southern end of the straight line. Other than that, only small fragments were found on top of the outcrop. The main wreckage ended up in a relatively concentrated area at the bottom of the slope. The main wreckage had been almost entirely consumed by fire, leaving only remnants of carbon fibre, heat-damaged steel parts and melted aluminium. The main wreckage included both engines and landing gear units. Some parts had separated from the main wreckage, including:

- The forward part of the nose, including the weather radar, had separated from the fuselage in the area of the luggage hatch. There was little damage to the front, but the underside of this part was crushed by the impact. It was found at the bottom of the slope, approximately three metres south of the main wreckage.[17] The nose part and canopy (transparent cockpit cover) were found in the same location, as was the upper right engine cover for the left engine.
- Both propellers, including the respective halves of the reduction gear boxes, were found together, approximately 15 metres down from the main wreckage. Five of the six propeller blades were knocked off at the hub. One half of a blade was still in place on the left propeller.
- The right winglet was intact and lay next to the main wreckage.
- The tank for anti-icing fluid, including a hose and two pumps, was found hanging from a tree half-way up the slope.
- The left aileron was significantly damaged by fire and was found some way below the point of impact (approximately 14 metres north of the place where the left winglet was found).
- No weights were found at the crash site (see chapter 1.6.11).
- A thorough search was made in the area around the crash site, but no parts were found that could have separated from the airplane before it hit the ground.

The wreckage was loaded into seven big bags and transported from the crash site by helicopter. It was then transferred by truck to the NSIA's hangar at Lillestrøm for further examination. This is described in more detail in chapter 1.16.

1.13 Medical and pathological information

The bodies of the three victims were found together in the middle of the wreckage. Autopsies were carried out at the Department of Forensic Medicine at Oslo University Hospital. The examination reports concluded that all three died instantly as a result of extensive injuries sustained in the impact with the ground.

Routine samples were taken to check for traces of alcohol (ethanol), medication and narcotic substances. Because of the condition of the victims, the results were difficult to verify, but the available results gave no reason to suspect that any of them were under the influence of illegal substances.

1.14 Fire

A fire broke out immediately after impact with the ground. The airplane carried just under 200 litres of Jet A-1 fuel and approximately 7 litres of engine oil in each engine. Small amounts of oil were also present in the airplane's hydraulic and brake systems.

The aircraft was largely made of carbon-reinforced plastic, with some smaller parts of fibreglass-reinforced plastic. These materials were mainly consumed by fire, leaving only fibres at the crash site.

[17] *To the right of the main wreckage seen from below the slope.*

Some trees were damaged by the fire, and the forest floor was burnt up where parts of the wreckage lay burning on the ground.

1.15 Survival aspects

When the aircraft disappeared from the radar, the crew did not respond to the traffic controller's calls and a witness notified of a possible accident, it became clear that LN-PFM must have crashed. Hence, shortly after 0922 hrs, a general alert went out to the Joint Rescue Coordination Centre (JRCC), SAR helicopters and air ambulance service, before the exact position of the airplane had been ascertained. The Air Force's Sea King SAR helicopter arrived approximately 45 minutes after the accident. It was established that no lives could be saved. Because of the demanding terrain and few suitable access routes, it took longer for the ground-based emergency services to arrive at the scene.

The airplane was equipped with an emergency locator transmitter (ELT) of the Artex ME406 type. An airplane that passed over the area around the time of the accident picked up some ELT signals for a few seconds. The crew assumed that it was a test in connection with maintenance and did not associate the signals with the accident until later, when it became known that there had been an accident. The signals were transmitted for such a short time that they were not picked up by other aircraft or by the satellite-based warning system.

Only the ELT bracket was found at the crash site and the NSIA has therefore concluded that the ELT was completely consumed by the fire.

The airplane was fitted with three-point seatbelts for both crew and passengers.

1.16 Tests and research

1.16.1 GENERAL EXAMINATION OF THE WRECKAGE

Because of the health hazards associated with carbon fibre dust, it was decided that the wreckage parts in the big bags could not be examined inside the NSIA's hangar. A temporary shed was therefore erected outdoors, where all the wreckage parts were sorted into three categories:

- Carbon fibre and small parts of which further examination was clearly of no interest were sorted out.
- Parts that were not of immediate interest, but which might be subject to examination at a later date, were stored separately outdoor.
- Parts, mainly of the aircraft's structure, control surfaces, flight controls, engines, propellers and landing gear were cleaned for carbon fibre dust and transferred to the NSIA's hangar, where they were examined further, laid out and positioned as correctly as possible in relation to each other (see Figure 13).

Figure 13: Parts of the aircraft viewed from the front, laid out and positioned as correctly as possible in relation to each other. The left wing is on the right in the photo. The engines are placed on pallets in the lower part of the photo. Photo: NSIA

The parts were examined with the assistance of a licensed aircraft technician from Flyteknisk Notodden AS, the flight school's maintenance organisation. Examination of the wreckage gave the following results:

1. Parts of the wings (including the winglets) and horizontal and vertical stabilisers were found.
2. Remains of all control surfaces (elevator, rudder, ailerons and flaps) were found.
3. It was possible to reconstruct the flight control mechanisms from the stick and pedals for the respective control surfaces. The flight controls had many fractures. It was considered that these could be ascribed to strong impact with the ground, and the fractures bore clear signs of overloading or other external impact.
4. Damage to the stick (aileron control) indicated that it was in a neutral position when the airplane hit the ground.
5. The position of the rudder trim corresponded to barely one dot left (10° nose left) on the indicator.
6. The rod that was connected to the elevator trim tab had been pushed in all the way. That means that the elevator was trimmed to nose down. The flexible cable from the elevator trim tab to the cockpit was torn apart inside the fuselage, however, which means that this finding is unreliable.
7. The landing gear showed damage and overload fractures in several places after having been knocked backwards while extended (see Figure 14).
8. The flaps actuator had melted down completely, but the steel parts were found. The mechanism was cut open. The screw was found to be positioned against the end stop, indicating that the flaps were fully deployed (see Figure 15).

9. The pitot tube was bent steeply upwards.
10. The tank for anti-icing fluid had ruptured in a way that indicated that it had contained fluid. It was not possible, however, to estimate how much fluid it had contained.
11. The bracket for the emergency locator transmitter was found, but not the transmitter itself.
12. All electronic components in the aircraft had been destroyed by fire. It was thus impossible to retrieve any data from these units.

Figure 14: Left landing gear on the left and right landing gear on the right. Red arrows show the flight direction. Both sets of landing gear were knocked backwards. The right landing gear had been knocked off and the upper part of the leg buckled in from being struck from the front after the lower part broke off (marked with a green arrow). Photo: NSIA

Figure 15: The rod for the flaps actuator on the left, with the jackscrew extending out to the right. The arrow points to the place where the screw has stopped against the end stop. Photo: NSIA

1.16.2 EXAMINATION OF THE ENGINES

1.16.2.1 Introduction

Both engines were heavily damaged. Among other things, the reduction gearboxes including associated components had been knocked off. The reduction gearbox for the left engine had broken in two (see Figure 16). The larger part was still bolted to the propellers. The engines had been exposed to high temperatures so that wires and other combustible components had melted or been consumed by fire (see Figure 17).

Both engines were disassembled and examined in the NSIA’s hangar. An experienced licensed aircraft technician from Flyteknisk Notodden AS, the maintenance company, took part in the work. Generally speaking, both engines appeared to have been in good working order before the accident, and they showed similar patterns of damage.

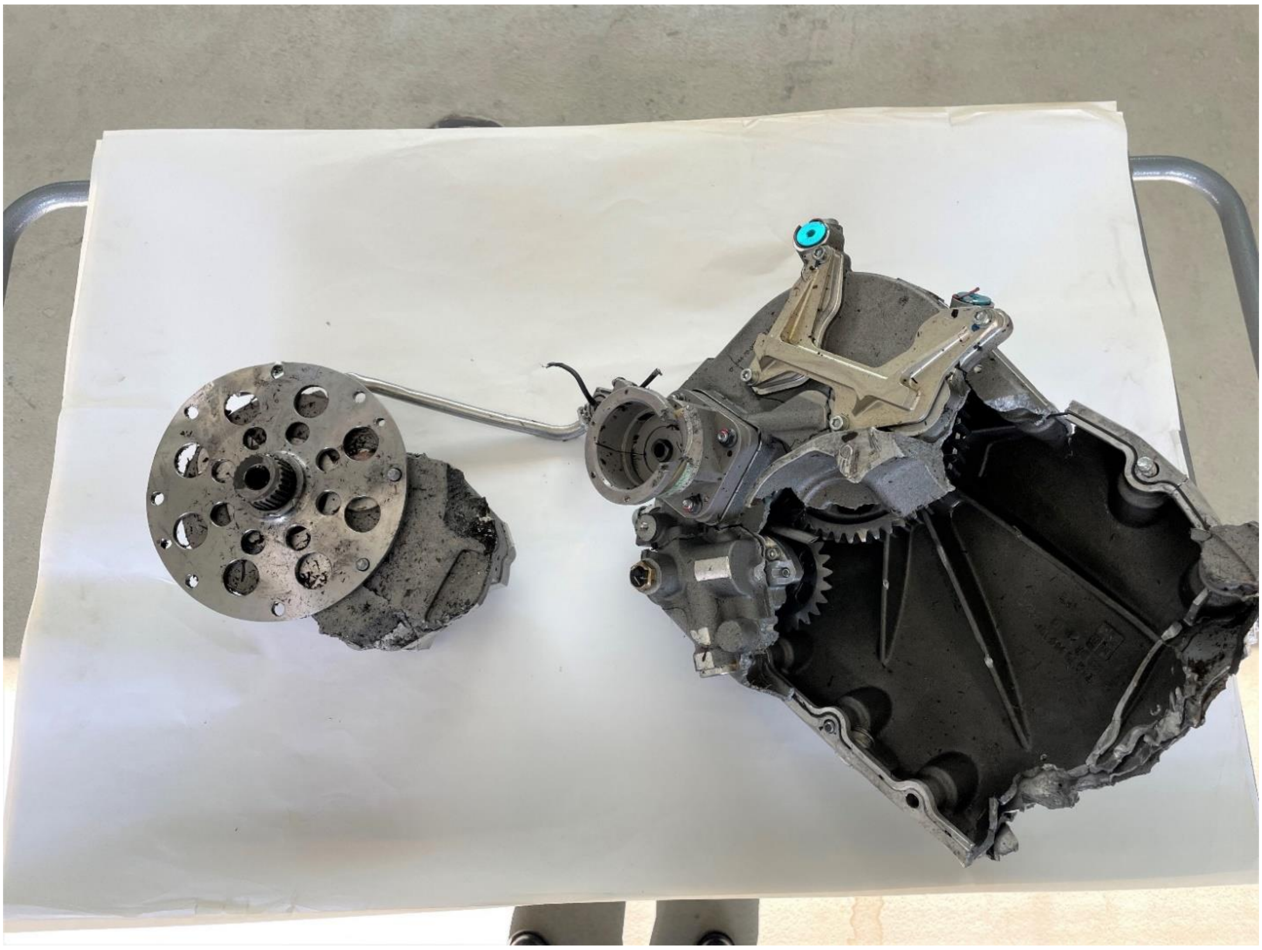

Figure 16: The reduction gearbox from the left engine. Photo: NSIA

Figure 17: The left engine before it was disassembled. Photo: NSIA

1.16.2.2 Left engine

The following was established during disassembly of the engine:

- The fuel injector nozzles for the engine were externally damaged by heat, but had not suffered internal damage.
- The glow plugs were externally damaged by heat, but had not suffered internal damage.
- The turbo compressor housing had partially melted.
- There was no oil inside the valve covers and the cams were corroded. Both camshafts were otherwise intact and the camshaft bearings appeared to be in order.
- Several cam followers had been displaced and two had come completely loose.
- The sprocket and chain that operate the camshafts were intact.
- The cylinder head and valves appeared to be in good order.
- The pistons and cylinder walls above the pistons bore no traces of abnormal combustion or wear.
- The crankcase was empty of oil. The interior of the engine showed patches of soot and corrosion.
- The crankshaft was broken between the third main bearing and rod no 3 (see Figure 18).
- Rod no 4 came loose because the bolts in the big-end bearing were broken. The bolts appeared to have been broken by overload fracturing in connection with the broken crankshaft.
- Rod bearings nos 3 and 4 were removed. The bearings bore no traces of abnormal wear.

- The oil pump housing had partially melted, but the pump bore no other obvious damage.
- The forward part of the crankcase was crushed (see Figure 18).
- Unambiguous traces could not be found of contact between the flywheel and crankcase during flywheel rotation.
- All damage in the reduction gearbox was compatible with heavy impact with the ground.

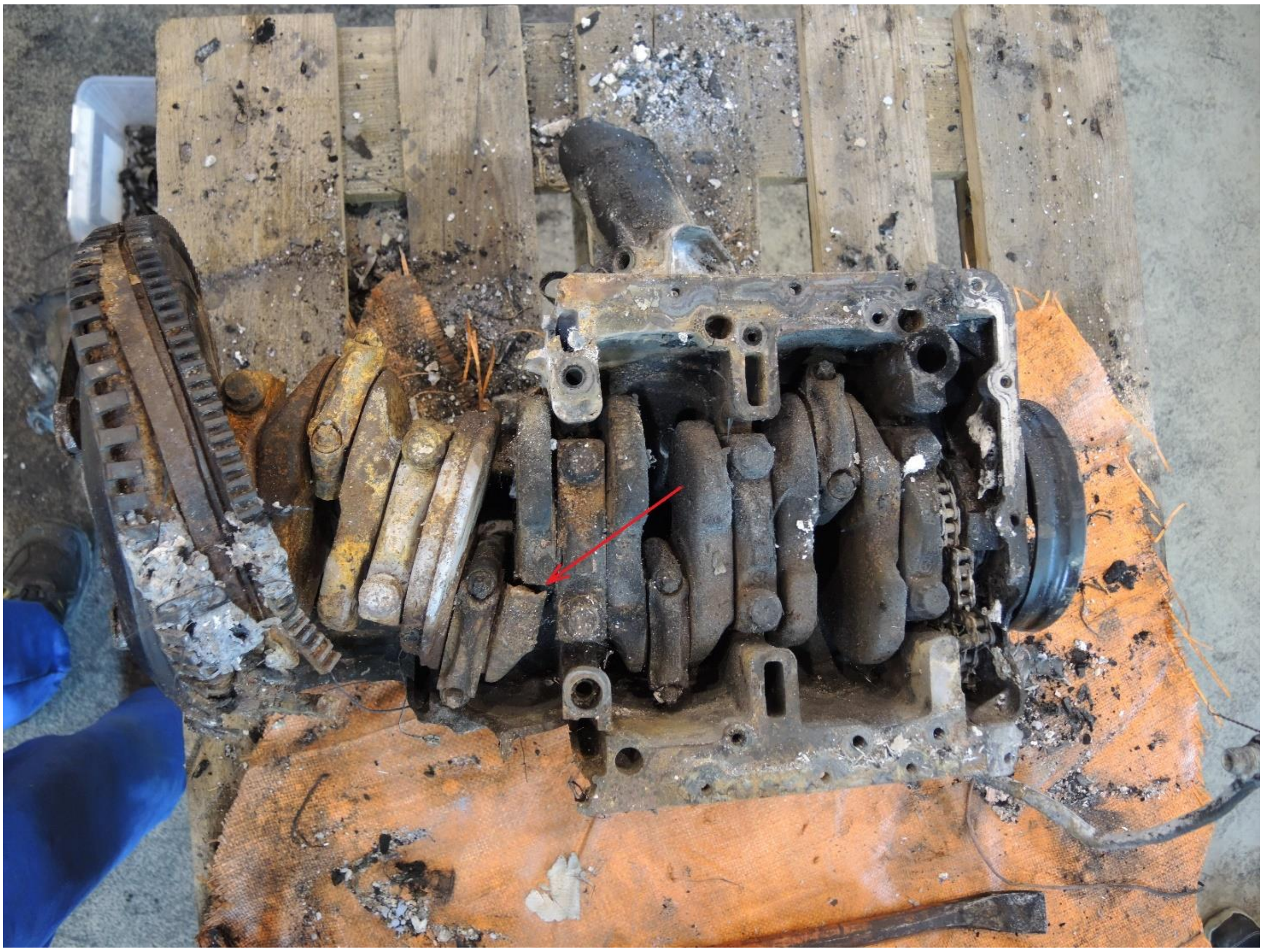

Figure 18: Damage to the left engine, viewed from below. The crankcase is largely crushed or missing. The red arrow points to where the crankshaft is broken. Photo: NSIA

1.16.2.3 Right engine

The following was established during disassembly of the engine:

- The fuel injector nozzles for the engine were externally damaged by heat, but had not suffered internal damage.
- The glow plugs were externally damaged by heat, but had not suffered internal damage.
- There were traces of contact between the compressor rotor and compressor housing during turbo rotation (see Figure 19 and Figure 20).
- There was no oil inside the valve covers and the cams were corroded. Both camshaft were otherwise intact and the camshaft bearings appeared to be in order.
- Four cam followers had been displaced, and two of these had come completely loose (inlet valves)
- The sprocket and chain that operate the camshafts were intact.

- The cylinder head and valves appeared to be in good order (see Figure 21).
- The pistons and cylinder walls above the pistons bore no traces of abnormal combustion or wear.
- The crankcase was empty of oil. The interior of the engine showed patches of soot and corrosion.
- The oil pump could rotate freely.
- Damage was found on the aft face of the flywheel (facing the crankcase), indicating that the flywheel had rotated while being pushed against the crankcase. Furthermore, several of the boltholes had become oval (see Figure 22).
- All damage in the reduction gearbox was compatible with heavy impact with the ground.

Figure 19: Compressor housing from the turbo for the right engine. The arrows point to damage to the housing from contact with the compressor rotor. Photo: NSIA

Figure 20: Compressor rotor from the turbo for the right engine. The arrows point to bent rotor blades. Photo: NSIA

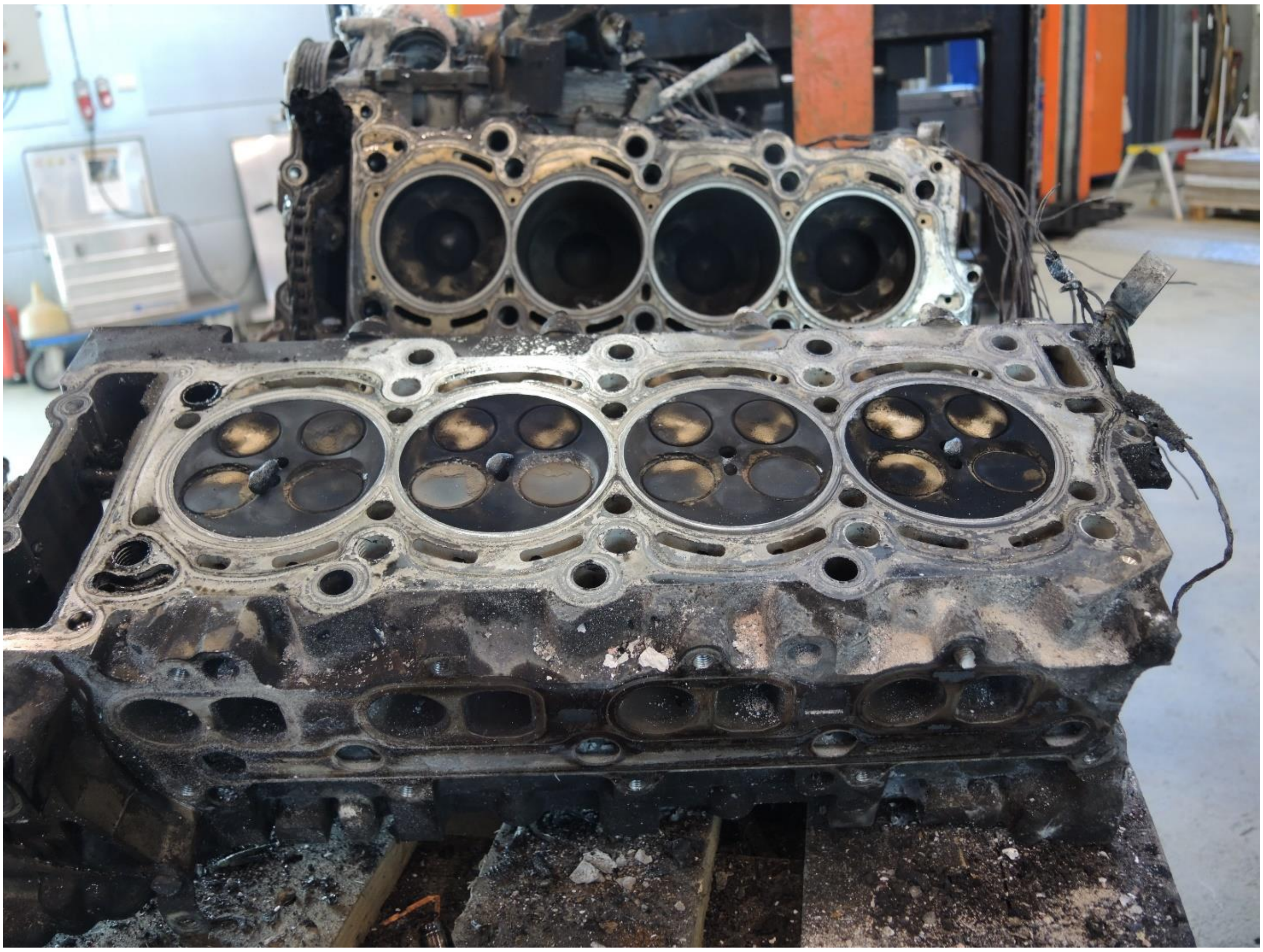

Figure 21: The cylinder head from the right engine with the engine block behind. Photo: NSIA

Figure 22: The aft face of the flywheel for the right engine. The blue arrow points to a scrape mark. The red arrows point to some of the oval boltholes. Photo: NSIA

1.16.3 EXAMINATION OF THE PROPELLERS

1.16.3.1 Examination of the propellers at Norrønafly Propeller & NDT

The propeller blade angle can tell us something about engine power, so the NSIA decided to have the propellers examined at Norrønafly Propeller & NDT in Oslo, an approved maintenance organization for several types of propellers, including MT propellers. The primary aim of the examination was to determine what blade angle the propellers had on impact with the ground. The propellers were heavily damaged, which made the work difficult. The numbers in the following description refer to the numbers in Figure 23.

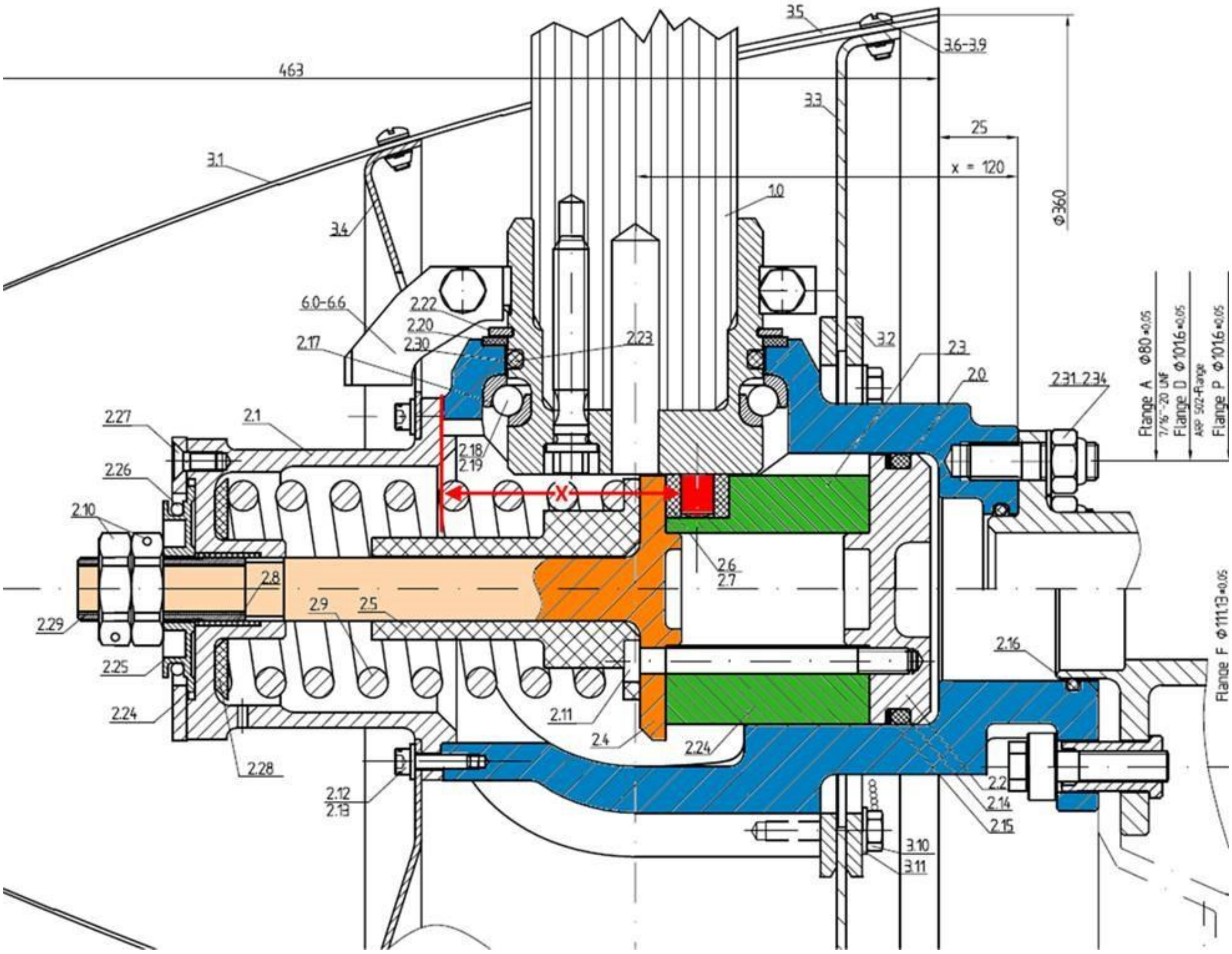

Figure 23: Section drawing of propeller. Source: MT-Propeller/NSIA

<u>Left propeller (serial number 200093)</u>

The left propeller was heavily damaged and the front housing (2.1), including the return spring (2.9), had been knocked off. Blade 1 was broken near the middle. The two other blades were broken at the root. The hub (highlighted in blue in the drawing) had fractured and blade 1 was loose. Damage to the hub made it impossible to take out the piston (highlighted in green in the drawing). Furthermore, the black plastic blocks around the guide pins (highlighted in red in the drawing) for blades 1 and 2 were fractured. To establish the blade angle, if possible, the distance from the blades' guide pins to the forward end of the hub was measured (see the red arrow in Figure 23). The following distances were measured:

Blade 1: 51.5 mm

Blade 2: 53.7 mm

Blade 3: 48.6 mm

These distances could not be converted to blade angle without access to an undamaged propeller, and further examination was postponed.

<u>Right propeller (serial number 200094)</u>

The right propeller was heavily damaged, but the hub (highlighted in blue in the drawing) appeared to be undamaged. The front housing (2.1) and return spring (2.9) were removed. The bolts (2.11) were then unscrewed and the piston extension (highlighted in orange in the drawing) removed. The plastic blocks around the blades' guide pins (highlighted in red in the drawing) and the piston (highlighted in green in the drawing) were removed next. Before removing the blades, their positions were marked with alignment marks on the counterweights and hub. The blades could then be removed after removing the retention ring (2.22). When blade 2 was removed, its position was not marked on the blade bearing races. The inner blade bearing race consists of two halves, loosely fitted around the blade root, and these came loose (similar to 2.17, but not assigned a separate number in the drawing). Hence it was not possible to establish where the bearing race had been positioned on the blade root. The outer bearing race is fixed to the hub (2.17). Before removing blades 1 and 3, the positions of the two bearing halves were marked. Further examinations to determine the angle of blades 1 and 3 are described in chapter 1.19.2.

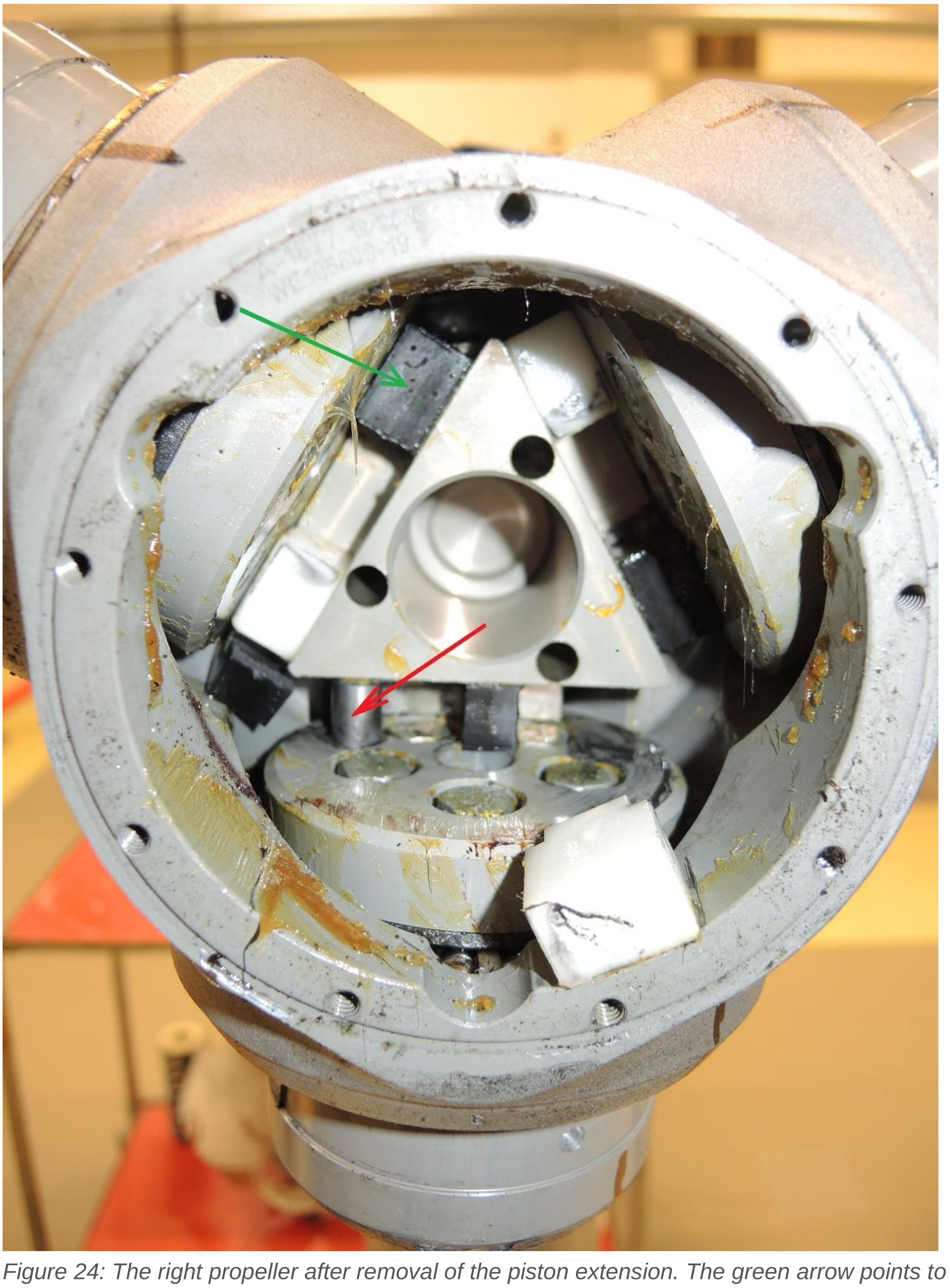

Figure 24: The right propeller after removal of the piston extension. The green arrow points to the black plastic block around the guide pin for blade 1. The red arrow points to the guide pin for blade 3, whose plastic block had fractured and fallen off. The white blocks in the photo are end stops that limit blade movement. Photo: NSIA

1.16.3.2 Examination of the propellers at MT-Propeller

MT-Propeller, the German manufacturer, has experience of determining propeller blade angle based on marks left on the propeller piston (highlighted in green in the drawing). If the plastic block around the guide pin fractures, the guide pin (highlighted in red in the drawing) can knock into and leave marks on the piston. It was therefore decided to send the propeller to MT-Propeller. The examinations were led and monitored by the German Federal Bureau of Aircraft Accidents Investigation (Bundesstelle für Flugunfalluntersuchung – BFU). The following information is taken from a report prepared by BFU.

Left propeller (serial number 200093)

Blade 1 was loose and blade 3 was assessed as displaced. With the aid of the counterweights on blade 2, the blade angle was measured to be 24.6°. Because of damage to the hub, some special alternative tools had to be used to remove the blades. There were no marks on the piston (highlighted in green in the drawing) from contact with the guide pin (highlighted in red in the drawing). Hence it was not possible to determine blade angle using MT-Propeller's method.

Further examination of the blade bearings showed that the balls had left visible marks in the bearing races. The method used is described in chapter 1.19.2.

Right propeller (serial number 200094)

Blades 1 and 3 were reinstalled in the hub using the alignment marks made by the NSIA (see chapter 1.19.2). Measurements carried out with the aid of the counterweights gave the following blade angles:

Blade 1: 13°

Blade 2: 48°

Blade 3: 16.1°

1.16.4 COLLECTION AND ANALYSIS OF DATA FROM AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B) AND ENHANCED SURVEILLANCE (EHS)

As the wreckage, crash site and witnesses provided little information, the NSIA decided to investigate whether a better understanding of the flight could be gained by compiling Automatic Dependent Surveillance-Broadcast (ADS-B) and Enhanced Surveillance (EHS) data. Data were obtained from both Avinor and Flightradar24 and analysed (see Appendix A). The data give a good understanding of the flight up until the time when control of the airplane was lost. In the compounded data set, there are data points that are incompatible with flying. These points suggest that the aircraft may have moved significantly between each data point. A graphical presentation of the final data from the flight is given below.

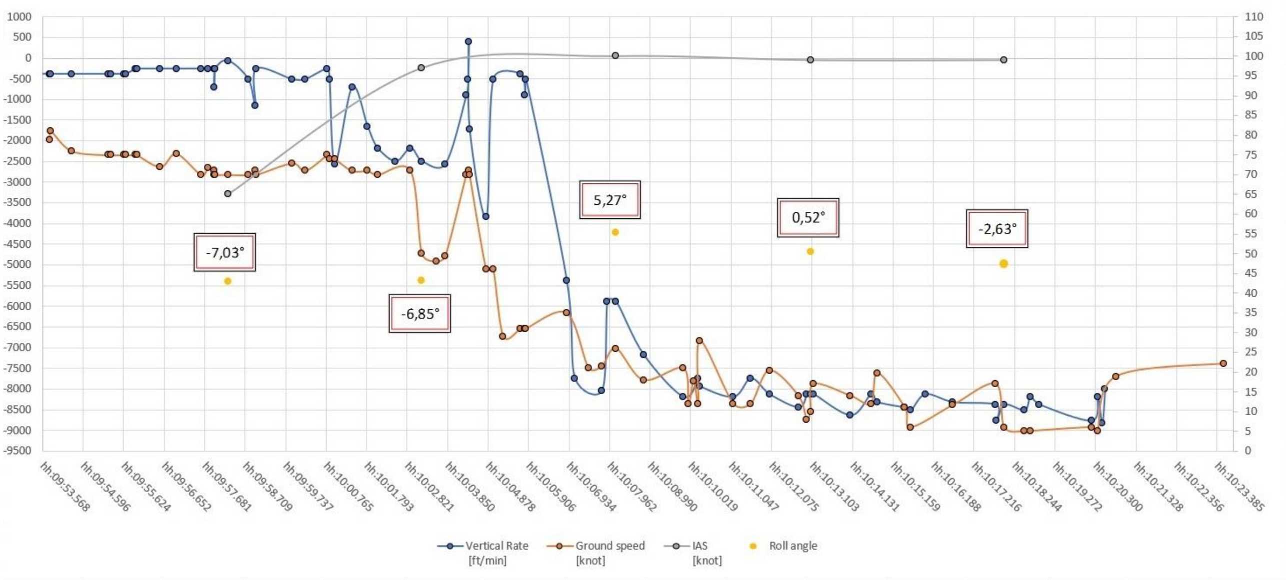

Figure 25: A compilation of data for the final 30 seconds for which data were available. The scale on the left shows vertical speed in feet per minute. The scale on the right shows speed in knots. Data for roll angle is indicated as yellow dots. Negative angles indicate rolling to the left. The graph was prepared by the NSIA

1.16.5 THE STUDENT'S MOBILE PHONE

The student's mobile phone was found at the crash site, undamaged. It was opened using a pin code and examined. The phone had Air Navigation Pro software installed, but it was not activated and could not provide information about the flight. Some photos of the airplane, taken in the morning before departure, were examined. The photos show no abnormal features in the aircraft.

1.16.6 REVIEW OF PREVIOUS FLIGHTS AT PILOT FLIGHT ACADEMY

Pilot Flight Academy's DA 42 NGs were all equipped with a Garmin G1000 NXi avionic system and a 3-axis autopilot. This system stores a series of data that enable a detailed review of flights. The NSIA has gained access to data from a number of instruction flights conducted with DA 42 NG airplanes before the accident. A review of slow flight sequences and stalling exercises did not reveal any situations that could contribute to explaining what happened with LN-PFM. For example, the NSIA did not find any stalls that had resulted in significant wing drop or other unusual attitudes. The speed was sometimes as low as 65 kt before normal flight was resumed.

1.17 Organisational and management information

1.17.1 PILOT FLIGHT ACADEMY (PFA)

Pilot Flight Academy's predecessor, Luftfartsskolen Notodden AS, was established in 2007. The flight school subsequently moved to Sandefjord Airport Torp and was named Luftfartsskolen Torp AS. On 4 January 2008, the school was approved as an Approved Training Organisation (ATO) by CAA Norway. At first, the school offered modular flight training, but in August 2010, the first class of students were admitted to an integrated study programme. The flight school gradually attracted international students and partners, and in 2016, it changed its name to Pilot Flight Academy.

At the time of the accident, the flight school had bases at Torp and Notodden and cooperated closely with US Aviation Academy (USAA) in Denton, Texas. The cooperation with US Aviation Academy was a result of capacity problems in Norway. Pilot Flight Academy found the transition from completion of the three first phases on the Cessna 152 in the USA to phase 4 in Norway demanding. The school therefore decided to include additional simulator training so as to prepare the students for flying DA 42 NGs under Norwegian conditions.

At the time of the accident, Pilot Flight Academy employed a total of 95 full-time and part-time staff. This included 45 instructors, 2 of whom worked part time. The school also used 15 hired consultants. At the time of the accident, the school had 324 students.

The school operated 10 airplanes of the Diamond DA 40 type (single-engine) and 7 airplanes of the DA 42 NG type. The school also had one American Champion 8KCAB airplane used for advanced upset prevention and recovery training (UPRT) of instructors and students.

PFA's aircraft were maintained by Flyteknisk Notodden AS, an EASA Part 145 organisation.

1.17.2 PFA'S PROCEDURES AND TRAINING PROGRAMME

1.17.2.1 Procedures

Activities at Pilot Flight Academy are regulated by a number of manuals. Relevant manuals and procedures include the *Organisation Management Manual* (OMM), *Operations Manual* (OM), *Training Manual Airline Transport Pilot Issue 4* (TM ATP ISSUE 4) and *Standard Operation Procedures* (SOP) with relevant checklists. The school is also required to act in accordance with the manuals for the individual aircraft it operates. Applicable in the case of LN-PFM was *Diamond Aircraft, Airplane Flight Manual DA 42 NG, revision 5,* dated 10 June 2021.

OMM Chapter 4 describes the school's safety management system (SMS), including its governing policy and objectives, risk management and handling of nonconformities. In that connection, the school had prepared a pre-flight checklist to be completed before every flight. Among other things, the checklist is used for risk assessment of the flight in question, and it forms part of the school's Threat and Error Management (TEM) system.

The SOP describes how the various exercises are to be conducted. The investigation indicates that control of the airplane was lost during a slow flight or stalling exercise with the aircraft in landing configuration. Chapters 3.2.7 and 3.2.9 of the SOP are therefore cited in full below.

3.2.7 Slow flight - Landing configuration

Objective:

To develop the ability to recognize changes in the airplanes flight characteristics and control effectiveness at a critically slow airspeed in landing configuration, while maintaining positive airplane control, altitude and heading as specified.

For more information on the subject: Slow flight

Procedure description:

1. Entry procedure:
   a) Perform CARBS check.
   b) Smoothly reduce power to 30% load.
   c) Below 133 KIAS select and verify flaps APP.
   d) Below 188 KIAS select and verify landing gear DOWN.
   e) Below 113 KIAS select and verify flaps LDG.
   f) 5-10 knots before reaching target airspeed, apply power as required for level flight.
   g) Trim.
   h) Maintain altitude, heading, and airspeed as instructed.

2. Recovery procedure:
   a) Smoothly increase power to 92% load and simultaneously press right rudder as required to maintain coordinated flight.
   b) Maintain altitude and heading.
   c) Select and verify flaps APP.
   d) Select and verify gear UP (below 152 KIAS).
   e) As airspeed increases, gradually pitch nose down to maintain level flight.
   f) When airspeed is above 80 KIAS select and verify flaps UP.
   g) Trim.

Special emphasis:

- Maximum bank angle in slow flight is 20°.

Illustration:

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3.2.9 Stall level flight - Landing configuration

Objective:

To develop the ability to recognize changes in the airplanes flight characteristics and control effectiveness as the aircraft approaches stall in power-off landing configuration. To make prompt and effective recovery either before (imminent stall recovery) or after the stall occurs (full stall recovery).

For more information on the subject: Stalls

Description:

1. Entry procedure:
   a) Perform CARBS check.
   b) Smoothly reduce power to 30%.
   c) Maintain altitude and heading.
   d) Below 133 KIAS select and verify flaps APP.
   e) Below 188 KIAS select and verify landing gear DOWN.
   f) Below 113 KIAS select and verify flaps LDG.
   g) Reduce power to idle.
   h) Keep wings level in coordinated flight.
   i) At the sound of the horn, call-out ***«Stall warning»***.
   j) Recover on stall warning, buffet or full stall, as requested by the instructor.

2. Recovery procedure:
   a) Decrease angle of attack to break the stall.
   b) Smoothly increase power to max and simultaneously press right rudder as required to maintain coordinated flight.
   c) When sufficient airflow/control is regained, level the wings with coordinated aileron/rudder input.
   d) Select and verify flaps APP.
   e) When a positive rate of climb is achieved, select and verify gear UP (below 152 KIAS).
   f) Smoothly pitch up for climb speed V_Y 85 KIAS (flaps APP).
   g) Maintain heading and climb to initial altitude.
   h) Accelerate and select flaps UP (minimum 80 KIAS).

Special emphasis:

- If recovery is practised beyond stall warning, e.g. fully developed stall, call-out ***«Stall warning – disregard»***
- "Smoothly increase power to max" means that it should take about 3 seconds from idle to max (if the power was set to idle during the entry).
- Spin awareness - If a wing drop occurs, which often happens because of poor pilot technique where the aeroplane is out of balance at the stall, or aileron input is being used, we must somewhat alter our stall recovery. Once the wing stalls, aileron input will not stop the roll, it will worsen the situation, in these cases rudder should be used to prevent the nose of the aeroplane yawing. If the wing-drop is not promptly recovered, a spin may develop. Excessive rudder should not be applied (to level the wings through the secondary effect of rudder) as this may cause a stall and flick manoeuvre in the opposite direction to the initial roll (wing drop).
- The goal of this exercise is not to have the least possible altitude loss, but to perform a safe recovery.
- Stall speeds at various flight masses, flap settings and angle of bank are published in the AFM section 5.3.4.

The Stalls link refers to Airplane Flying Handbook (FAA-H-8083-38), published by the FAA's Office of Accident Investigation and Prevention

The CARBS link refers to preparations to be made before conducting the exercise. The letters are an acronym for *Clear the area, Altitude, Reference point, Bugs* and *Speed.* The following is stated about *Altitude*:

> *Check that you have sufficient altitude to recover no later than 2000 ft AGL or 2500 ft AGL for solo flights (3000 ft AGL for advanced stalling manoeuvres).*[18]

The flight school's SOP list all check lists that shall be known by heart (Memory items) in chapter 1.3.1. A list about how to stop an incipient spin or exit a fully develop spin is not included in this chapter.

According to SOP section 1.9.1, PFA permits passengers on instruction flights. This does not apply on solo flights, when there is no instructor on board.

1.17.2.2 Training programme

Pilot Flight Academy's training programme is described in the school's training manual (TM). The training programme was developed in accordance with requirements laid down by EASA. Every requirement in the training programme refers to requirements in EASA Part-FCL (Flight Crew Licensing) with associated guidelines (Acceptable Means of Compliance – AMC). The training programme reflects the skills to be demonstrated in the skill tests.

The training programme is divided into six phases:

1. Basic airwork
2. VFR manoeuvring, circuit training (continuing training to prepare for the first solo flight)
3. Navigation training, VFR navigation (phases 1–3 correspond closely to private pilot licence (PPL(A)) training
4. IFR ME, IFR SPIC (multi-engine flights in accordance with instrument flight rules)
5. Advanced UPRT (Upset Prevention and Recovery Training)
6. APS MCC (Airline Pilot Standard Multi Crew Cooperation)

For phase 4, the following relevant exercises are described in point 35:

35. Airwork

- Straight and level flight at various airspeeds
- Stall
- Stall in turn with approach configuration
- Stall in landing configuration
- Stall in climb
- Asymmetric demo
- Spin avoidance
- Steep turn 45° and 60° bank
- Slow flight
- Slow flight in landing configuration

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[18] *In Airplane Flying Handbook (FAA-H-8083-3C), the FAA recommends a minimum altitude of 3,000 ft above the terrain during slow flight sequences with twin-engine airplanes.*

Any significant changes to the training programme must be approved by CAA Norway. Pilot Flight Academy has been in a dialogue with the Norwegian Aviation Authority arguing that it would have been desirable to carry out phase 5 before phase 4.

The NSIA has discussed with the school's management whether the relevant slow flight exercise might have included slow flight with one engine idling, to practise handling the airplane with only one engine running. PFA considered that imposing such a demanding exercise on a student during a first lesson in the DA 42 NG would not be a natural thing to do. Slow flight training with just one engine would create asymmetry and require more than ordinary vigilance. With the exception of V_{mca} demonstrations, slow flight with one engine idling is not permitted. Stalls are not permitted under any circumstances with one engine idling.

1.17.3 FLIGHT INSTRUCTORS AT PILOT FLIGHT ACADEMY

EASA has defined requirements for training of flight instructors (Flight Instructor Airplanes – FI(A)). According to Part FCL.FI *FI-Training course* and AMC.930.FI *FI-Training course*, an instructor must demonstrate practical handling of both stalling and a fully developed spin before approval can be granted. The instructor on board LN-PFM completed the practical part of this training in the school's American Champion 8KCAB.

The NSIA has interviewed three instructors at Pilot Flight Academy. They all expressed the view that, up until the time of the accident, the LN-PFM flight, as documented with the aid of Flightradar24, proceeded in accordance with what would be expected during a 4.1 lesson. They themselves would have started with familiarisation with the training area, and then flown turns with bank angles of 30°, 45° and 60° to the right and left. It would also have been natural to start slow flight training and stalling exercises. The rate of progression would depend on how quickly the student mastered the different exercises. It was not inconceivable that the instructor would also demonstrate loss of engine power during this lesson. If so, they thought, this would be done in a cautious and controlled manner.

The instructors explained that the first group of students who arrived from US Aviation Academy experienced some problems in handling all that was new when they returned to Pilot Flight Academy. For these students, the DA 42 NG was a new and unknown airplane type, and there were differences between procedures in Norway and procedures in the USA. To remedy this, two extra lessons were added to the training programme, and lessons 4.4–4.11 were carried out before the students were allowed to fly the DA 42 NG. That way, they could become more familiar with the cockpit, flight equipment and characteristics as well as Norwegian conditions.

During the interviews, it emerged that there was no standard practice with respect to whether the instructors should demonstrate an exercise before the student was allowed to try. An alternative to demonstrating the exercise was to explain to the student how the exercise should be performed and then let the student try. The PFA management told the NSIA that, for a period before the accident, there had been too few standardisation meetings, partly as a result of restrictions during the COVID-19 pandemic.

The school stated that, at the time of the accident, there were no requirements for regular spin recovery training of flight instructors. Nor was this required by the relevant authorities. However, the flight school has stated that they have introduced requirements for refresher training for the instructors every three years on the aircraft type American Champion 8KCAB. About a third of the instructors have undergone this program during 2022.

1.17.4 INSPECTIONS/SUPERVISION

CAA Norway oversees organisations and individuals with roles in civil aviation. The purpose of such supervision is to ensure compliance with legislation and regulatory requirements, and to measure the level of compliance.

The NSIA requested copies of CAA Norway's reports following flight operation inspections of Pilot Flight Academy from the years 2019–2021. CAA Norway classifies its findings from level 1 to 5. Level 1 nonconformities represent a threat to safety, while level 2 nonconformities represent a potential threat to safety. CAA Norway has informed the NSIA that the COVID-19 pandemic affected the inspection activity so that the number of audits periodically became fewer. The supervisory activities that were conducted showed that Pilot Flight Academy gave serious attention to safety and the flight school gave a good impression.

The NSIA has reviewed six of the relevant inspection reports. Level 2 nonconformities were found during two of these inspections. They mainly concerned lack of documentation in the system of manuals and organisational nonconformities in the HSE organisation. The NSIA found no direct connection between the reported nonconformities and the accident.

1.18 Additional information

1.18.1 OTHER INCIDENTS AND ACCIDENTS INVOLVING THE DA 42

1.18.1.1 Introduction

It is difficult to find reliable statistics showing accident rates of individual aircraft types. According to available statistics, however, the DA 42 is not more accident prone than other comparable aircraft types.

The NSIA has searched for information about accidents and incidents involving DA 42 and DA 42 NG type airplanes. Among other sources, Aviation Safety Network (aviation-safety.net) has a list of 90 incidents between 2006 and 2022, of which 18 were fatal accidents. Based on available information, the NSIA consider the following to be relevant to the accident involving LN-PFM.

1.18.1.2 Accident on 22 January 2016 in Sweden, involving a DA 42 (registration SE-LVR)[19]

The accident occurred during flight training with an instructor and a student in the front seats, and another student in the rear seat. The flight was undertaken at night under instrument meteorological conditions, with a layer of clouds from 300–400 to 2,000 ft. The instructor had said that he would demonstrate a situation in which the airplane entered a deep stall. This was done by bringing the airplane into a steep climb with an attitude of approx. 25–30º while it banked 30º to the left. During deceleration when approaching stall speed, both engines were set to full power and the stick was pulled fully back.

It was estimated that the pitch attitude during the climb was approximately 50° and that the airplane had reached an altitude of approximately 4,500 ft when it entered a left spin. The instructor tried to exit the spin, among other things by varying the engine power. Both students indicated that the rotation stopped temporarily, but that the aircraft continued to spin for about 30 seconds before it crashed into some woodland. The rate of descent in the initial phase was

[19] *Accident investigated by the Swedish Accident Investigation Authority https://www.havkom.se/utredningar/civil-luftfart/olycka-pa-aengsoe-i-vaesteras-kommun-med-flygplanet-se-lvr-av-typen-diamond-da42*

estimated to have been approximately 10,200 ft/min (52 m/s), which then gradually decreased to approximately 3,700 ft/min (19 m/s) prior to impact.

Though the three occupants were not unanimous in their descriptions of how the airplane spun, they all suggested that it spun with the nose pointing towards or slightly below the horizon. The aircraft was relatively level when it crashed, so that it was the belly of the fuselage that took the impact in the woodland. The two people in the front seats were seriously injured, while the passenger in the rear seat was thrown out of the airplane and sustained relatively mild injuries.

Diamond Aircraft Industries concluded in its report that the airplane had been flown advanced beyond its defined limits. It was thus not relevant to perform test flights to gain a better understanding of the airplane's characteristics during this type of flight.

The instructor had no acrobatic training. When the accident occurred, the airplane had an estimated mass of 1,682 kg. The DA 42 had a maximum take-off mass of 1,785 kg.[20] The centre of gravity was estimated at 2.45 metres, i.e. within the limits.

1.18.1.3 Accident on 12 September 2017 in France, involving a DA 42 NG (registration F-HFBS)[21]

The pilot had performed a go-round at Ghisonaccia-Alzitone Airport (LFKG) on Corsica due to difficult wind conditions. On the subsequent initial climb, the airplane stalled and crashed. All four people on board died in the crash. When the accident occurred, the airplane exceeded its maximum mass by 15 kg and the centre of gravity was estimated at 2.53 metres, which was significantly beyond the aft limit of 2.48 metres.

1.18.1.4 Incident on 20 July 2021 at Pilot Flight Academy, involving a DA 42 NG

An instructor flew a lesson with a student towards the very end of the program. A stall was carried out on a simulated final (approx. 5,000 feet) with flaps and undercarriage and landing gear extended. A go-around was initiated immediately on receiving the stall warning, but shortly after starting the climb-out, the crew experienced tail buffeting. The nose was pitched down to prevent stalling. Following the incident, the crew reviewed the mass and balance calculations. They showed a mass of approximately 1,850 kg with the centre of gravity at 2.45 metres, i.e. well within the limits and in the grey area in Figure 5.

1.18.1.5 Anonymously reported incidents involving DA 42 airplanes

An instructor who was providing flight training in Sweden has anonymously reported two spin incidents to the NSIA. He submitted the report when he learnt that there had been three people on board the airplane that crashed near Larvik.

The first incident occurred in August 2019. The instructor and a student were simulating a go-around at 5,200 ft (with a simulated runway at 5,000 ft). The student retracted the landing gear and flaps, and initiated climb-out. The instructor simulated failure in one engine (pulled back the power lever to 18%) and the student pitched up the nose of the airplane to achieve the right speed for a climb-out with power from one engine (85 KIAS, V_{YSE}/blue-line speed). At the same time, the student pressed the wrong rudder pedal and the airplane entered a spin. The instructor pitched the nose down and pulled back both engines to idle. He had to use full force on the pedal to counteract the student's action and exit the spin by 'kicking' the rudder in the opposite direction to the spin.

[20] The DA 42 has a lower maximum take-off mass (MTOM) than DA 42 NG.
[21] Investigated by the French Accident Investigation Authority. [Safety investigations - BEA - Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile]

The instructor experienced another spin incident in March 2021, this time with a passenger in the rear seat. The instructor and a student were simulating a go-around at 7,000 ft (with a simulated runway at 7,000 ft). The student retracted the landing gear and flaps, and initiated climb-out. At 7,400 ft, the instructor simulated failure in one engine (pulled back the power lever to 18%) and the student pulled the stick abruptly in order to achieve the right speed for a climb-out with power from one engine (85 KIAS). At the same time, the student pressed the wrong rudder pedal. The instructor joined the student at the controls and, as he was about to push the stick a little forward to pitch down the nose, the airplane entered a spin. The airplane rotated violently and the people on board were thrown sideways with some force. The instructor set both engines to idle, and kicked the rudder to the opposite direction of the spin. He did not manage to pitch the nose down and tried using asymmetric engine power to no avail. At one time he observed that the airplane was descending at a rate of 8,000 ft/min. It was difficult to read the instruments and the spin was very fast. The instructor had no control of the airplane and was holding the stick in the forward position when the spinning stopped, without him understanding why. When he regained control and the airplane started to climb, the altimeter showed 850 ft. The terrain in the area was at around 300 ft. One of the students withdrew from the pilot training programme after the incident, and the instructor requested and was granted a few days off.

The instructor noted that the nose-up pitch when the airplane entered the spin was steepest during the first incident (August 2019). Nonetheless, the spin in August 2021 was substantially more ‘brutal’, and he believed that this was possibly because there were three people on board. The instructor has therefore stopped simulating go-arounds with loss of engine power with three people on board. He also warns others in the industry against simulating go-arounds with loss of engine power with three people on board.

The instructor did not specify in which direction the aircraft was spinning.

1.18.2 MEASURES IMPLEMENTED AFTER THE ACCIDENT WITH LN-PFM

Following the LN-PFM accident, Pilot Flight Academy immediately decided that carrying passengers in the rear seat would no longer be permitted during instruction flights. PFA has subsequently lifted this limitation, and instead introduced centre of gravity limits for certain exercises, including slow flight and stall training. During such exercises, the centre of gravity must be between 2.438 and 2.46 metres, which, in practice, precludes carrying passengers (see Figure 5).

After an extensive review of the school’s activities, a number of steps have been taken to improve safety, including extending the time for preparations before each lesson, a 5-kt speed increase during slow flight sequences and a review of standardisations and procedures.

1.18.3 SPINNING

1.18.3.1 Introduction

An airplane can stall when flying at low speed. One wing will normally stall (lose lift) before the other, and the asymmetric lift can cause a wing to drop. If this is not stopped through correct use of flight controls, the airplane can start to rotate around its vertical axis (spin). Spinning involves a significant rate of descent.

Spins fall into three main categories:

- Upright spin. The nose points down and the airplane moves in a spiral pattern. Air is thus flowing over the tail surfaces and the flight controls work. Most upright spins can be exited by means of the right techniques.

- Inverted spin. An inverted spin has much in common with the upright spin, except that the airplane is upside down. This makes it difficult to understand what is happening and to take the right steps to exit the spin.
- Flat spin. The nose-up attitude is steeper than in an upright spin. The airplane has little or no speed forward and there is little or no airflow over the tail surfaces. A flat spin can occur if the centre of gravity is far aft (most likely outside the limit) or if such spin characteristics are typical for the airplane type. It may be impossible to exit a flat spin.

1.18.3.2 Guidelines from the Australian Civil Aviation Safety Authority

In April 2020, the Australian Civil Aviation Safety Authority published an advisory circular (AC 61-16v1.0) entitled *Spin avoidance and stall recovery training.* The following is taken from the introduction:

> *Stalling and spinning are aerodynamic phenomena which remain common causes of fatalities due to departures from controlled flight in all categories of aeroplanes. Unrecognised stall or poor recovery technique continue to be contributing factors even in transport category accidents.*
>
> *Stall – spin related accidents continue to account for approximately one-quarter of all fatal general aviation accidents worldwide, including many during dual flight training. Most unintentional spins other than during dual instruction, occur at altitudes too low for recovery, generally on climb after take-off and turns onto final approach.*

The following is stated about instruction in multi-engine aircraft:

> *For the stalling exercise in multi-engine aircraft, the aircraft should be recovered from the stall before power is applied to ensure yaw and roll are controllable with normal and coordinated inputs. Stall training should never be done with asymmetric power. Multi-engine aircraft are certified to the point of stall recovery but are not certified to enter a spin.*

1.18.3.3 Guidelines from EASA

The European General Aviation Safety Team (EGAST), an organisation under EASA, has published a leaflet entitled *Stall and spin loss of control.* The following is copied from the leaflet:

> *If a stalled aircraft rolls or yaws, perhaps as a result of a pilot's control inputs, it will start the incipient stage of a spin.*
>
> *Be prepared to react to the unexpected; if the aeroplane does not respond correctly to the control inputs, moving the control column forward will almost certainly be the most appropriate action to save the situation.*

1.18.4 STATISTICS

The US Aircraft Owners and Pilot Association (AOPA) strives, among other things, to improve the safety of general aviation. In 2003, the organisation published a report entitled *Stall/Spin: Entry point for crash and burn?* The report refers to a review of 44 fatal stall/spin accidents during the period 1991–2000. These accidents occurred in connection with flight training. As many as 91% occurred with an instructor on board, while only 9% occurred when the student was flying solo. Accidents during manoeuvring represented 64.4% of the total.

1.19 Useful or effective investigation techniques

1.19.1 COLLECTION AND ANALYSIS OF DATA FROM AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B) AND ENHANCED SURVEILLANCE (EHS)

As the wreckage, crash site and witnesses provided little information, the NSIA decided to investigate whether a better understanding of the flight could be gained by compiling *Automatic Dependent Surveillance-Broadcast* (ADS-B) and *Enhanced Surveillance* (EHS) data. Data were obtained both from Avinor and from Flightradar24. The data were validated and obvious errors excluded. Data from different sources were corrected to enable comparison. The data were then collated and presented graphically. Based on the data, it has been possible to gain a better understanding of the flight up until the time when it was 417 ft above the terrain. The purpose was primarily to understand the airplane's movements when the crew lost control and it subsequently fell to the ground. A further description of the methods used is given in Appendix A.

1.19.2 EXAMINATION OF PROPELLER BLADE ANGLE

It can be difficult to measure propeller blade angle if the propeller blades are broken or if the propeller's internal mechanism is damaged or displaced. Experience has shown that, in propellers where the blades are retained by ball bearings, heavy loads can damage the bearings. Such damage can tell us something about the position of the blades, and the NSIA therefore decided to investigate this.

When disassembling the right propeller at Norrønafly Propeller & NDT, it was decided to mark the position of the bearing races on the blade roots (see Figure 26). Once the blade roots and bearing races for blades 1 and 2 had been cleaned of dirt and grease, they were glued back into their correct position.

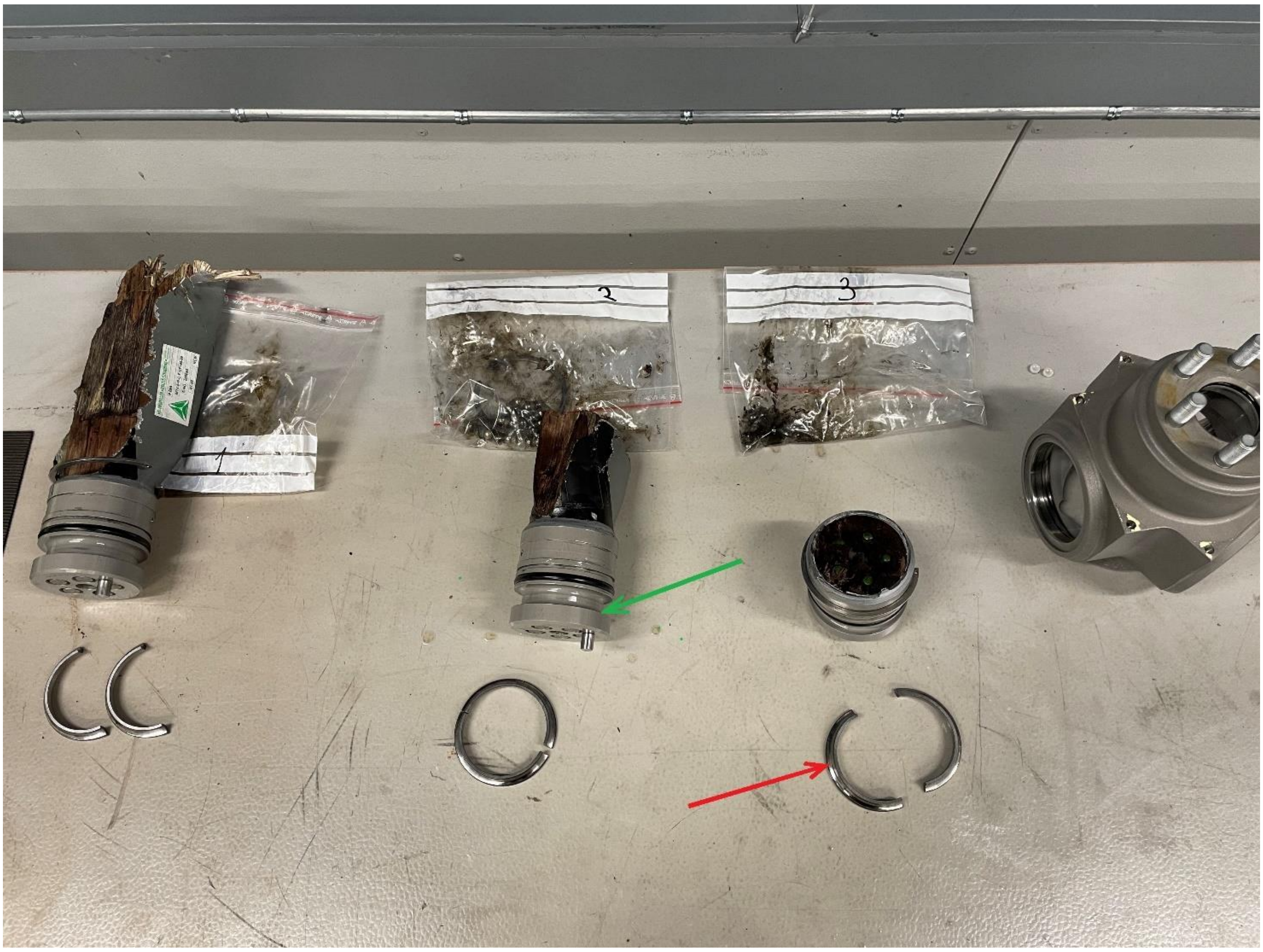

Figure 26: The three blade roots from the right propeller (blade 1 on the left) and the propeller hub (on the far right). The red arrow points to the two half races that were found on blade 3. The green arrow points to the groove on the blade roots where the bearing races belong. Photo: NSIA

Using a magnifying glass and strong light, dents imprinted into the bearing races were marked with a black marker pen. This applied to imprints into the inner bearing races in the propeller hub and the outer bearing races on the blade roots (see Figure 27). To facilitate comparison, distinct dents were marked with the number 3, and indistinct dents were marked with the number 1. The blade roots were then reinstalled in the hub, while trying to achieve the best possible alignment between the lines and numbers that represented the dents (see Figure 28). Once the blade roots had been correctly positioned, the distances between the blades' guide pins and the face of the hub were measured (marked with red arrows in Figure 23 and Figure 29). These distances were:

Blade 1: 48.3 mm.

Blade 3: 48.5 mm.

With the aid of an undamaged propeller and measuring equipment at Norrønafly Propeller & NDT, these measurements were found to correspond to blade angles of 12.1° and 12.2° for blade 1 and 3, respectively.

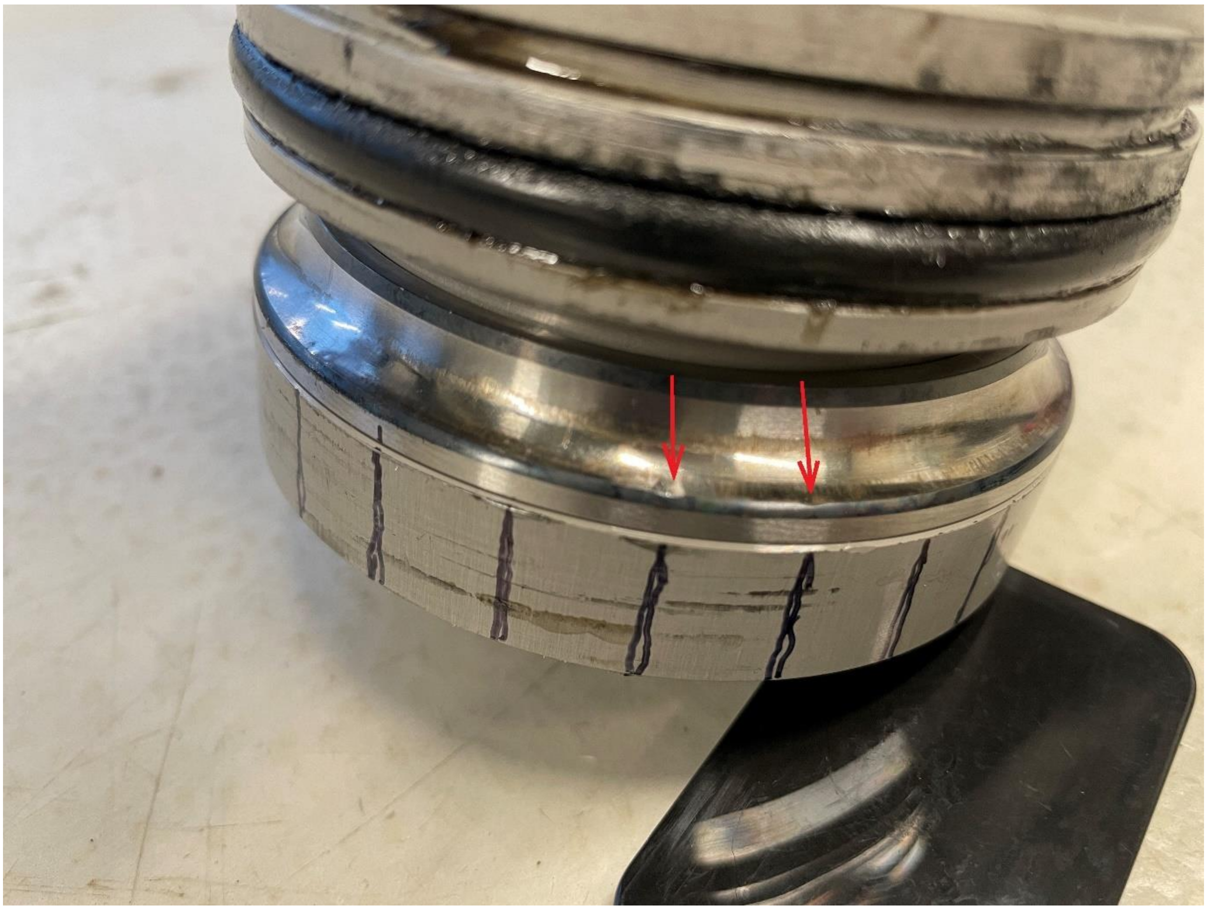

Figure 27: Photo of the root of blade 1 after marking the dents with a black marker pen. Two dents that are visible in the photo are marked with red arrows. Photo: NSIA

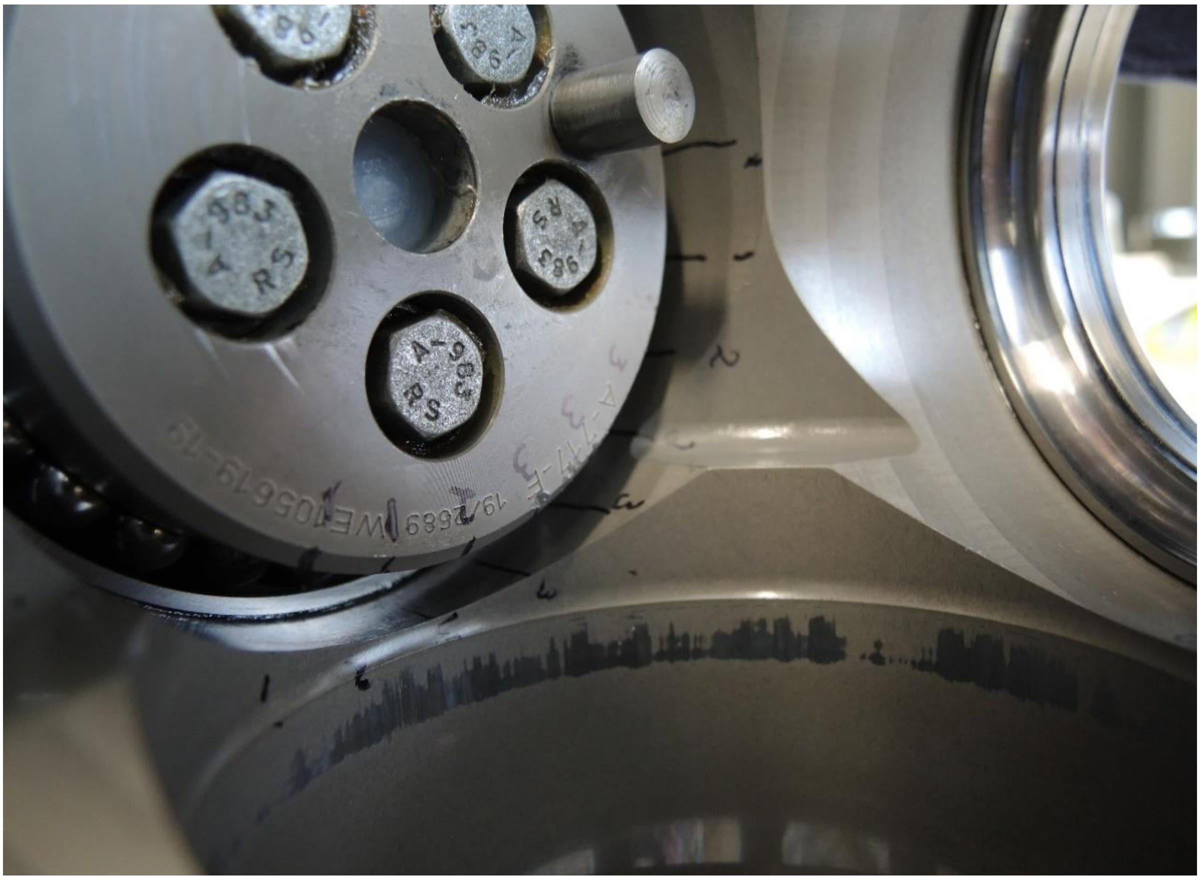

Figure 28: Blade 1 installed in the propeller hub. The numbers representing the extent of damage can be seen on both the blade root and hub. Photo: NSIA

Figure 29: Measuring the distances between the blades' guide pins and the face of the propeller hub.
Photo: BFU/NSIA

2. Analysis

2. Analysis

2.1 Introduction

Loss of control of the airplane was not observed by any eye witnesses and it has not been possible to retrieve data from the airplane or from navigational aids on board. Furthermore, the extent to which the airplane was destroyed meant that only limited information could be obtained from the wreckage.

Automatic Dependent Surveillance Broadcast (ADS-B) data, data from Flightradar24 and Avinor, and Enhanced Surveillance (EHS) data from Monopulse Secondary Surveillance Radar (MSSR) from Avinor have been the most important sources of information in the present investigation. In addition, the NSIA has managed to gather some information from the wreckage and crash site. It has thus been possible to establish the most probable sequence of events for important parts of the flight.

The flight was performed in what the NSIA deems to be fair weather conditions. The weather is therefore not subject to further analysis. The NSIA is also not aware of any mental or physical health problems pertaining to any of the persons involved. Such problems are therefore not discussed in this report.

2.2 Sequence of events

2.2.1 LOSS OF CONTROL

During the minutes preceding the accident, the airplane flew towards the periphery of the Helgeroa 1 training area. This gave the student a chance to get an overview of the area. A series of manoeuvres followed. The NSIA understands that it is not unusual to carry out these manoeuvres early on during training in a new airplane type. The manoeuvres were in line with the programme described by the school. Available information indicates that the flight proceeded as normal until control was lost during slow flight at an altitude of approximately 3,600 ft above ground level (AGL).

Two slow flight sequences were performed during the relevant period (see the labels with green outline in Figure 3). The speed was reduced to 81 kt and 72 kt, respectively. It is likely that a stall warning (first indication) was received during the second sequence. The NSIA believes that control of the airplane was probably lost during a third sequence, while the speed was being reduced once again. Examination of the wreckage showed that both flaps and landing gear had been deployed when the airplane hit the ground. It can therefore be assumed that the flaps and landing gear were also extended during the slow flight. It has been impossible to determine whether the instructor was flying the airplane to demonstrate the manoeuvre to the student, or whether the student was at the controls. Regardless of who flew the airplane when the problems arose, the instructor would be required to abort the manoeuvre and level the flight if the student did not master the situation.

Slow flight and stalls normally result in only a limited loss of altitude. Initiating such manoeuvres at approximately 3,600 ft (1,097 m) above the ground was within the requirements set by the flight school.

2.2.2 THE FALL TOWARDS THE GROUND

Available information indicates that the airplane entered a spin. The pitot tube is located under the left wing. A leftward rotation will therefore result in a significantly lower indicated airspeed (IAS) than a rightward rotation.[22] In the present case, a relatively high IAS was recorded, suggesting a rightward spin. That the airplane spun rightwards is supported by the witness's observations.

As suggested by Diamond Aircraft Industries' test pilot, the airplane probably oscillated a few times before gaining a stable sink rate after 7–8 seconds. That would explain the initial wide variations in sink rate and ground speed (GS) shown in Figure 31.

The airplane initially descended at a relatively low rate, but after losing altitude for approximately 8 seconds, the sink rate increased to approximately 8,000 ft/min (146 km/h). According to Diamond Aircraft Industries, the spin may have been flat. Available data indicate that the spin was relatively stable down to an altitude of approximately 200 metres above the ground.

Lack of information means that what happened during the final 200 metres of descent remains unknown. The witness's description suggests that the airplane spun with a steep nose-down attitude during the period he saw it. According to the NSIA's interpretation of findings at the crash site, the airplane must have hit the ground at a steep angle, heading in a direction of about 195°. Given that a tree approximately 2.5 metres from the point of impact remained undamaged, the angle of impact is assumed to have been at least 70°. Furthermore, the point of impact was so close to the edge of the rocky outcrop that the very forward part of the airplane was not damaged, but crushed from below. This can explain why the nose sustained relatively little damage.

It was not possible to find any traces of rotation at the crash site. This possibly suggests that the airplane had stopped rotating when it crashed and that control had partially been regained. It could also mean that the airplane hit the slope in a manner that left no recognisable traces of rotation.

It is not possible to determine exactly when the crew lost control of the airplane, but the NSIA estimates that it was out of control for approximately 30 seconds before impact with the ground.

The instructor probably tried to exit the spin by completing the first four steps of the spin recovery checklist (see chapter 1.6.4.3). Whether attempts were made to stop the rotation, for example by using asymmetric engine power, is not known. The flaps were fully extended when the airplane hit the ground. It is thus unlikely that any attempt was made to complete step 5 of the checklist.

In conclusion, it has not been possible to give a unequivocal description of the airplane's fall towards the ground or of what steps were taken to regain control.

2.2.3 ENGINES AND PROPELLERS

The engines were heavily damaged. In the NSIA's opinion, however, all the engine damage is compatible with heavy impact with the ground followed by intense heat and the application of extinguishing agents. The engines appeared to have been in good working order before the accident, and no findings indicate that they were unable to deliver the intended output.

The damage to the right engine's turbo system indicates that the engine was delivering power when the airplane hit the ground. The damage to the flywheel also indicates that it was rotating when the engine hit the ground with great force. Similar findings were not made in the left engine, but that does not exclude the possibility that it was also rotating and delivering power when the airplane hit the ground.

The propellers are designed so that the blades will feather if the engine is switched off with the ENGINE MASTER switch, or if the engine stops rotating or the oil pressure that regulates blade angle is lost for some other reason. Since blade angle is controlled by a common piston, the blade

[22] Clockwise rotation seen from above.

angle of all three blades on each propeller should be identical. Examination of the left propeller has been difficult, but attempts at measuring blade angles indicate that the propeller was close to the low pitch stop position. Corresponding measurements in the right propeller showed that it had reached the low pitch stop position. This suggests that the engines delivered little power, or that the airplane crashed to the ground at a relatively low airspeed. In the NSIA's opinion, based on the assessment of the blade angle, feathering of either propeller can be excluded. Feathering would have meant that one engine had stopped, whether by intention or some other cause.

2.2.4 CAUSE OF THE FIRE

The airplane carried an estimated 214 litres of fuel on impact with the ground. The fuel tanks probably ruptured in the crash and the fuel spread over the wreckage and crash site. There were several possible sources of ignition in the airplane, including hot engine components, the electrical system and points of intense heat produced in connection with the heavy impact with the ground. Hence the fuel was probably ignited immediately.

The aircraft was mainly made of carbon composite with combustible matrix material (binding agent). The total amount of combustible material in the airplane produced an intense fire of long duration.

2.3 DA 42 NG's flight characteristics

There are no requirements for approval or documentation of the spin characteristics of multi-engine airplanes. Exiting a spin in a multi-engine aircraft is difficult, because inertia from the engines on the wings will tend to maintain the rotation. In connection with design and certification, the emphasis is therefore on giving it benign flight characteristics that protect the airplane from entering a spin.

One previous spin accident with a DA 42 is known and documented with a repport. During the investigation, the NSIA has received anonymous tips about two other incidents in which the airplane type entered a spin. These incidents indicate that the airplane type can enter a spin when the centre of gravity is close to the aft limit, particularly if the flight is uncoordinated (incorrect use of flight controls) or if engine power is asymmetric. These incidents indicate that this type of airplane can be particularly difficult to get out of a spin if there are passengers in the rear seat.

The centre of gravity limits of an airplane is defined and approved on the basis of extensive calculations and tests. This means that an airplane may be flown as long as the centre of gravity is within the given limits. Safety, however, is often about giving yourself extra margins. This also applies to the position of the centre of gravity. Slow flights increase the risk. The NSIA is therefore of the opinion that Pilot Flight Academy made the right decision when, following the accident, it introduced stricter centre of gravity limits, including for slow flights and stalls. In practice, this means that passengers may not be taken on board during such training.

LN-PFM's auxiliary tanks were almost full. It is also likely that the difference in fuel volume between the main tanks was well within the maximum difference of 18.9 litres (see chapter 1.6.8). The rear seat passenger would have sat on one side, but the distance from the airplane's centreline would not have any significant effect on the lateral balance of the airplane. Uneven weight distribution is thus not considered to have played a role in causing the airplane to spin.

2.4 Flight school

The NSIA considers that, despite the DA 42 NG simulator training carried out at Pilot Flight Academy, the preparations for the student's first flight in Norwegian airspace included many elements with which the student was unfamiliar. The student had previously only flown in the USA, where procedures and phrases used for communication with the air traffic service are somewhat different. Even if the simulator gives the student good insight into systems and characteristics, it is very different from a real flight. Some of the school's pre-flight preparation procedures were also different from those used for simulated flights.

Due to a mistake, only one hour was set aside for pre-flight preparations, and not an hour and a half as prescribed. To what extent this had a bearing on the preparations is unknown. That important documents were mistakenly not left behind at the school and that the code from the previous flight (P620M) was left unchanged in the ADS-B transmitter indicate that there was a certain element of stress during the preparations. The departure also had to be delayed because they were squeezed for time. Flight instructions can be demanding to both student and instructor. The fact that the flight came out somewhat "wrong" right from the start may thus have had a bearing on the entire flight. However, the communication between the student and air traffic control did not indicate a high level of stress.

Since what caused loss of control of the aircraft remains unknown, it is also hard to determine what factors might have had a bearing on the sequence of events. During interviews, the school's flight instructors told the NSIA that the flight appeared to have proceeded as normal up until the time when control of the airplane was lost. No abnormal manoeuvres were observed and the flight was performed in line with what could be expected. According to the school's management, it was natural to demonstrate or let the student try a slow flight sequence in landing configuration (flaps and landing gear extended), with reduction of speed to just above stalling speed. There are clear indications that they performed three manoeuvres, reducing the minimum speed each time. Loss of control may have occurred during a slow flight at or just above stalling speed.

Spin training is not permitted with the DA 42 NG. It is important, however, that whoever is flying the airplane has a good theoretical knowledge of spins, knows by heart what steps to take to prevent a spin from escalating and are well knowledgeable in spin recovery. In addition, the flight school should make sure that all students and instructors are familiar with the content of spin recovery checklists. Before any lesson that includes slow flight, the student should for instance demonstrate having learnt by heart what steps to take to exit a spin. The NSIA is under the impression that Pilot Flight Academy has not devoted sufficient attention to spins. The fact that the recovery from spin checklist is not an explicit required memory item may be an indication of insufficient spin attention.

A key question is the extent to which the points above could have been captured by the school's Safety Management System, so that the overall risk was as low as reasonably practicable. This must be seen in relation to the increased consequences by the fact that a passenger was on board.

2.5 Possible causal factors

2.5.1 INTRODUCTION

As mentioned above, the NSIA has been unable to give a clear explanation of what caused loss of control of the airplane. Some possible scenarios that could explain why control of the airplane was lost and why nobody managed to regain control before it fell to the ground are described below.

2.5.2 TECHNICAL FAULTS IN THE AIRCRAFT

The NSIA cannot rule out that technical faults occurred in connection with the slow flight. In a thorough examination of the wreckage, remnants were found of all essential parts of the airplane. No parts were found that could have fallen off the airplane before impact with the ground. Seen together, this indicates that the accident was not caused by structural failure. Based on examinations of the wreckage, it can also be virtually ruled out that any mechanical fault occurred in the flight controls.

All mechanical faults cannot be excluded, however. For example, if the rods for the right or left flaps broke, the flaps on one side would go up. The resulting imbalance would be great enough for the airplane to enter a spin. The flaps mechanism is robust and simple, however. Such a fault is therefore unlikely, but, if it occurred, it could have caused a spin that would be very difficult to exit. Most other flight control faults would have had a less critical effect on the flight.

The NSIA has no reason to suspect that other types of faults have affected the aircraft, but it cannot be ruled out. Such failures may in that case have taken attention away from the flight or caused confusion. For example, if the stall warning system failed, the speed may have been lower than intended before the slow flight should have been aborted. Since there were no icing conditions during the flight, the stall warning system would not be affected by any failure of the heating element.

2.5.3 ENGINE OR PROPELLER FAULTS

The engines were heavily damaged in the crash and the subsequent fire. No faults that could have arisen prior to the accident were found during the examinations. All the mechanical damage that was found is compatible with heavy impact with the ground. Because the engine damage was so extensive, faults cannot be ruled out, particularly relating to control systems and wires.

The NSIA believes that damage to the right engine indicates that the right engine was rotating and delivering power when the airplane crashed. Damage to the left engine provides no clear answer.

The propellers were knocked off the engine and found together out of reach of the fire, and had thereby escaped fire damage. The examinations of the propellers gave no indication of any obvious mechanical fault that could have arisen before the accident. The damage to the propellers suggests that they were rotating on impact with the ground, but gives little indication of the speed of rotation.

Examinations of the right propeller showed minimum or close to minimum blade angle (low pitch stop) on impact with the ground. Examinations of the left propeller did not give an equally clear indication, but suggest that these blades were also close to the low pitch stop position. It is therefore unlikely that the propellers were feathered, which would have been an indication that the engines had stopped.

Normal spin recovery procedures include pulling the power lever back to idle. It is thus natural to expect that the engines were rotating at low output and that the blade angle was close to low pitch stop when the airplane crashed, as indicated by findings on the right propeller.

One possible cause of spin during slow flight is asymmetric propeller thrust. Such asymmetry can be due to:

- An engine fault that reduces or stops power output from one of the engines at the same time as output from the other engine is increased.
- Fault in pitch regulation on one propeller.

The investigating authority has no basis for concluding whether any of these factors came into play.

2.5.4 MANOEUVRING OF THE AIRCRAFT

Whether it was the student or the instructor who flew the airplane when control was lost remains unknown. Available information indicates that the crew had already completed two slow flight sequences. It is therefore possible that the third slow flight sequence, when control of the airplane was lost, was flown by the student. If the training had been so successful that they had reached the stage of slow flight with one engine idle, on the other hand, the student is less likely to have flown the airplane.

When training slow flight sequences and stall recovery, possible mistakes can be made, for example:

- On completing a slow flight sequence, the increase in engine power requires stepping on the right pedal. Stepping on the left pedal, on the other hand, can initiate a left roll. Setting the rudder trim tab 10° to the left may have resulted in a significant force having to be applied to the right rudder pedal during the exercise. This may have led to an uncoordinated flight, causing an unexpected wing drop (roll).
- If the power levers are pushed forward unevenly when completing a slow flight sequence, the asymmetric increase in engine power can cause the airplane to enter a spin.
- On the other hand, if the throttles are moved forward too abruptly on completing the slow flight sequence, torque from the two engines can cause the left wing to drop (roll).
- Reducing the speed to just above the stalling speed during a slow flight sequence can cause one wing to drop. Instinctively, the pilot will try to move the stick towards the other wing to try to pick up the dropping wing. This will lower the aileron and increase the angle of attack of that part of the wing that is already about to stall. This exacerbates the situation and can cause the airplane to enter a spin.

Common to the examples mentioned above is that the airplane can enter a spin unless the situation is handled immediately and correctly. Based on the present accident and previous incidents, the airplane type appears to be difficult to handle in certain situations if the centre of gravity is far aft, even if it is within limits. Following the accident, the flight school has therefore introduced stricter centre of gravity limits for certain types of flights.

The NSIA believes that it is unlikely that the Variable Elevator Stop or Electronic Stability and Protection System had a negative impact on the manoeuvring of the aircraft.

2.5.5 THE FLIGHT INSTRUCTOR'S ROLE

Instructors are faced with a well-known dilemma: At what stage should the instructor interfere when the student makes a mistake? Too soon means poorer learning because the student does not understand the consequences of his/her own actions. Too late can give rise to dangerous situations. There are many examples of accidents in which the instructor has failed to interfere soon enough. The consequences become less visible if the instructor intervenes too soon, and examples of this are therefore difficult to document.

In the present accident, a situation most probably arose in which, for reasons unknown, control of the airplane was about to be lost. The next question then is why the instructor also failed to regain control before the airplane started to spin.

The space of time from when the flight proceeded as expected until control was lost was probably very short. The sudden transition to a critical situation may briefly have reduced the instructor's cognitive capacity and ability to handle the airplane (startle effect). That would be a normal human reaction and may have caused delayed or incorrect intervention on his part.

The instructor is meant to constitute a safety barrier against hazardous situations. Other than theoretical instruction, the instructor had received only 45 minutes of flight training related to stalling and spinning. In the NSIA's opinion, theoretical instruction and 45 minutes' practical training do not provide a sufficient basis for preventing a spin. The skills required to recognise and exit a spin cannot be learnt theoretically. Spins must be experienced and training given so that they are handled instinctively. Statistics from AOPA (see chapter 1.18.4) suggest that instructors do not constitute the desired safety barrier.

In the NSIA's view, instructors should have the mental capacity to recognise and intervene in situations that can arise if a student makes a mistake. The ability to recover from a spin must be refreshed regularly. Requirements should therefore be defined for maintaining the necessary knowledge and skills.

Based on this the Norwegian Safety Investigation Authority recommends that the European Aviation Safety Authority (EASA) consider the requirements for practical training and refresher training of flight instructors, with the emphasis on spin prevention and spin recovery.

A draft report was sent to EASA for consultation. The response was that EASA considered the applicable rules to be robust enough. However, the NSIA chooses to retain the safety recommendation.

2.6 Survival aspects

The airplane crashed into the hilly terrain at an estimated speed of around 145 km/h. The NSIA believes that the forces involved in the crash were so great that it would have been impossible to survive, even with optimum use of recognised protective equipment.

The air traffic service lost contact with the aircraft and, shortly afterwards, received verification that a fire had broken out in the area. Approximately 12 minutes after the accident, it was assumed that LN-PFM had most probably crashed. Even with full deployment of the emergency services, it was not possible to affect the outcome.

Signals from the emergency locator transmitter were picked up for a brief period after the accident. This suggests that the transmitter came on, but that the transmitter, antenna cable or antenna was soon destroyed by the fire.

3. Conclusion

3. Conclusion

3.1 Main conclusion

During slow flight training with the landing gear and flaps deployed (landing configuration) at an altitude of approximately 3,600 ft above the terrain, control of the airplane was lost and it spun to the ground. The NSIA has had limited access to information and it has not been possible to establish unequivocally why control of the airplane was lost and could not be regained in time to prevent the accident.

3.2 Investigation results

A. The commander was licenced for providing instruction on the flight.

B. There are no requirements for practical refresher training for instructors in spin prevention and spin recovery.

C. The accident flight was the student's first training flight in Norway, the first flight with a twin-engine airplane and first flight in a DA 42 NG type airplane.

D. The flight was part of an approved training program.

E. Because of a mistake, too little time was set aside for pre-flight preparations. This may have caused some degree of stress.

F. The NSIA is not aware of any mental or physical health problems pertaining to any of the persons involved.

G. Type approval of the DA 42 airplane type was granted by the European Aviation Safety Agency (EASA) in July 2005.

H. The airplane was airworthy and without known faults when it took off from Sandefjord Airport Torp.

I. The airplane's mass and centre of gravity were within the limits, even if the centre of gravity was close to the aft limit.

J. The flight was performed in what the NSIA considers to be fair weather conditions.

K. After departure, LN-PFM flew to the Helgeroa 1 training area where it started performing manoeuvres, including turns and slow flight sequences. The accident occurred in connection with the third slow flight sequence.

L. Based on analyses of the flight up until the accident occurred, the flight academy is of the opinion that it proceeded as expected.

M. The flight is well documented up until the point at which the speed was reduced to 65 KIAS at an altitude of 3,960 ft (AMSL) and the airplane banked 7° to the left. From then on, the airplane lost altitude quickly. Because of a limited amount of available data, it is not possible to describe what happened next.

N. Whether it was the student or the instructor who flew the airplane when control was lost remains unknown.

O. During the descent towards the ground, the rate of altitude loss became stable at approximately 8,000 ft/min (40 m/sec).

P. A witness approximately 2 km from the crash site saw the airplane spin vertically towards the ground.

Q. It would have been impossible to survive the impact, and the three people on board died instantly.

R. The impact with the ground was heavy and virtually all parts of the wreckage were consumed by fire or damaged by the heat.

S. The wreckage showed heavy damage and it has not been possible to determine what caused loss of control of the airplane based on examinations of the wreckage parts.

T. The airplane type is not certified for spinning as this is not required for multi-engine airplanes in the normal category (CS-23).

U. The airplane type is sensitive to loading and centre of gravity position.

V. In common with most other aircraft types, the flight characteristics on the DA 42 NG become more demanding with respect to stalling when the centre of gravity is close to the aft limit. Available information indicates that the same applies to spinning.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority submits the following safety recommendation:[23]

Safety recommendation Aviation No 2023/04T

On Tuesday 23 November 2021, a student and an instructor were practicing slow flight at 3,600 ft above ground level in a Diamond DA 42 NG. The airplane entered a spin and crashed for unknown reasons. Whether it was the student or the instructor who flew the airplane when control was lost remains unknown, but the flight instructor should be the safety barrier. There are no requirements for practical refresher training for instructors in spin prevention and spin recovery.

The Norwegian Safety Investigation Authority recommends that the European Aviation Safety Authority (EASA) consider the requirements for practical training and refresher training of flight instructors, with the emphasis on spin prevention and spin recovery.

Norwegian Safety Investigation Authority
Lillestrøm, 14 February 2023

[23] The Ministry of Transport forwards safety recommendations to the Civil Aviation Authority and/or other involved ministries for evaluation and follow-up; see Section 8 of the Regulations on Public Investigations of Accidents and Incidents in Civil Aviation.

Abbreviations and references

Abbreviations

A	Aircraft
ADS-B	Automatic Dependent Surveillance Broadcast
AMM	Aircraft Maintenance Manual
AMSL	Above mean sea level
AOPA	Aircraft Owners and Pilot Association
ATPL(A)	Air Transport Pilot Licence, Airplane
BFU	Bundesstelle für Flugunfalluntersuchung – the German investigating authority
CS	Certification Specifications
CWS	Control Wheel Steering
EASA	European Aviation Safety Agency
EHS	Enhanced Surveillance – Monopulse Secondary Surveillance radar
ESP	Electronic Stability and Protection System
FI	Flight Instructor
ft	foot/feet (0.305 m)
GPS	Global Positioning System
GS	Ground speed
hPa	Hectopascal
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization (a UN organisation)
IFR	Instrument Flight Rules
IR	Instrument Rating for Airplane
JAR	Joint Aviation Requirements (for Europe before the establishment of EASA)
KIAS	Knots indicated airspeed
kt	knot(s) – nautical mile(s) (1,852 m) per hour
ME	Multi-engine
MHz	megahertz
NSIA	Norwegian Safety Investigation Authority

PFA	Pilot Flight Academy
PPL(A)	Private Pilot Licence Airplane
QNH	Altimeter pressure setting related to pressure mean sea level
SPIC	Student Pilot In Command (student flying solo)
SOP	Standard Operating Procedures
TMA	Terminal control area; airspace in a defined altitude above/near a controlled airport
UPRT	Upset Prevention and Recovery Training
UTC	Coordinated Universal Time
VFR	Visual Flight Rules

Appendices

Appendix A COLLECTION AND ANALYSIS OF DATA FROM AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B) AND ENHANCED SURVEILLANCE (EHS)

INTRODUCTION

In this investigation, the NSIA has obtained data from Automatic Dependent Surveillance Broadcast (ADS-B) data from Flightradar24 and Avinor, and Enhanced Surveillance (EHS) data from Monopulse Secondary Surveillance Radar (MSSR) from Avinor, facilitating analysis of the accident flight. A total of 8,058 datapoints were collected during the 44 minutes that it took from the airplane started recording until it crashed. The three datasets were not recorded on a common timeline, and it was therefore important to establish a common timeline where the datapoints from all datasets could be plotted in chronological order. Flightradar24's first datapoint for the flight was at 08:25:58.578 (local time) and was chosen as the 00:00:00.000 point on the timeline. The last data point (from Avinor ADS-B dataset) was at 09:10:23.000 and corresponds to 00:44:24.972 on the timeline.

Datapoints were chosen from the different datasubsets for inclusion in the superset of datapoints. The following data were selected and analysed:

- Local time
- Position (longitude and latitude)
- GPS altitude
- Barometric altitude
- Vertical speed
- Ground speed
- Indicated airspeed
- True airspeed
- Heading
- Bank angle

Datapoints where a value deviated greatly from previous and subsequent datapoints values in the superset chronological overview were excluded from or corrected for further analysis. Great deviations in values were defined as deviations greater than those that could be expected on a normal flight during the relevant time period. Some datapoints showed zero values ('0.00') and were also excluded from further analysis.

Analysis of the accident sequence shows that the airplane departed controlled flight during the final 30 seconds for which data are available, and particular attention has been given to analysing data from those 30 seconds.

ADS-B DATASET FROM AVINOR

The airplane transmitted ADS-B data out via its Mode S transponder. ADS-B data broadcasted from the airplane were received by an Avinor ground system in Norway. In the area of Sandefjord Airport Torp, Avinor lacks ADS-B coverage down to ground level, and the first datapoint was therefore received by Avinor's ground system at 08:37:05.990, approximately 12 minutes after the first datapoint from Flightradar24. The NSIA has analysed a total of 984 datapoints from Avinor, the first being at 08:37:05.990 and the last at 09:10:23.550. The NSIA has analysed the following data from the ADS-B dataset from Avinor:

- Local time
- Position (longitude and latitude)

- GPS altitude
- Barometric altitude
- Barometric vertical speed
- Ground speed
- Heading

The received ADS-B data from Avinor were not corrected with respect to GPS altitude and barometric altitude, which means that GPS altitude is stated as elevation above the WGS84 ellipsoid[24] while barometric altitude is stated with standard pressure (1,013 hPa).

Geoid undulation calculating the difference between the geoid height (referred to as the mean sea level – MSL) and the WGS84 ellipsoid height. An uncorrected GPS altitude only shows the distance between the GPS receiver and the WGS84 ellipsoid as shown in Figure 30.

The NSIA has used a geoid height calculator[25] to calculate actual GPS altitude for all the datapoints on the flight based on uncorrected GPS altitudes and relevant GPS positions (longitude and latitude).

The geoid undulation needs to be calculated for each specific GPS position (longitude and latitude). It calculates a height difference that must be added to or subtracted from the GPS altitude to get a correct GPS altitude depending on if the ellipsoid is above or below the geoid. In the area where the accident occurred, the ellipsoid lies below the geoid, so that uncorrected GPS altitudes show higher values than actual GPS altitudes. In the area where the accident flight was conducted, there was an average difference of 116 ft between the ellipsoid and the geoid. The average correct altitude will therefore be 116 ft below the stated altitude.

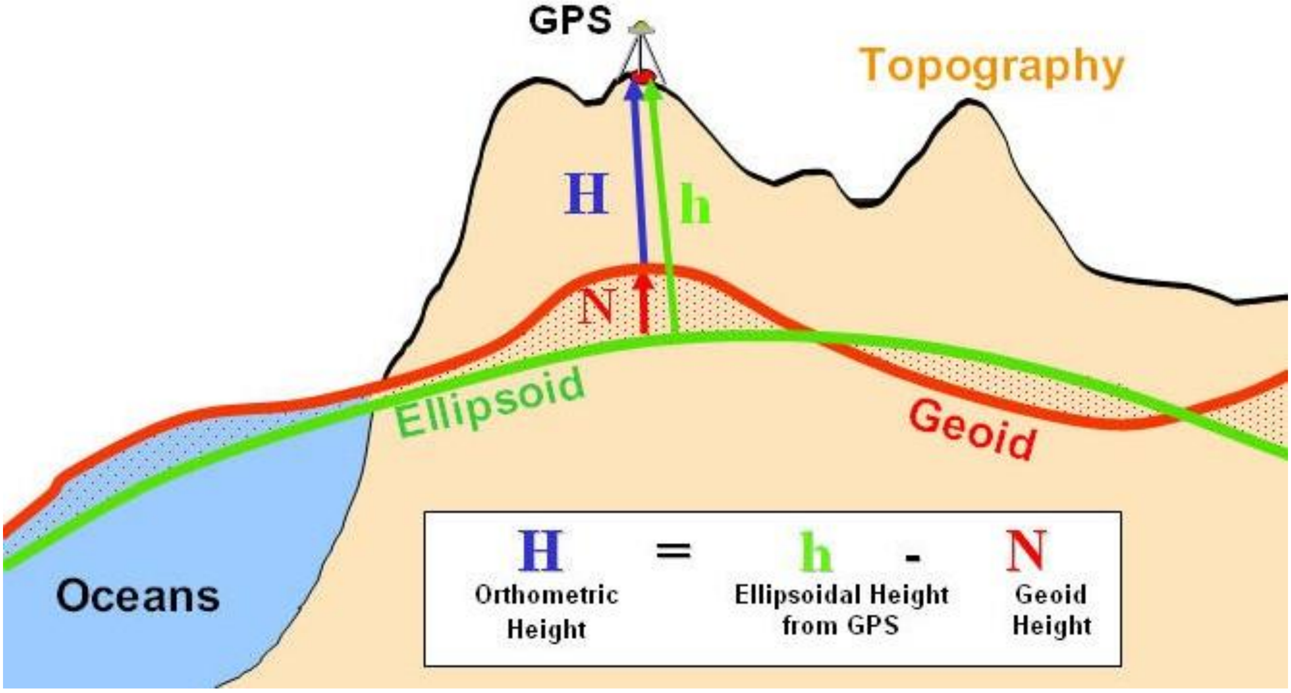

Figure 30: Geoid and ellipsoid. Source: National Center for Polar and Ice Research/ NSIA

[24] *The elevation used by GPS as height reference*
[25] *https://www.unavco.org/software/geodetic-utilities/geoid-height-calculator/geoid-height-calculator.html*

The ADS-B standard allows aircraft to broadcast both GPS altitude and barometric altitude. The airplane involved in the accident transmitted both GPS altitude and barometric altitude as part of its ADS-B data.

The barometric or pressure altitudes reported by the airplane are based on its pitot static system. A pressure altimeter uses standard pressure (1,013 hPa) as the basis for calculating and presenting altitudes. If the local pressure differs from the standard pressure, the crew must make a correction (QNH) for the pressure altitude displayed in the cockpit to be correct. In this case, Avinor has confirmed that the local pressure at Lavik was 1,018 HPa. This is a difference of 5 hPa, which results in a difference of (5 x 27 = 135 ft) on the aircraft's barometric altimeter. For example, if the airplane's altimeter showed 4,025 ft and local QNH had not been set, the actual altitude would be 4,160 ft. QNH was set correctly in LN-PFM, but ADS-B data for barometric altitude are broadcast without QNH correction.

ADS-B DATASET FROM FLIGHTRADAR24

On the NSIA's request, Flightradar24 submitted all ADS-B data transmitted by LN-PFM for the accident flight.

The NSIA have analysed a total of 6,670 datapoints from Flightradar24, the first being at 08:25:58.578 and the last at 09:10:20.536. The dataset was used for analysis of:

- Local time
- Position (longitude and latitude)
- Barometric altitude
- Vertical speed
- Ground speed
- Heading

The barometric altitude data transmitted by the airplane's Mode S transponder were uncorrected, which meant that barometric altitude had to be corrected for local QNH as described in the previous chapter before the data could be compared with barometric altitude data and GPS altitude data from Avinor ADS-B.

EHS DATASET FROM AVINOR

Enhanced surveillance is made possible through use of an MSSR. The airplane's Mode S transponder transmits Binary Data Store (BDS) register data in response to MSSR interrogation on frequency 1,030MHz. The airplane replies by sending the contents of BDS registers 4, 5 and 6 to the ground system on frequency 1,090 MHz. The MSSR antenna rotates, and the groundstation can only receive data when the antenna points towards the airplane. The frequency by which new datapoints are recorded is therefore dependant on the antenna's speed of rotation. The NSIA has analysed a total of 404 EHS datapoints from Avinor, the first being at 08:37:00.422 and the last at 08:10:17.948. This corresponds to data intervals of approximately five seconds.

The dataset was used for analysis of:

- Position (longitude and latitude)
- Barometric altitude (Flight Level (FL))
- Vertical speed
- Bank angle
- Local QNH setting
- Heading
- Ground speed

- Indicated airspeed
- True airspeed

Barometric altitude is shown as flight level (FL). For example, FL1.25 corresponds to an altitude of 125 ft at standard pressure. That meant that altitude data had to be converted from FL to foot and then corrected for local QNH to determine the correct altitudes. Barometric altitude was corrected as described in the chapter ADS-B dataset from Avinor.

EVALUATION OF DATA

GPS position

The airplane's GPS positions from Avinor ADS-B and Flightradar24 ADS-B were compared by plotting position data from Flightradar24 and data from Avinor separately and then comparing them in a graphical presentation. The ADS-B dataset from Avinor consisted of 984 GPS datapoints and all these were retained. The ADS-B dataset from Flightradar24 contained 6,670 GPS datapoints, 2,962 of which were excluded because they showed zero values ('0.000') for both longitude and latitude, while the remaining 3,707 datapoints were retained for further analysis. The superset thus comprised 4,691 GPS datapoints for further analysis.

Barometric altitude

Altitude data included GPS altitudes from the Avinor ADS-B dataset and barometric altitudes from the Avinor EHS dataset and Flightradar24 ADS-B dataset. GPS altitudes were corrected for geoid undulation and barometric altitudes were corrected for local QNH, as described above. This made it possible to compare the altitudes.

The ADS-B dataset from Avinor contained 984 datapoints for barometric altitude, and all these were retained. The EHS dataset from Avinor contained 404 datapoints for barometric altitude, of which 2 were excluded and 402 retained. The ADS-B dataset from Flightradar24 included 6,670 datapoints for barometric altitude, of which 13 were excluded and 6,657 retained. The graphical presentation of the airplane's barometric altitude is thus based on 8,043 datapoints.

Vertical speed

The airplane's vertical speed was based on datapoints from all three datasets (Avinor ADS-B, Avinor EHS and Flightradar24 ADS-B). The ADS-B dataset from Avinor contained 984 datapoints for vertical speed, and all these were retained. The EHS dataset from Avinor contained 404 datapoints for vertical speed, 11 of which were excluded. This left 393 datapoints that were subjected to further analysis. The ADS-B dataset from Flightradar24 contained 6,670 datapoints for vertical speed. Many datapoints were excluded because of great deviation, particularly those recorded during the final 25 seconds of the airplane's descent. The graphical presentation of vertical speed is thus based on 8,045 datapoints.

Ground speed

The airplane's ground speed was based on datapoints from all three datasets (Avinor ADS-B, Avinor EHS and Flightradar24 ADS-B). The ADS-B dataset from Avinor contained 984 datapoints for ground speed, and all these were retained. The EHS dataset from Avinor contained 404 datapoints, 11 of which were excluded. This left 393 datapoints that could be subjected to further analysis. The ADS-B dataset from Flightradar24 contained 6,670 datapoints for ground speed. Many datapoints were deleted because of great deviations. Some of the deleted datapoints were replaced by interpolated datapoints. The graphical presentation of ground speed is thus based on 8,037 datapoints.

Indicated airspeed and true airspeed

The EHS dataset from Avinor included datapoints for the airplane's indicated airspeed (IAS) and true airspeed (TAS). These datapoints have a frequency of approximately 0.20 Hz, corresponding to datapoint intervals of five seconds. The dataset contained 404 datapoints, 11 of which were excluded. The graphical presentation of the airplane's airspeed is thus based on 393 datapoints.

Heading

The airplane's heading was based on datapoints from all three datasets (Avinor ADS-B, Avinor EHS and Flightradar24 ADS-B). The ADS-B dataset from Avinor contained 984 datapoints for aircraft heading, and all these were retained. The EHS dataset from Avinor contained 404 datapoints for aircraft heading, 11 of which were excluded. This left 393 datapoints that could be subjected to further analysis. The ADS-B dataset from Flightradar24 contained 6,670 datapoints for aircraft heading. Many datapoints were deleted because of great deviations. The deleted datapoints were replaced by interpolated datapoints. The graphical presentation of the airplane's heading is thus based on 8,047 datapoints.

Bank angle

The airplane's bank angle is based on datapoints from the EHS dataset obtained from Avinor. These datapoints have a frequency of approximately 0.20 Hz, corresponding to datapoint intervals of five seconds. The dataset contained 404 datapoints, 11 of which were excluded. This left 393 datapoints that could be subjected to further analysis. Note that the 11 datapoints that were excluded were the same as for the airplane's airspeed. It is therefore likely that these datapoints were incompletely read or that an error occurred whereby time and barometric altitude are the only true values.

GRAPHICAL COMPILATION OF DATA

The data were analysed by creating graphical representations of different time periods of the flight. Graphical overviews were created for the whole flight (08:25:58–09:10:23), the final 04:25 minutes of the flight (09:05:58–09:10:23) and the final 30 seconds of the flight (09:09:53–09:10:23), respectively. The following data were presented graphically for each of the three time periods:

- Position
- Barometric altitude and ground speed
- Barometric altitude and vertical speed
- Vertical speed and ground speed
- Ground speed and indicated air speed
- Vertical speed and indicated airspeed
- Bank angle
- Aircraft heading
- GPS altitude and barometric altitude

The data give a good understanding of the flight up until the time when it departed controlled flight. In the superset, we find data points that are incompatible with normal flying. These points suggest that the aircraft may have moved significantly between each data point. A graphical presentation of the final data from the flight is given below. Only relevant data are used in the graphical presentations in this report.

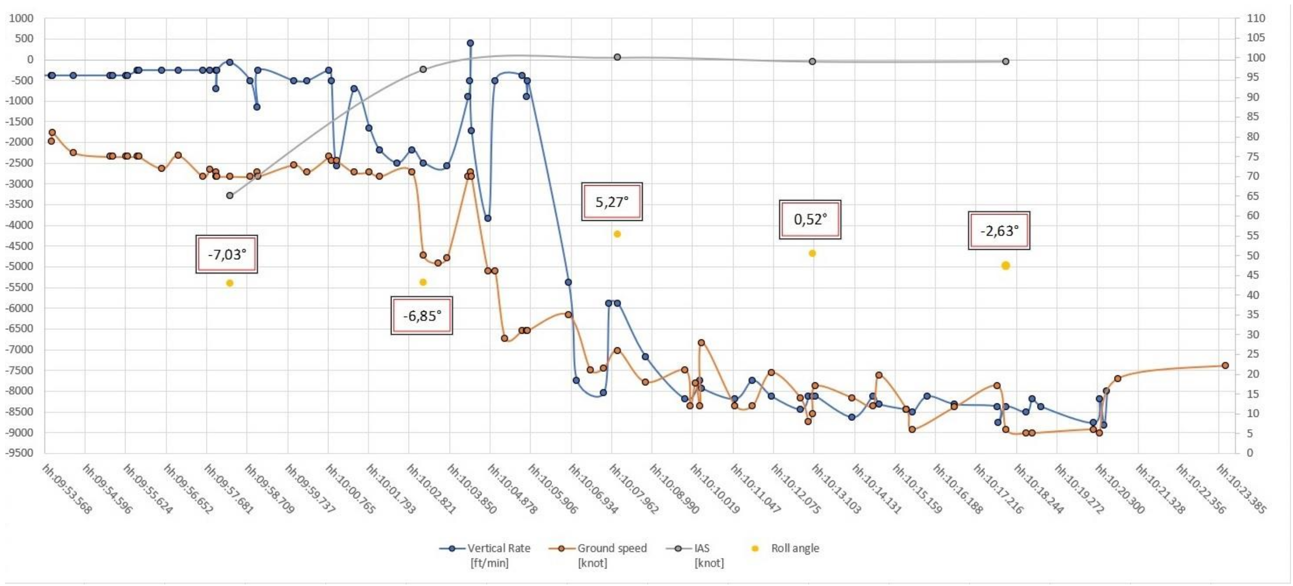

Figure 31: A compilation of data for the final 30 seconds for which data were available. The scale on the left shows vertical speed in feet per minute. The scale on the right shows speed in knots. Data for roll angle is indicated as yellow dots. Negative angles indicate rolling to the left. The graph was prepared by the NSIA