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SAFETY BOARD

Fatal loss of control accident with a Pipistrel Alpha Electro near Stadskanaal airfield

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The Hague, July 2020

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Cover photo: H. Ranter.

The Dutch Safety Board

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N.B. This report is published in the Dutch and English languages. If there is a difference in interpretation between the Dutch and English versions, the English text will prevail.

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SUMMARY

On 13 October 2018, the electric-powered aeroplane, an Italian registered Pipistrel Alpha Electro, departed from Drachten airfield and set course towards Stadskanaal airfield. The pilot was its only occupant. At the destination, he joined the aerodrome traffic circuit. In the circuit, after turning from downwind to base leg, the aeroplane suddenly lost altitude and impacted the ground. Shortly thereafter the aeroplane caught fire. The pilot was fatally injured. The aeroplane was destroyed as a result of the crash and the post-impact fire.

Since this was the first accident with an electric-powered aeroplane in the Netherlands and the first worldwide with a Pipistrel Alpha Electro, the Dutch Safety Board examined multiple aspects beyond the direct cause of the accident. This investigation answers three questions: What caused the aeroplane to crash? To what extent does the permission for this microlight aeroplane with a foreign registration to operate in Dutch airspace guarantee a minimum level of safety? What concerns can be identified in case of an accident with a microlight aeroplane powered by lithium-ion batteries?

The Dutch Safety Board has reached the following conclusions. First it was found that there were technical problems with the batteries prior to the fatal flight. The investigation has shown that the batteries nevertheless played no role in the cause of the accident. The accident was caused by a low airspeed situation, close to the stall speed. This led to a stall followed by an incipient spin from which the aeroplane did not recover. Contributing factors to the accident were the aeroplane's full wing span flaperons in combination with the unusual aeroplane's landing configuration of +25° flaps on base leg, the aeroplane's stall properties, the lack of a stall warning system and the pilot's limited flying experience, proficiency and training with the Pipistrel Alpha Electro. The investigation did not reveal any technical defect that could have been a factor to the cause of the accident.

Second an equivalent level of safety and airworthiness, as imposed on Dutch registered microlight aeroplanes, is not guaranteed in the case that foreign-registered microlight aeroplanes from member states of the European Civil Aviation Conference make temporary use of Dutch airspace.

No pan-European regulations exist that apply to the design and use of microlight aeroplanes. They are excluded by the Basic Regulation EU 2018/1139. Regulations concerning microlight aeroplanes are a national matter. The aeroplane in question operated in Dutch airspace while not complying with Dutch and Italian regulations. It did not use Dutch airspace temporarily, but made 42 flights in a period of more than 4 months, and it exceeded the maximum takeoff weight. The Human Environment and Transport Inspectorate stated not to perform oversight on microlight aeroplanes. Therefore the inspectorate is not aware of the risks concerning the operation of microlight aeroplanes.

Third, in general when innovation is introduced, such as electric propulsion, one would expect the authorities to fulfil a proactive role. This role should safeguard safety in aviation. The Dutch Safety Board did not observe this role. For instance, regulatory requirements concerning electric-powered aircraft do not yet exist in the Netherlands.

Fourth, the fire hazard of lithium-ion batteries used in the propulsion of microlight aeroplanes is characterized by a fire with a high calorific value, the speed at which the fire develops, and the fact that such a fire is hard to extinguish. In this particular case, the fire department extinguished the fire in accordance with their instructions: copious water was used for a long time.

RECOMMENDATIONS

The Pipistrel Alpha Electro 167 and similar microlight aeroplanes, fall within the category of aeroplanes to which the European common rules on civil aviation do not apply (Basic Regulation, Regulation (EC) 216/2008, which was applicable when the aeroplane was registered, now replaced by Regulation (EU) 2018/1139). These aeroplanes fall under the regulatory control of the member states, in light of their limited risk to civil aviation safety, simple design, or operations mainly on local basis. However, microlight aeroplanes have become more advanced and increasingly popular over the years and they are also operated across borders. With the growing numbers and the increasing complexity of the design of microlight aeroplanes, the Dutch Safety Board believes also for these aircraft a minimum level of safety within Europe should be determined.

The Dutch Safety Board therefore issues the following recommendations:

To the Minister of Infrastructure and Water Management:

1. To improve the safety of microlight aeroplanes registered and/or operating in the Netherlands and the safety of third parties, by setting up and implementing effective oversight of the sector.

2. With regard to the innovation of microlight aeroplanes, determine additional requirements that microlight aeroplanes registered and/or operating in the Netherlands must meet and implement them within the Netherlands. Then actively strive to accept these requirements as standard within the member states of European Civil Aviation Conference (ECAC), with the aim of creating a minimum level of safety for this category of aircraft.

3. For the long term to promote that the requirements and oversight of microlight aeroplanes will be evaluated and reconsidered by European Union Aviation Safety Agency (EASA).

J.R.V.A. Dijsselbloem
Chairman Dutch Safety Board

C.A.J.F. Verheij
Secretary Director

LIST OF ABBREVIATIONS

AAL	Above aerodrome level
AIC-A	Aeronautical Information Circulars, series A
AIP	Aeronautical Information Publication
AMSL	Above mean sea level
ATC	Air traffic control
ATSB	Australian Transport Safety Bureau
CTR	Control zone
DSB	Dutch Safety Board
EASA	European Union Aviation Safety Agency
ECAC	European Civil Aviation Conference
EHST	Stadskanaal airfield
ELT	Emergency locator transmitter
ICAO	International Civil Aviation Organization
ILT	Human Environment and Transport Inspectorate
kg	kilogram
(K)IAS	(knots) indicated airspeed
km/h	kilometers per hour
kts	knots (1 kt = 1,852 metres per hour)
kW	kilowatt
LAPL	Light aircraft pilot license
LOC-I	Loss of control in-flight
MAC	Mean aerodynamic chord
MLA	Microlight aeroplane
MLH	Microlight helicopter
MTOW	Maximum takeoff weight
PPL(A)	Private pilot license (aeroplanes)
PRS	Parachute rescue system
RPL(A)	Recreational pilot license (aeroplanes)
RPM	Revolutions per minute
SEP(land)	Single engine piston (land)

V_{NO}	Velocity normal operating
V_{S0}	Stall speed, flaps extended
V_{S1}	Stall speed, clean
VSI	Vertical speed indicator

GENERAL OVERVIEW

Identification number:	2018110
Classification:	Accident
Date, time of occurrence:	13 October 2018, 12.48 hours[1]
Location of occurrence:	Near Stadskanaal airfield, the Netherlands
Registration:	I-D057
Aircraft type:	Pipistrel Alpha Electro 167
Aircraft category:	Microlight aeroplane (MLA)
Type of flight:	Private
Phase of operation:	Approach
Damage to aircraft:	Destroyed
Flight crew:	One
Passengers:	None
Injuries:	Pilot, fatally injured
Other damage:	None
Light conditions:	Daylight

1 All times in this report are local times.

1 FACTUAL INFORMATION

1.1 General

On 13 October 2018, the electric-powered aeroplane, a Pipistrel Alpha Electro, departed from Drachten airfield and set course towards Groningen Airport Eelde. The pilot was its only occupant. After crossing the Eelde control zone, the aeroplane flew towards Stadskanaal airfield where the pilot joined a lefthand circuit for runway 24 at an altitude of approximately 500 feet. After turning from downwind to base leg, the aeroplane suddenly lost altitude and impacted the ground. Shortly thereafter the aeroplane caught fire. Bystanders carried the pilot, who was fatally injured, out of the aeroplane. The aeroplane was destroyed as a result of the crash and the post-impact fire.

The investigation into the accident answers the following three questions: What caused the aeroplane to crash? To what extent does the permission for this microlight aeroplane with a foreign registration to operate in Dutch airspace guarantee a minimum level of safety? What concerns can be identified in case of an accident with a microlight aeroplane powered by lithium-ion batteries?

To answer these questions the following factual information was gathered and considered relevant.

1.2 History of the flight

1.2.1 Flight preparation

In the morning of 13 October 2018, the pilot made preparations to fly the Pipistrel Alpha Electro 167, an electric-powered microlight aeroplane with registration I-D057, as the only occupant from Drachten airfield to Stadskanaal airfield. The pilot was scheduled to give an Alpha Electro 'Tech talk' with an associate at 13.00 hours at Stadskanaal airfield.

It is confirmed that the pilot made preparations for his flight. He did not file a flight plan with Air Traffic Control the Netherlands. Further details of his flight preparation are unknown to the Dutch Safety Board.

1.2.2 Flight execution

The pilot departed Drachten airfield's runway 26 at 12.12 hours. He made a right turn and set course towards Groningen Airport Eelde. En route, the pilot flew at altitudes between 500 and 1,000 feet AMSL. He contacted Eelde Tower requesting to enter the control zone. After crossing the Eelde control zone the aeroplane flew towards Stadskanaal airfield, see Figure 1.

Figure 1: Flight route of I-D057 (red line). (Source: ATC the Netherlands and OpenStreetMap)

At 12.46 hours, the aeroplane entered the circuit area of Stadskanaal airfield, joining downwind leg for a lefthand circuit for runway 24 at an altitude of approximately 500 feet. The pilot extended the downwind leg before initiating the turn to base leg.

After turning from downwind to base leg, the aeroplane developed a left overbanked and nose down attitude, resulting in a high sink rate. After having turned for approximately 270 degrees, the aeroplane came down on a country road, before bouncing between two trees and over a cycling path and a ditch.[2] The aeroplane then hit the embankment of the ditch from where it skidded on farmland and came to a halt about 30 meters from the initial impact, see Figure 2. Shortly hereafter the aeroplane caught fire. Bystanders managed to carry the pilot out of the aeroplane.

2 The first impact point was at a distance of approximately 1,250 metres from the threshold of runway 24 of Stadskanaal airfield.

Figure 2: Accident location. (Source: Dutch Aviation Police)

As depicted in Figure 3, the location of the crash was outside the circuit area.

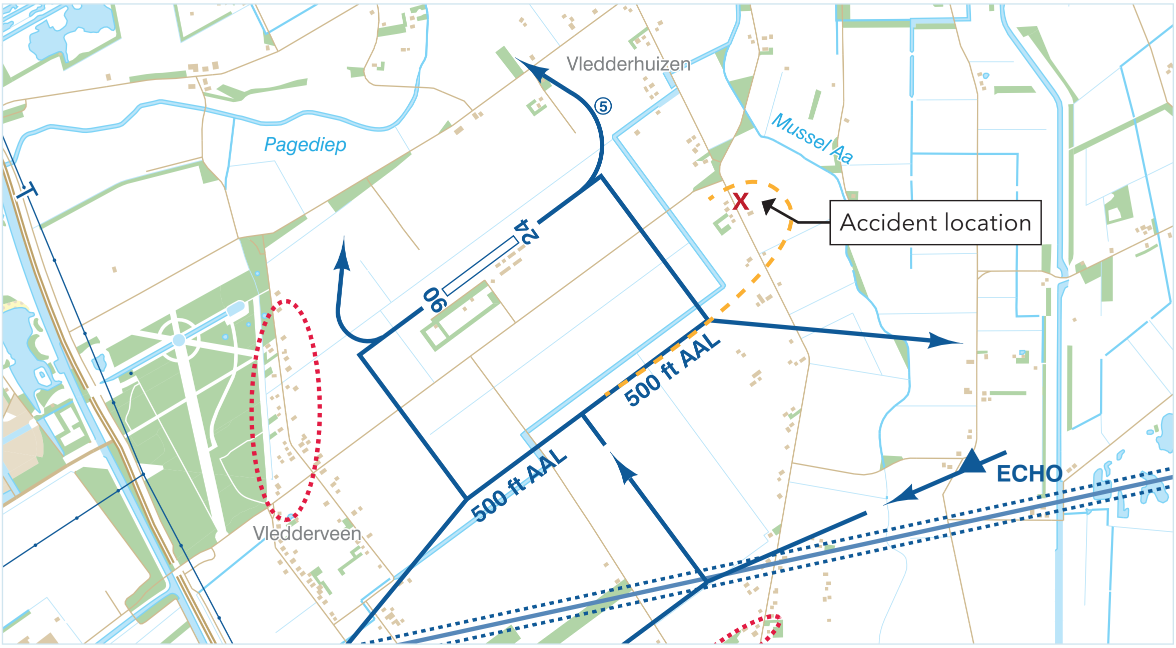

Figure 3: Accident location. (Source: EHST Visual Approach Chart, AIP the Netherlands)

1.3 Injuries to persons

The pilot suffered fatal injuries as a result of the crash.

1.4 Damage to aircraft

The aeroplane was destroyed as a result of the crash and the post-impact fire, see Figure 4.

Figure 4: Wreckage of the aeroplane. (Source: Dutch Aviation Police)

1.5 Other damage

As a result of the crash and subsequent fire, the soil at the crash site was contaminated with cooling fluid and battery chemicals released during the fire.

1.6 Personnel information

1.6.1 Pilot's licencing

The Dutch pilot was a 55 year old male. He held an European private pilot licence (EU-PPL(A)) with a single engine piston (SEP(land)) rating as well as a Dutch national microlight aeroplane (MLA) rating that was annotated on an attachment to the EU-PPL(A). He also held a valid medical certificate for class 2 (PPL) and LAPL and a privilege to operate radiotelephony equipment.

The first date of issue of his RPL(A) was 24 January 2001 with the SEP(land) rating issued on the same date. He had obtained a PPL(A) on 30 September 2002 and applied for an MLA rating on 17 May 2015. The MLA rating was valid up to and including 30 June 2019 and the SEP(land) rating up to and including 31 October 2018.

1.6.2 Pilot's flying experience

The pilot's total flying experience was 571 hours. His total flying experience on MLAs was 41 hours, mostly on the Aerospool Dynamic WT9.

The pilot made eleven flights with the Pipistrel Alpha Electro (I-D057) in Dutch airspace with a total flight time of 7 hours and 20 minutes. His first flight with I-D057 was on 27 June 2018, his last (before the accident flight) on 10 September 2018. He made his first two flights with I-D057 with a second pilot[3] to familiarize himself with the aeroplane. With that pilot, he also made a flight in a Pipistrel Alpha Trainer, an aeroplane similar to I-D057 but equipped with a piston engine.

According to the pilot's logbook, he flew to Stadskanaal airfield once before, on 17 May 2015. That day, the pilot made three landings at the airfield with an Aerospool Dynamic WT9.

The day before the accident, the pilot made a check flight with a Reims F172N for the renewal of his SEP(land) rating. The pilot passed this check flight.

1.7 Aircraft information

1.7.1 General

The Pipistrel ALPHA Electro 167 is a 2-seat electric-powered T-tail high-wing aeroplane, made almost entirely of composite materials, see Figure 5. All composite parts are made of glass, carbon and kevlar fiber. It has a 10,5 meter wingspan and a non-retractable undercarriage. The aeroplane features flaperons, meaning that one movable surface on the trailing edge of each wing acts both as the flap and the aileron. Three flap settings can be selected: retracted (0°), +15° and +25°. The elevator trim is electric.

I-D057 was fitted with a standard propeller, not with an energy recuperating propeller. The energy recuperating propeller entered production at a date later than the date of production of I-D057. The propeller fitted on I-D057 windmills when the power lever is set to idle and has minimal ability to extract energy from the airflow, so effective recuperation is zero. Therefore the propeller does not produce extra aerodynamic drag; the aeroplane will sink with its natural sink rate.

3 This pilot was working as a business associate of the Pipistrel dealer for the Benelux.

Figure 5: Archive photo I-D057. (Source: H. Ranter)

1.7.2 Registration and permit to fly

I-D057 was manufactured in 2018 by Slovenian manufacturer Pipistrel d.o.o. Ajdovšcina. The owner registered it in Italy as a microlight aeroplane.

The aeroplane was entered in the aircraft register of Aero Club d'Italia on 20 April 2018. The 'certificate of registration and issue of flight permit' for the microlight aeroplane was issued by Aero Club d'Italia on 24 April 2018. The Aero Club d'Italia has the task of promoting and divulging aeronautical sports. For microlight aeroplanes, the Aero Club d'Italia is tasked with issuing the certificate of registration, under responsibility of the Italian government.

1.7.3 Aeroplane flight time

The aeroplane's logbook listed 53 flights, the last of which had taken place on 30 September 2018. This flight was from Oostmalle airfield in Belgium to Rotterdam The Hague Airport in the Netherlands. After that flight, the aeroplane was transported to Drachten airfield on a trailer. It then had flown a total of 25 hours and 14 minutes.

1.7.4 Weight and balance

The aeroplane's empty weight, including the parachute rescue system and the standard battery system, was 380.5 kilograms. The actual takeoff weight of the aeroplane, including the pilot, was approximately 476 kilograms. This weight was below the maximum takeoff weight of 550 kilograms, as established by the manufacturer. Depending on where the aeroplane is registered, different maximum takeoff weights apply. For Italian registered aeroplanes, this value is 472.5 kilograms. The takeoff weight of the aeroplane exceeded this regulatory weight limitation by approximately 4 kilograms. This was not a contributing factor to the accident.

The center of gravity position during flight was 28.5% of mean aerodynamic chord.[4] The aeroplane's safe center of gravity position ranges between 20% and 38% of mean aerodynamic chord. The center of gravity during flight was within the prescribed limits of the flight envelop.

1.7.5 Aeroplane figures relevant to the analyses

The figures below are taken from the Pipistrel Pilot's Operating Handbook for the Alpha Electro. They are based on an aeroplane weight of 550 kg, standard atmospheric conditions, level hard-surfaced dry runways and no wind.

Figures	
Stall speed (flaps extended +25°)	38 KIAS (70 km/h)
Stall speed (flaps retracted 0°)	43 KIAS (80 km/h)
Typical cruise speed	85 KIAS (157 km/h)
Standard endurance, traffic patterns	55 minutes + 30 minutes reserve
Standard range at cruise 85 kts	65 NM (120 km)

Battery system	
Maximum voltage	398 V
Minimum voltage	288 V
Total battery capacity	21.0 kWh

Source: Pipistrel Pilot's Operating Handbook, revision A02, 13 September 2018.

The operating speeds of I-D057 were shown on a placard in the cockpit. See Figure 6.

4 The distance between the leading and trailing edge of the wing, measured parallel to the normal airflow over the wing, is known as the chord. The average length of the chord is known as the mean aerodynamic chord.

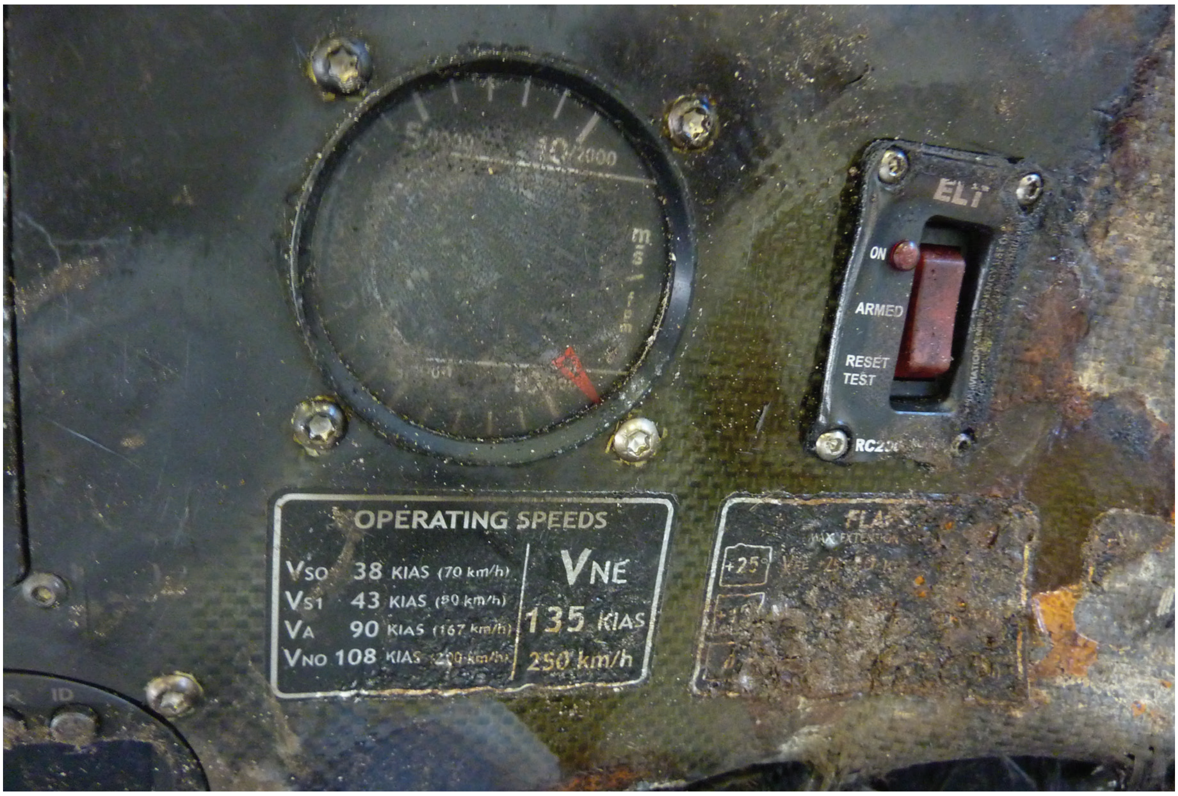

Figure 6: Placard in cockpit with operating speeds.

1.7.6 Safety features

The aeroplane was equipped with a ballistic parachute rescue system (PRS), located in the aft fuselage. The PRS is activated manually, by pulling the activation handle mounted on the top of the cabin bulkhead. The wreckage of the aeroplane was found with the PRS not activated.

The aeroplane was not equipped with a stall warning system. This was not a requirement for MLAs registered in the basic category, like I-D057.[5]

The aeroplane was equipped with an emergency locator transmitter (ELT). The ELT was not activated during the crash. The switch on the front panel of the ELT module (transmitter) was found in the position "OFF". The switch on the remote control panel in the cockpit was found in the "ARM" postion.

1.7.7 Electric propulsion system

The Pipistrel Alpha Electro is an electric-powered microlight aeroplane. Its propulsion system consists of two main batteries that provide electrical energy, the motor's power controller and an electric motor driving the propeller. A small 12 V DC battery is used for operating the main electrical system, which supplies the instruments and avionics in the cockpit.

5 See 1.16.1 *Italian regulations* for conditions for registration in the basic category.

Main batteries
The main batteries, each weighing 58 kg, consist of lithium-ion cells, assembled in two battery packs. One battery pack is positioned forward of the firewall; the other is located behind the cabin rear bulkhead. The batteries are connected in parallel via a junction box to the power controller, which drives the electric motor. In the event of a defect in one of the batteries, the other battery supplies the electric propulsion system. The batteries are charged with an external charger via a fast charge port located on the starboard side of the motor compartment (see Figure 5).

The typical discharge curve of the lithium-ion battery cell is shown in Figure 7. A lithium-ion cell has a nominal voltage of 3.7 V, which is the default, resting voltage of a battery pack. Lithium-ion batteries are fully charged when they reach 4.2 V/cell (point 1); their minimum safe charge is 3.0 V/cell (point 4). The discharge of a cell is not linear, but it is relatively flat and then drops rapidly. This accelerated discharge occurs at about 3.6 V/cell (point 2) and becomes very rapid at 3.4 V/cell (point 3).

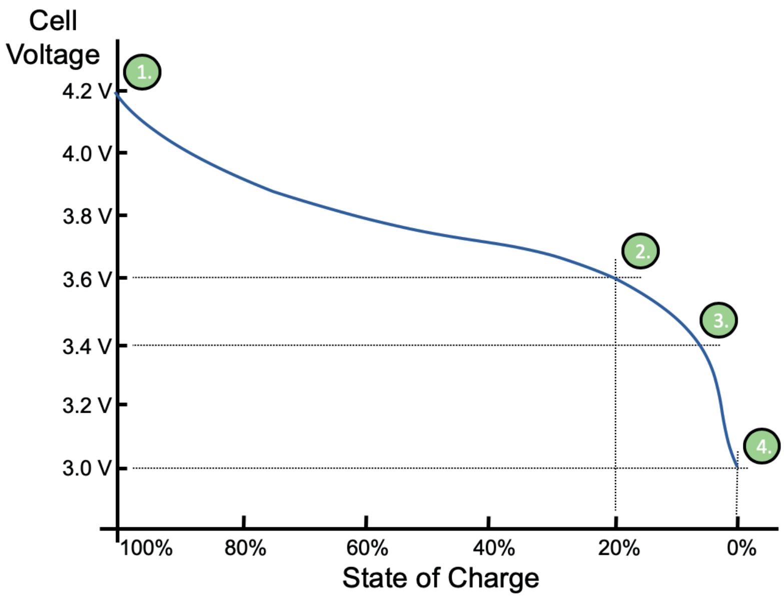

Figure 7: Typical lithium-ion battery discharge curve.

Power controller
The power controller converts the direct current voltage of the batteries into a three-phase alternating current voltage to drive the motor. The power controller is cooled by a liquid coolant system.

Electric motor
The 60 kW electric motor is manufactured by Emrax.[6] It is an out-runner type electric motor that provides direct-drive to the propeller. The motor is also cooled by the liquid coolant system. Automatic power derating protects the motor in the event of exceeding

6 Model 268, serial number 137, motor configuration MV_LC_P.

the maximum temperature. The composite propeller is of a fixed pitch, three-blade design.

The Pipistrel Pilot's Operating Handbook states that the motor is not certified for aviation use and that there is no assurance it won't fail during operation at any given moment, without prior notice. The motor is not certified because certification requirements[7] for electric motors did not exist at the time of the accident. This means that the motor could never have been certificated.

1.7.8 Flight characteristics

The aerodynamic design and flying characteristics of the Alpha Electro require attention when flown. Those characteristics are emphasized in the Pipistrel online instructions for flying the aeroplane. The following excerpt is from the Pipistrel online course for flying the Alpha Electro.

> An area of concern for pilots in all phases of flight on the Alpha Electro is flying without sideslip. When seated on the left seat of the Alpha Electro the cockpit false lines and the convergent body position will make ''straight ahead'' seem much more to the right where it really is. It is recommended to rotate your head slightly to the left and check the sideslip ball often, especially during slow speed when the directional stability is less.

Source: Pipistrel online course for flying the Alpha Electro (https://www.pipistrel-online.com/).

A pilot who had flown with I-D057 stated that the application of the rudder by the pedals required extra attention, because the rudder has the property of remaining in the position in which it was placed, after the pedals are released. Other pilots who flew with I-D057 have not reported this. Pipistrel stated that it had not received any reports regarding indifferent balance of the rudder control system of I-D057. This indifferent balance could have been a contributing factor to the loss of control situation that occurred with I-D057. As the aeroplane was destroyed by the crash and the subsequent fire, the statement of the pilot could not be verified during the technical investigation of the aeroplane wreckage.

7 Certification is any form of recognition that a product, a part of a product, an organization or person complies with applicable requirements.

1.7.9 Traffic pattern/approach

Below, the prescribed speeds and flap settings for the Alpha Electro in the traffic pattern and for the descent and approach are listed.

Traffic pattern

Downwind: Reduce speed to maintain a minimum of 70 knots IAS at the end of downwind.

Base: In descent reduce speed. At 60 knots IAS extend flaps to 15°. Do not maintain an airspeed below 55 knots IAS.

Final: Reduce speed to 60 knots IAS and extend flaps to 25°. Maintain 55 knots IAS.

Full flaps can be deployed before the turn to final, however, the rate of the roll will decrease and adverse yaw will increase, therefore any turn will require more rudder coordination.[8]

Source: Pipistrel online course for flying the Alpha Electro.

Descent and final approach

Descend at speeds at or below V_{NO}[9] with the flaps retracted (0°).

For approach reduce speed to 70 kts (130 km/h) and extend flaps to 15° only after turning base leg. Adjust motor power to maintain proper airspeed. Set the trim to neutralize stick force if necessary.

During the descent, monitor temperatures and keep them within operational limits.

On final, extend flaps to 25°. Align the aircraft with the runway and reduce power to idle. Maintain an airspeed of 55 kts (102 km/h). Use the throttle to control your descent glide path. Control your attitude and crab if necessary.

Source: Pipistrel Pilot's Operating Handbook, revision A02, 13 September 2018.

8 Adverse yaw is most evident with full flaps, since they produce a lot of drag and this effect is amplified with the fact that the Alpha Electro does not use ailerons, but full span flaperons (Source: Pipistrel online course for flying the Alpha Electro).

9 Velocity normal operating; maximum structural cruising speed in turbulent air (V_{NO} = 108 knots).

1.7.10 Stall and spin recovery

The Pilot's Operating Handbook of the Pipistrel Alpha Electro provides in Chapter 6, Emergency procedures, information on how to react when confronted with typical flight hazards, like stall and spin.

Stall recovery
First reduce the angle of attack by easing-off on the control stick, then:

1. If the motor is running, add full power.
2. Resume horizontal flight.

Spin recovery
The Alpha Electro is constructed in such a manner that it is difficult to fly into an inadvertent spin. However, once spinning, react as follows:

1. If the motor is running, set throttle to idle (lever in full back position).
2. Apply full rudder deflection in the direction opposite to spin direction.
3. Lower the nose towards the ground to build up speed (stick forward).
4. As the aircraft stops spinning neutralize rudder deflection.
5. Slowly pull up and regain horizontal flight.

Alpha Electro tends to recover from spin by itself after spinning about 90°. Resume normal flight when the aircraft is straight and level.

Source: Pipistrel Pilot's Operating Handbook, revision A02, 13 September 2018.

1.8 Meteorological information

A southern current brought warm, continental tropical air, which was unstable up to around 2,500 feet. At 500 feet the wind came from the direction 170 degrees with a speed of 17 knots. The temperature was 22 degrees Celsius at that altitude. There was a broken and overcast cirrus cloud cover at 40,000 feet. Visibility was more than 10 kilometers and there was slight turbulence.

1.9 Communications

The pilot of I-D057 reported flying overhead Stadskanaal airfield's compulsory reporting point Whiskey when he was approaching the circuit area of the airfield.

1.10 Aerodrome information

Stadskanaal airfield has one grass runway (06/24[10]), with a length of 500 metres and a width of 30 metres. At the time of the accident runway 24 was in use.

The circuit altitude is 514 feet AMSL (500 feet AAL).

1.11 Flight recorders

The aeroplane was not equipped with flight recorders. However, the Dutch National Police´s Digital Tracing Team downloaded data, including basic flight parameters[11], from the altimeter's air data computer. The sampling rate was 1 Hz; one sample was obtained per second for all variables. The data was made available to the Dutch Safety Board and used for a flight animation and analysis.

On 2 April 2019, the flight animation was shown to representatives of the manufacturer in Slovenia, in the presence of investigators of the Dutch Safety Board. The animation was also presented to two experienced pilots for evaluation. The statements from these pilots were used in the analysis.

1.12 Wreckage and impact information

Despite the fact that the aeroplane was largely destroyed by the crash and the subsequent fire, the cockpit instrument panel was partly intact and flight instruments were still readable. See Figure 8. These flight instruments showed the value of the parameters at the time of impact[12]:

1. airspeed indicator: 80 knots
2. altimeter: 40 feet
3. vertical speed indicator: descending velocity against the stop (meaning 2,000 feet per minute or more)
4. RPM indicator: 1,500 RPM

10 Magnetic azimuth of the runway's heading in decadegrees.

11 Parameters including latitude, longitude, IAS, groundspeed, RPM, static pressure, static altitude, yaw, pitch, roll et cetera.

12 The analogue instruments are constructed in such a way that at the moment of impact the needles of the instruments will maintain their present indication.

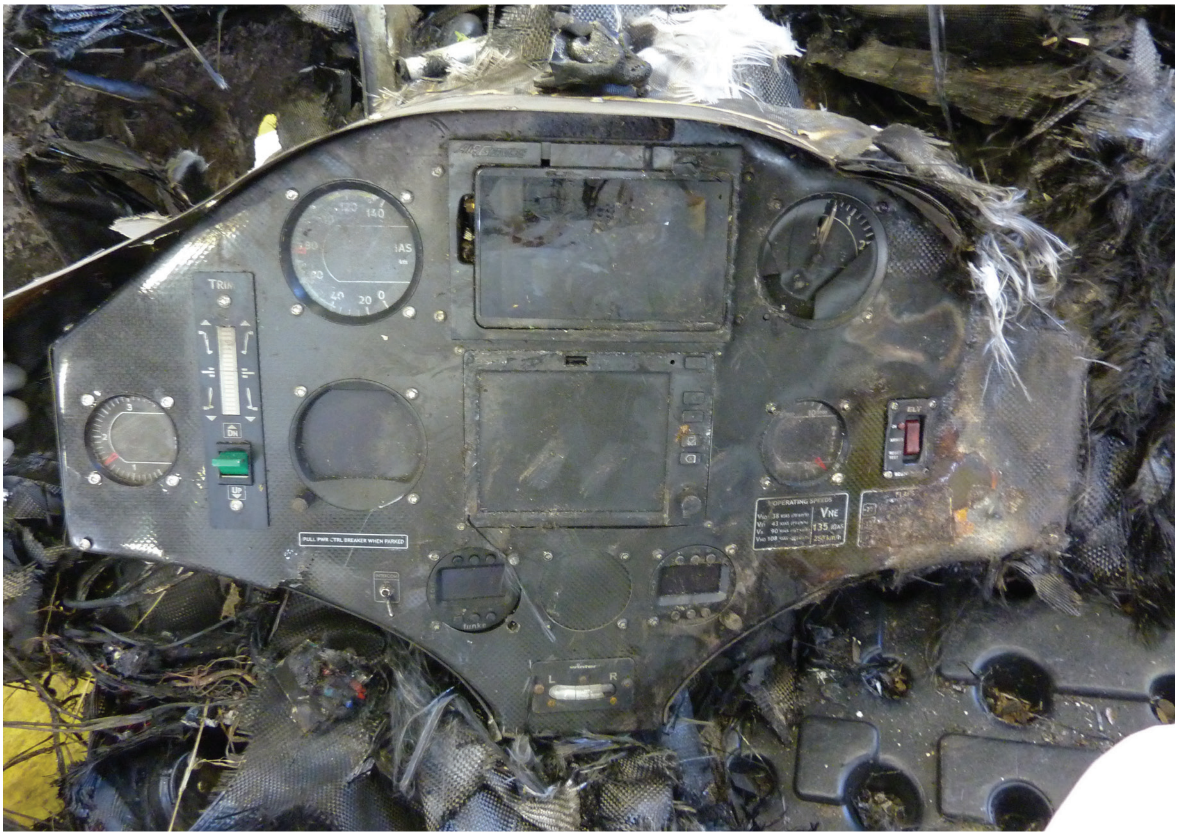

Figure 8: Instrument panel and flight instruments.

1.13 Medical and pathological information

The Netherlands Forensic Institute conducted a post-mortem examination on the pilot on behalf of the Dutch Safety Board. This examination consisted of a radiological scan, a forensic autopsy and a forensic-toxicological investigation into chemical substances in body material (tissue).

The examination report states that the pilot was fatally injured as a result of a high-energy trauma (i.e. the crash). No traces of ethanol (alcohol), carbon monoxide, medication, drugs and/or pesticides were found. The examination did not reveal any medical condition that could have been a contributing factor to the accident.

1.14 Fire

Shortly after the aeroplane impacted the ground, a fire started under the right wing. This fire was caused by the damaged front battery pack which was forcefully ejected from the front battery compartment during the crash. The front battery pack was burnt-out completely, see Figure 9. The rear battery did not catch fire; it was found fully intact in the aft fuselage, see Figure 10.

Figure 9: The burnt-out front battery pack.

Figure 10: The intact rear battery pack.

1.15 Electric related technical problems

1.15.1 Technical abnormalities in the months before the accident

I-D057 had been flying in Belgium and the Netherlands since May 2018. The Pipistrel dealer in the Benelux had visited various events with the aeroplane to promote sustainable aviation and to demonstrate the feasibility of electric-powered flight. From 11 May 2018 up to and including 14 September 2018, the aeroplane made 42 flights in the Netherlands.

In the months before the accident, several technical abnormalities occurred with the aeroplane. They consisted of an indication of the battery voltage outside limits[13], the propeller making a mechanical noise and showing friction while turned by hand and a charging problem of the batteries (related to the electric infrastructures at some airfields causing the external charger to malfunction).[14]

1.15.2 Technical abnormalities on the day of the accident

In the morning of the day of the accident, trouble shooting to solve the charging problem was done. Pipistrel recommended, as a remedial action, first to apply a rest charge[15] procedure and thereafter a full charge procedure.

To accomplish this, the pilot taxied the aeroplane to the battery load station. However, the aeroplane electrical motor suddenly stopped working. Shortly after, the pilot noticed that the rear battery made a siffling noise, which he could not explain. At the load station,

13 Pipistrel's response to this statement from the aeroplane owner was that the aeroplane does not show the pilot if the voltage of the batteries is within limits or not, as this is not considered as practical information for the pilot. The status of the battery is communicated via the state of charge indicator and alerts/status messages. The pilot can access a system page that shows the minimum and maximum cell voltage of every battery pack as well as the total voltage of the front and rear battery packs.

14 Pipistrel stated they were contacted by the customer on 13 June and 3 September 2018 about a defective charger. In both cases a new charger was sent to the customer, respectively on 15 June and on 6 September 2018. Concerning the propeller making a mechanical noise and showing friction while turned, Pipistrel found no records of these events or of any communication with the customer about these events.

15 Rest charge will charge the battery to an optimum level for aircraft storage.

the aeroplane was connected. During the loading, the state of charge[16] of the front battery increased to 94% and the rear battery increased rapidly from 69% to 85%. However both batteries could not be charged to a 100% state of charge. At 10.48 hours, this anomaly was communicated with Pipistrel technical department in Slovenia. The reply was that there could be a problem with the voltage sensor inside the rear battery. Pipistrel advised to go through the entire charging cycle again and keep the batteries connected at full charge to equalize the voltages. Eventually the battery voltages equalized and the batteries were charged at a 100% state of charge.

Because of these loading abnormalities, the aeroplane owner advised the pilot by phone to double-check and tighten the data cables.[17] Shortly before noon the pilot contacted the owner and informed him that both battery displays indicated 100%. A family member of the pilot, who was present at Drachten airfield, later confirmed that the batteries were 100% charged and that the pilot had also checked the data cables. Both the owner of the aeroplane and the pilot's associate suggested the pilot would first fly a local circuit to make sure everything was working correctly, before leaving Drachten airfield. The pilot did not fly a circuit after takeoff, instead he flew a right turn and set course towards the destination.

1.16 Regulatory framework for MLA

This paragraph describes the regulatory framework for MLA operation in Italy, the Netherlands and Europe.

1.16.1 Italian regulations

In Italy, MLAs are not governed by the Civil Aviation Authority. Instead, Italian law requires the Aero Club d'Italia to issue the certificate of registration. The Aero Club d'Italia does not have the authority to issue a permit to fly. With regard to operating MLAs in Italian airspace, the Italian regulation consists of the DPR133/2010 and *the Law n. 106, March 25, 1985, concerning the discipline of the recreational or sport flight*. The regulation stipulates the option to register MLAs as a basic or advanced type.

Appendix of the law n. 106, March 25, 1985, concerning the discipline of the recreational or sport flight
(…) Conditions for registration in Italy in the basic category are amongst others:

- Maximum two seats;
- Maximum takeoff weight 472,5 kg, when equipped with a parachute rescue system;
- Stall speed or minimum speed at stabilized flight in landing configuration not exceeding 35 knots for microlight aeroplanes with a rigid wing.

16 State of charge is the equivalent of a fuel gauge for the battery pack. The units of state of charge are percentage points (0% = empty; 100% = full). It indicates the currents state of a battery in use. The state of charge of the battery is computed using an algorithm that takes into account various parameters like cell temperature and cell voltage.
17 Each battery is connected to a power supply cable and data cable.

The requirements for the advanced type MLA, which consist of a comprehensive list, are described in appendix II, Part B of the DPR133/2010.

1.16.2 Dutch MLA regulations

The Dutch definition of an MLA is described in the *Aircraft Decree 2008* (in Dutch: *Besluit luchtvaartuigen 2008*) and reads:

> Land plane, amphibian or floatplane having no more than two seats, a stall speed not exceeding 35,1 knots calibrated airspeed and a maximum takeoff weight of no more than:
>
> […]
>
> 472,5 kg for a land plane, two-seater equipped with an airframe mounted total recovery parachute system;
>
> […]

The use of Dutch or foreign registered MLAs in Dutch airspace is governed by the *MLAs, MLHs and motorized paragliders Regulation* (in Dutch: *Regeling MLA's, MLH's en schermvliegtuigen*[18]), which is issued by the Minister of Infrastructure and Water Management.

In relation to this investigation, article 9a of the abovementioned regulation is relevant and governs the permission for MLAs registered in other member states of European Civil Aviation Conference (ECAC) to enter and make temporary use of Dutch airspace.[19] Italy is a member of ECAC and hence an MLA registered in Italy has the permission to make temporary use of Dutch airspace under certain conditions. Temporary is not further specified.

18 *Regeling MLA's, MLH's en schermvliegtuigen*: https://wetten.overheid.nl/BWBR0015237/2018-04-01
19 The Dutch definition of an MLA, as described in the Aircraft Decree 2008, also applies to article 9a. So only MLAs registered abroad, that meet the Dutch definition are allowed to make temporary use of Dutch airspace.

Article 9a, MLAs, MLHs and motorized paragliders Regulation
With regard to the temporary use in Dutch airspace of MLAs, MLHs, or motorized paragliders registered in other member states of the European Civil Aviation Conference that do not possess a valid certificate of airworthiness as intended in article 3.8 of the Dutch Aviation Act (*Wet luchtvaart*), the following regulations and restrictions apply:

a. The competent authority of the member state issuing the certificate of registration has also issued a statement certifying that conducting flights with the relevant aircraft is permitted in that state, and
b. The conditions and restrictions, as imposed by the competent authority, with regard to the use of the aircraft shall be complied with.

1.16.3 Registration of I-D057

The registration of MLAs in Italy is subdivided in two categories: the basic and advanced MLAs. I-D057 was registered in Italy in the basic category. According to Italian law[20], the conditions for registration in the basic category are amongst others: maximum two seats, maximum takeoff weight 472.5 kg and a stall speed not exceeding 35 knots. At the time of registration the aeroplane's owner must declare that it complies with these conditions.

1.16.4 European MLA regulations

On the day of the accident, no pan-European regulation existed that applies to the design and use of 'Annex I aircraft'[21], including MLAs.[22,23]

Article 2(3) of the Basic Regulation (EU) 2018/1139 states that without prejudice to the obligations of member states under the Chicago Convention, aircraft covered by Annex I to this regulation and registered in a member state may be operated in other member states, subject to the agreement of the member state in the territory of which the operation takes place.

20 Annex to Law no. 106, 25 March 1985.
21 Annex I of the Basic Regulation (EU) 2018/1139 (https://www.easa.europa.eu/document-library/regulations/regulation-eu-20181139) lists aircraft not under EASA scope. Article 2(3)(d): This Regulation shall not apply to: the design, production, maintenance and operation of aircraft the operation of which involves low risk for aviation safety, as listed in Annex I, and to the personnel and organisations involved therein, unless the aircraft has been issued, or has been deemed to have been issued, with a certificate in accordance with Regulation (EC) No 216/2008.
22 MLA is terminology that is not used by EASA.
23 At the time of registration of I-D057, Basic Regulation (EU) 216/2008 was in force. This regulation did not apply to aircraft referred to in Annex II, like aeroplanes (as I-D057) having a maximum takeoff mass, as recorded by the member states, of no more than 472,5 kg for a land plane, tow-seater equipped with an airframe mounted total recovery parachute system.

1.17 Witness statements

Several people witnessed the accident, four of which saw the aeroplane flying on downwind and base leg. In addition to the analysis of the downloaded data from the altimeter's air data computer and the findings of the technical investigation, these statements were used for the reconstruction of the flight path.

1.18 Accidents with electric-powered aeroplanes

The accident with I-D057 was the first accident with a Pipistrel Alpha Electro world-wide. During the investigation into this accident, two other accidents occurred with this type of aeroplane in Switzerland (on 3 January 2019) and in Norway (on 14 August 2019). The investigations into these accidents were still ongoing when this investigation was finished.

The following two accidents with other electric-powered aeroplanes are known to the investigation team of the Dutch Safety Board. On 31 May 2018, an electric-powered experimental aeroplane, a Magnus eFusion, crashed in the circuit of Pécs-Pogány Airport in Hungary. After the crash, it caught fire. Both pilots suffered fatal injuries. The Transportation Safety Bureau of the Ministry of Innovation and Technology of Hungary published the preliminary report which states that the electric motor system (motor, battery pack, inverter) operated normally during flight.[24]

On 10 August 2017, during touchdown at Parham Airfield in the United Kingdrom following an uneventful flight, the HPH Glasflugel 304 eS glider's forward FES lithium polymer battery ignited due to an electrical arcing event. The pilot was unaware that the glider was on fire and the battery continued to burn, generating smoke and fumes which entered the cockpit during the latter stages of the landing roll. The pilot was not injured and the fire was extinguished using foam retardant. However the glider's fuselage battery box and surrounding structure were extensively damaged by the fire. A comprehensive investigation of the failed battery by the Air Accidents Investigation Branch did not identify the cause of the electrical arcing event.[25]

24 http://www.kbsz.hu/j25/dokumentumok/2018_322_4%20Prereport.pdf
25 https://www.gov.uk/aaib-reports/aaib-investigation-to-hph-glasflugel-304-es-g-gsgs

2 INVESTIGATION AND ANALYSIS

2.1 Introduction

The Dutch Safety Board (DSB) performed a technical investigation of the aeroplane wreckage and a flight path reconstruction to establish the cause of the accident. In addition, the DSB examined the Dutch MLA regulation and oversight policy and practice for the assurance of flight safety within the MLA sector. Finally, the DSB examined the risks associated with the use of large aircraft batteries as a main power source for flight and fire suppression methods against battery fires; this is described in Appendix C.

2.2 Technical investigation

The technical investigation consisted of an examination of the aeroplane wreckage, the motor and the batteries.

2.2.1 Aeroplane wreckage

As the aeroplane was destroyed by the crash and the subsequent fire, the technical investigation of the aeroplane wreckage was limited to those parts that were salvaged. The fire had destroyed a substantial part of the mid-section of the fuselage, the right-hand wing, the right-hand elevator, the right-hand side of the rudder and the right-hand side of the horizontal stabilizer. A part of the nose section was also affected by the fire.

The investigation of the aeroplane wreckage did not reveal any technical defects that could have contributed to the cause of the accident.

2.2.2 Motor

On 3 April 2019, the motor was inspected at the Emrax facilities in Slovenia in the presence of DSB investigators. Initial assessment showed that as a result of the crash, the motor could not be turned, because the motor mount bracket was bent and slightly pushed the outer casing into the motor. As a result, the rotor was blocked. After the bracket was removed, the motor spun freely again.

The motor was put on a test stand where it was spun to 2,600 RPM at no load. When the motor was opened, some oxidation was noticed on the inside of the motor (on magnets, cores and the rotor ring). This was probably caused by water used to extinguish the fire. In conclusion, the motor showed no defects during the test.

2.2.3 Batteries

On 29 November 2018, a technical and an operational expert of Pipistrel visited the Netherlands to assist in the inspection of the batteries of the aeroplane.

The front battery burnt-out completely, after it had been ejected from the front battery compartment during the crash. Neither the compartment of the front battery nor the electrical connection cable (of the front battery) showed signs of fire, which indicates that the whole battery pack started burning only after separation from the fuselage, i.e. after the impact. It was concluded that the battery most likely caught fire because of an internal short circuit as a result of physical damage during impact.

The rear battery pack was found fully intact in its compartment inside the aft fuselage. Although parts of the fuselage around the battery compartment were damaged by fire, the rear battery compartment showed no signs of fire damage. Inside the battery, signs of smoke and dust, which entered through ventilation openings, were present. The battery management system was visually inspected and found damaged, probably as a result of water used to extinguish the fire. The individual cells were measured: 86 out of the 96 cells were found in a normal voltage range. Ten cells were found below their normal voltage range. With normal voltage range is meant that the voltage of the cells corresponded to the duration of the flight.[26] In contrast, the battery management system display indicated a battery state of charge of 0% and a state of health of 90%. The cause of the difference between the state of charge indicating 0% and the measured voltages, which are indicative for approximately 50% capacity of the battery, has not been established. One possible explanation for the difference is that the state of charge is always based on the cell with the lowest voltage. This means that only one cell needs to be empty to have a state of charge indication of 0%. Another possible explanation is that the cells discharged during impact. This is possible in two ways. Either the battery management system was damaged during the impact and discharged the cells or a short circuit caused by dust or water that entered the battery post impact, discharged the cells.

The 12 volts instrument battery, positioned in the nose section, had a partially burnt housing. The voltage was measured and indicating a normal battery state of charge. All fuses on the switch panel were found in a working state, indicating that during the flight the aeroplane wiring had not been loaded by voltages over 12 volts. This indicates that the battery functioned properly.

2.2.4 Electrical power supply and motor performance prior the accident

In the months before the accident when the aeroplane flew in Belgium and the Netherlands, it experienced a number of technical problems related to the malfunction of the external charger and the operation of the electric motor. These included an 'overvoltage reading'[27,28], the propeller showing friction while turned by hand (at Oostmalle airfield) and a failure to completely charge (at Drachten airfield).

26 The standard endurance, including traffic patterns, of the Alpha Electro is 55 minutes and 30 minutes reserve. The flight of I-D057 took 36 minutes.

27 See footnote number 13.

28 When charging the batteries, the voltage of some individual cells can increase faster than in other cells due to multiple factors like aging of the cells. As soon as a cell voltage reaches the operative limit, the batttery management system disconnects the battery and the charging process is stopped. The message 'Battery disconnect due to overvoltage' would be shown on the display (EPSI570) inside the cockpit. It is important to note that the battery is not really overcharged, the batttery management system disconnects the battery before this is possible. Since the state of charge is based on the cell with the lowest voltage, the state of charge of the disconnected battery could be less than 100%.

In addition, a complete motor shutdown occurred while taxiing out at Drachten airfield on the day of the accident.

These battery problems might suggest a relation with the cause of the accident. The technical investigation of the power supply however did not reveal any abnormalities. Furthermore, flight data indicates that moments before the accident the aeroplane maintained altitude with RPM being about 1,550, decreasing to approximately 1,370 during the last part of the downwind leg. According to the manufacturer, power needed for level flight and on downwind is 20 kW, which equals approximately 1,500-1,600 RPM (depending on elevation).[29] The fact that both altitude and RPM remained more or less constant on downwind, suggests that the motor and the batteries functioned normally. See Appendix B.

Therefore, based on the results of the technical investigation of the batteries, and the RPM and altitude indications on downwind, it is concluded that the previous battery problems do not explain the crash.

The technical investigation did not reveal any technical problem that could have been a contributing factor to the cause of the accident.

2.2.5 Emergency locator transmitter (ELT)

The switch on the front panel of the ELT module was found in the position "OFF", which means that no part of the ELT is energized. Therefore the ELT was not activated during the crash. This had no effect on alarming the search and rescue operation.

According to the *Installation and operation manual*[30] of the ELT, the OFF mode must only be selected when the ELT is removed from the aeroplane or when the aeroplane is parked for a long period or for maintenance. In order to enable activation by the G-switch or with an optional remote control panel, as installed in the cockpit of I-D057, the ELT must be in the standby mode with the switch in the "ARM" position. The *Installation and operation manual* states that this mode is mandatory during flight.

The Dutch Safety Board has emphasized in a previous report[31] the usefulness, necessity and reliability of ELTs. Radio emergency beacons such as the ELT have proven themselves in emergency situations as an effective life-saving tool.

29 Base leg is not flown with a pre-determined power setting, it is usually flown with power near idle (typically around 3-5 kW).
30 Installation and operation manual, ELT KANNAD 406 AF-COMPACT 406 AF-COMPACT (ER), DOC08038F, Ref. 0145599F, kannad aviation, Revision 05, August 20, 2013.
31 Dutch Safety Board (2013), Aircraft missing, Cessna accident at Maasvlakte 2. https://www.onderzoeksraad.nl/en/page/2006/vliegtuig-vermist---cessna-ongeval-op-tweede-maasvlakte-28-mei-2012

The ELT was not activated during the crash because the ELT module was in OFF mode. This had no effect on alarming the search and rescue operation. Nevertheless, having the ELT system functional during flight is strongly recommended.

2.3 The accident

The entire flight was recorded by the altimeter´s air data computer. However, the last six seconds before the aeroplane impacted the ground were not covered by the data.[32] Based on the retracted data, the investigation team made a 3D-animation of the aeroplane's flight path. This animation corresponded with eyewitness statements and with radar data received from Air Traffic Control the Netherlands. As the recorded flight parameters are consistent throughout the flight, they are considered sufficiently reliable and were used for flight path reconstruction and analysis. See Appendix B.

2.3.1 The cause of the accident

The aeroplane joined a left hand downwind for runway 24 of Stadskanaal airfield at an altitude of approximately 500 feet. According to an eyewitness statement and the flight data, the aeroplane extended its downwind leg before turning left to base leg (see Figure 11). It could not be determined why the pilot extended the downwind leg.

Flight data shows that at the beginning of downwind, the aeroplane was flying airspeeds between 65 and 68 knots IAS. At the end of downwind, the airspeed had reduced to 55 knots IAS. After turning from downwind to base leg, an airspeed of 48 to 50 knots IAS was recorded and a varying left bank angle. When these actually flown airspeeds are compared with the prescribed[33] airspeeds of 70 knots IAS (downwind) and 60 knots IAS (base leg), it can be determined that the actually flown airspeeds were below the recommended airspeeds. The lowest measured airspeed from the flight data is 48 knots IAS; this is just 10 knots higher than the aeroplane's stall speed for level flight with flaps fully extended. These low airspeeds together with the left bank angle caused the aeroplane to manoeuvre in the flight envelop close to the stall. As a consequence, the aeroplane was susceptible to enter an incipient spin.[34]

32 This is because the data in the buffer was not yet written to an non-volatile memory.
33 In the Pilot's Operating Handbook and Pipistrel online course.
34 A spin is a yaw aggravated stall which results in rotation about the spin axis. The aircraft follows a steep, "corkscrew" like, downward path (Skybrary: https://www.skybrary.aero/index.php/Spin).

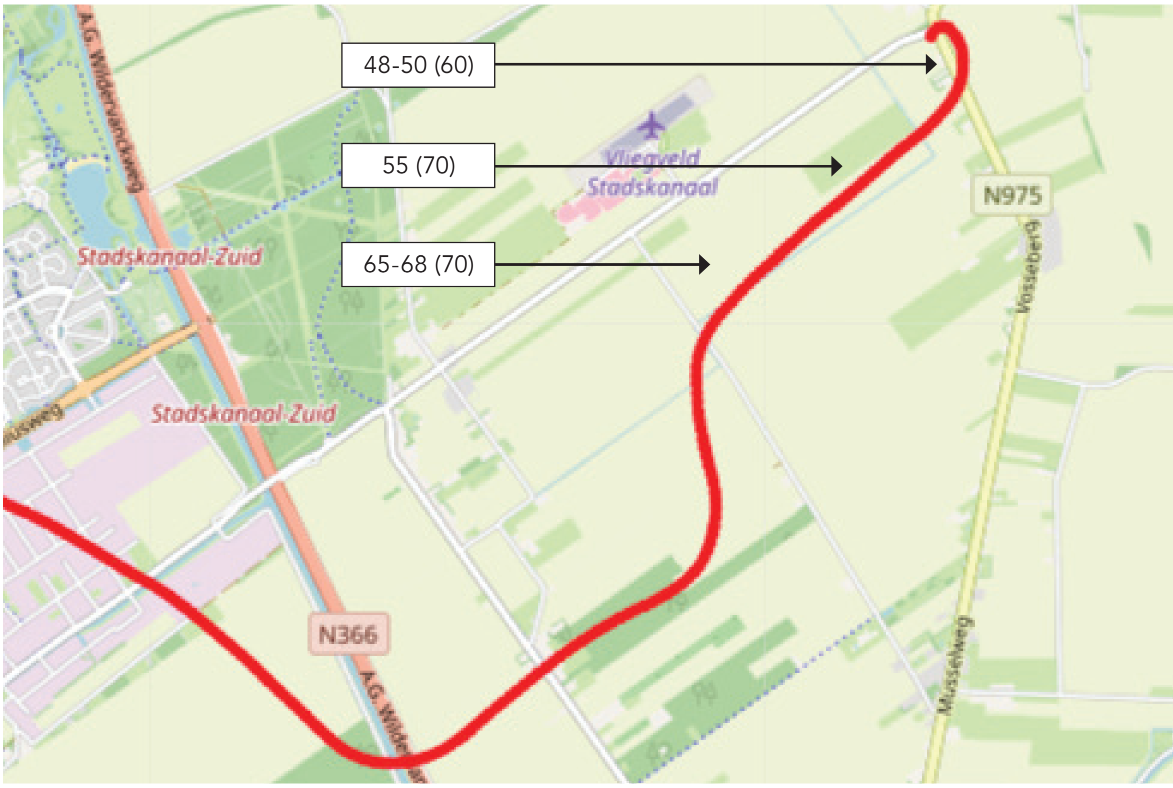

Figure 11: The last part of the flight; actual and prescribed (between brackets) airspeeds in knots. (Source: ATC the Netherlands and OpenStreepMap)

In addition to the low airspeed, the flight data also shows that the aeroplane made an uncoordinated turn while on base leg. An uncoordinated turn means that the pilot has applied insufficient or too much rudder input in a turn, which results in a skid or slip. This is visible by a yawing motion to the left to the inside of the turn. In general, uncoordinated flight increases the aerodynamic drag and has an adverse effect on the aeroplane's stability. It is worth noting that it is considered difficult to maintain coordinated flight in the Pipistrel Alpha Electro due to the pilot's seating position in the cockpit as mentioned before (in paragraph 1.7.8). Specifically in this case, the uncoordinated turn may have contributed to the loss of control situation.

The power is normally retarded to idle at the beginning of the base turn. Flight data confirms that the propeller RPM decreased to idle values of approximately 850 at the start of the base turn. This is according to the flight manual.

The actual wind at 500 feet was from direction 170 degrees and 17 knots. This resulted in an increasing tailwind component and subsequently, as a result of inertia, a decrease of true airspeed while the aeroplane turned to base leg. The wind at altitude while turning to base leg may have had an amplifying effect on the decreasing airspeed because of the light mass of the aeroplane.

Both the flight animation and the statements of the experts and eye witnesses confirm that the aeroplane's left-hand wing and the nose dropped sharply while half way on base leg. From there, the aeroplane quickly developed a left turning nose down attitude with a high descent rate from which it did not recover. It could not be determined whether the pilot had attempted to apply the recovery procedure for a stall and spin as stated by the Pilot's Operating Handbook. No communications from the pilot that he experienced problems with the aeroplane during the flight were received by radio. It could not be established whether the pilot made an effort to communicate that he was experiencing problems. It is concluded that the low airspeed, the uncoordinated turn and tailwind on base leg resulted into the stall and incipient spin.

The aeroplane came to a standstill in the farmland at a distance of approximately 30 meters after the initial impact with the road. This was caused by the aeroplane having a considerable forward airspeed (80 knots IAS indication on airspeed indicator) in relation to the vertical speed (more than 2,000 feet per minute descent) at the moment of impact.

The low airspeed, the uncoordinated turn and tailwind on base leg resulted into a stall followed by an incipient spin. This resulted in a left turning, nose down attitude with a high descent rate, from which the aeroplane did not recover.

2.3.2 Contributing factors

The following three factors have been established as contributing to the cause of the accident.

Landing configuration

The aeroplane was found with the flap lever in the +25° ('full flap') position, see Figure 12. This is the configuration for landing. The Pilot's Operating Handbook mentions that the flaps should be selected to +25° on final. With the flaps fully extended (resulting in increased drag forces), the aeroplane is more susceptible to adverse yaw and may therefore require extra attention to rudder coordination. The adverse yaw, which is amplified by the full wing span flaperons of the aeroplane, increased the chance of the loss of control.

Based on the lever construction, it is unlikely that the lever position was changed by the forces of the impact. The actual position of the flaps at the moment of the impact could not be determined, because of the damaged flaperons and wings as a result of the impact and post impact fire. Because of the flap lever construction, it is assumed that the flaps were put deliberately in the full flaps position. It could not be determined why full flaps were selected before being on final.

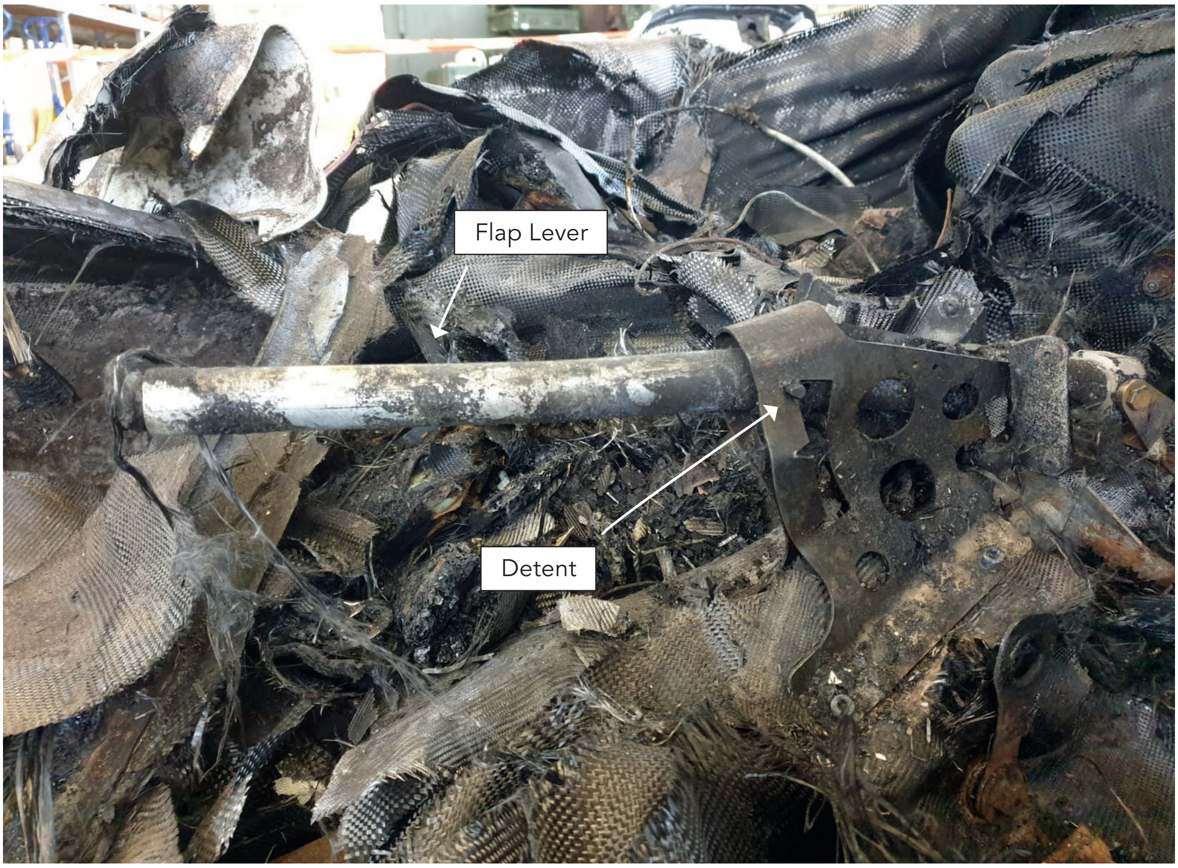

Figure 12: Flap lever set in detent for full flaps.

Aeroplane not equipped with stall warning system
A stall warning system warns the pilot for an approaching stall condition, so the pilot may prevent this with a timely correction. A stall warning system is normally required by design if the natural stall warning characteristics[35] of the aeroplane are found to be insufficient.

The inherent aerodynamic characteristics of the Pipistrel Alpha Electro provide natural stall buffeting that may not always be sufficient to warn the pilot of an approaching stall. The aeroplane was not equipped with a stall warning system which prevented the timely recognition of the approaching stall and an unsafe situation from occurring. Such a system was not a requirement for MLAs registered in the basic category; this in contrast to the advanced category where a stall warning system is required if the natural stall warning is insufficient.

The intended use of the Pipistrel Alpha Electro is *ab initio* pilot training. It is important in pilot training to properly train the recognition and recovery of a stall in its various stages of development. A stall warning system to warn the pilot of an approaching stall is therefore considered an essential part of the aeroplane's equipment, irrespective of its actual stall characteristics or airworthiness requirements. It is therefore remarkable that the aeroplane was not equipped with a stall warning system. Pipistrel has indicated to provide all its aeroplanes with stall warning devices as of 2020.

35 Also called aerodynamic buffeting.

The pilot's flying experience

The pilot was not considered as sufficiently familiar with Stadskanaal airfield because he had visited the airfield only in 2015, hence more than 3 years before the day of the accident. Furthermore, the accident flight was the first time the pilot visited Stadskanaal airfield with the Pipistrel Alpha Electro. His unfamiliarity and the following three factors may have had an worsening effect on the developing low airspeed on base leg.[36] First, the circuit height of Stadskanaal airfield is 500 feet AAL which is lower than the 700 feet AAL circuit height of the airfields he usually visited. This might have given the impression to the pilot that he was flying faster than he actually did. Second, the downwind leg is relatively short as a result of the runway length of 500 metres. This requires a different timing with regard to the power management (compared to a 'normal' circuit). This may have been amplified by the tail wind component the aeroplane encountered when turning to base leg. Third, the lower than normal circuit height also required the pilot to apply more engine power on base leg than he was used to when flying in 700 feet AAL circuits. The reason for the application of more engine power lies in the fact that a 500 feet AAL circuit base leg has a lesser descent gradient and therefore requires more power to maintain the airspeed.

The pilot's total flying experience was 571 hours. The pilot made eleven flights with the Pipistrel Alpha Electro with a total flight time of 7 hours and 20 minutes. His last flight on this aeroplane had been on 10 September 2018, more than a month before the accident. His total flying time on MLAs was 41 hours, which implies limited proficiency[37] with this MLA and limited flying experience[38] with MLAs in general.

Since the Alpha Electro is a new concept microlight aeroplane that is electric-powered, it is considered good practice to become adequately familiar with the technical and flying characteristic of the aeroplane. To familiarize himself with the aeroplane, the pilot had made two flights with a total flight duration of 1 hour and 25 minutes with another pilot in the Alpha Electro. This, however, did not entail a formal training program, and may have been insufficient to become adequately familiar with the aeroplane.

It is concluded that the limited flying experience, proficiency and training with this new concept aeroplane, contributed to a situation in which it was difficult to recognize the approaching stall and recover from the loss of control situation.

36 The DSB considers these factors, partly based on experiences of pilots with local knowledge of Stadsknaal airfield, important to list as possible contributing factors.

37 Proficiency is the fact of having the skill and experience for doing something (Source: https://dictionary.cambridge.org/dictionary/english/proficiency).

38 Experience is a function of the time spent performing a task and the variety of conditions of performance that have been encountered (Source: https://www.skybrary.aero/index.php/Experience).

The full wing span flaperons in combination with the unusual landing configuration of +25° flaps on base leg made the aeroplane more susceptible to adverse yaw and uncoordinated flight. This increased the potential for a loss of control situation while flying at an airspeed near the stall speed.

The aeroplane's stall properties and the lack of a stall warning system gave the pilot insufficient warning of the approaching stall.

The pilot's limited flying experience, proficiency and training with the Pipistrel Alpha Electro contributed to a situation in which it was difficult to recognize the approaching stall and recover from the loss of control situation.

2.3.3 Loss of control accidents

The accident with the Pipistrel Alpha Electro can be classified as a loss of control in-flight (LOC-I) accident. Loss of control can happen because the aircraft enters a flight regime that is outside its normal flight envelope and may quickly develop into a stall or spin.

LOC-I is the most frequent and most deadly type of accident in general aviation. There are approximatively 37 fatal LOC-I accidents per year in Europe leading to 67 persons on average losing their lives every year due to LOC-I (for fixed-wing aircraft only). The take-off and landing phase are particularly risky.

This accident signifies the importance of a warning of an approaching stall to prevent a loss of control situation.

2.3.4 Hazards associated with electric-powered MLAs

MLAs with electric propulsion are a new development. The energy that is necessary to propel these aircraft is delivered by high-capacity lithium-ion batteries. However, using these batteries creates a risk of fire.

The hazards associated with electric-powered MLAs are further described in Appendix C.

The fire hazard of lithium-ion batteries used in MLA propulsion is characterized by a fire with a high calorific value, the speed at which the fire develops, and the fact that such a fire is hard to extinguish.

2.4 Registration of I-D057

I-D057 was registered in Italy in the basic category. The owner of I-D057 had declared on registration that the aeroplane complied with the requirements for registration in the basic category. One of these requirements is that the aeroplane has a stall speed not exceeding 35 knots. However, I-D057 had a stall speed (in landing configuration) of 38 knots (exceeding 35 knots) and as such does not comply with the requirements for registration in the basic category.

Revision A00 (12 July 2017) of the Pipistrel Pilot's Operating Handbook contains a stall speed (in landing configuration) of 35 knots IAS. In 2018 Pipistrel decided to consolidate all its manuals to read V_{S1} and V_{S0} as 'retard-throttle' stall speeds. There is a difference in stall speed of approximately 3 knots, whether power is applied or not. Since 21 March 2018, the 'new' stall speed of 38 knots IAS has been mentioned in the Pipistrel Pilot's Operating Handbook (revision A01).[39]

The Italian advanced category for microlight aeroplanes contains requirements for traditionally powered aeroplanes. The advanced category does not specify requirements for electric-powered aeroplanes. It was therefore not possible to register the aeroplane in the advanced category. Moreover, taking the basic and advanced category requirements into account, it is inferred that I-D057 could not be registered in either category.

Nevertheless the owner stated that I-D057 complied with the conditions for registration in the basic category. Aero Club d'Italia issued the registration document ('certificate of registration and issue of flight permit'). This registration document allows the aeroplane to fly in Italian airspace under the restrictions set forth by the basic category for microlight aeroplanes. According to the Aero Club d'Italia, this document has only a registration function. Hence, it does not endorse whether the aeroplane complies with the requirements of the basic category. However, the wording 'flight permit' that was used on the front cover of the issued document for I-D057, may imply differently, i.e., that it was a Permit to Fly.[40] To prevent misinterpretation of the registration document in the future, Aero Club d'Italia has indicated to change the wording of the document.

I-D057 did not comply with the requirement of a maximum stall speed of 35 knots needed for registration in the Italian basic category for microlight aeroplanes.

2.5 MLAs with foreign registration in Dutch airspace

This chapter clarifies admission into Dutch airspace and the safety level of MLAs with foreign registrations compared to MLAs with Dutch registration.

Airworthiness requirements for MLA differ from those for conventional aeroplanes. An MLA is an aeroplane that has not been certified in accordance with international standards. This means that the safety level has not always been demonstrated, as is the

39 Prior to 2018, stall speeds were quoted as minimum achievable stall speeds, under certain power. With the throttle in idle position, the minimum speed with full aft elevator control is 38 knots IAS. Adding power would actually result in a slower flight of 35 knots IAS, because a higher angle of attack can be achieved.

40 A Permit to Fly is generally issued when a certificate of airworthiness is temporarily invalid, or when a certificate of airworthiness cannot be granted, but the aircraft is nevertheless capable of performing a safe flight (Source: EASA Fact Sheet).

case for EASA-certified aircraft. As such, MLAs are outside the scope of EASA's sphere of responsibility; hence national regulations apply.

In Dutch airspace, the *MLAs, MLHs and motorized paragliders Regulation*[41] formulates requirements for the admission and use of MLAs with a Dutch registration. One of the requirements relates to airworthiness. A special certificate of airworthiness (*Bewijs van Luchtwaardigheid*, BvL) is required for the registration and licensing of MLAs in the Netherlands. With regard to airworthiness, the Dutch regulation is primarily derived from the British, German and Czech MLA technical requirements. These countries have established airworthiness requirements for the design and safe use of MLAs. In the Netherlands, MLAs must have a safety level equivalent to the airworthiness requirements as established in one of the mentioned countries. As such, there are internationally derived airworthiness requirements for Dutch MLAs. However no international certification exists for those requirements such as issued by EASA.

There are no airworthiness requirements established or in a developing phase in the Netherlands or in one of the three countries mentioned above for innovation, like electric-powered aeroplanes. Therefore it is not yet possible for electric-powered aeroplanes to register and obtain a special certificate of airworthiness in the Netherlands.

MLAs with a foreign registration are not freely allowed into Dutch airspace. Admission and temporary use in Dutch airspace is based on article 9a of the *MLAs, MLHs and motorized paragliders Regulation*. Article 9a applies to MLAs registered in one of the member states of European Civil Aviation Conference (ECAC).[42] I-D057 was registered in Italy, which is a member state of ECAC. The term 'temporary', as mentioned in article 9a, is not further specified. I-D057 did not use Dutch airspace temporarily, but made 42 flights in a period of more than 4 months. For comparison: the *Framework of exemptions airworthiness 2015* (in Dutch: *Normenkader ontheffingen luchtwaardigheid 2015*[43]) refers to an exemption (regarding the permanent use of Dutch airspace) that is limited in time and place. The legislator mentions here that it concerns "one or a few flights". This framework applies to all aircraft in Dutch airspace.

The Italian regulations with regard to basic MLAs contain no specific design requirements, making it less restrictive than the Dutch regulations. As a result, the Italian regulations do not require the same airworthiness and safety levels.[44]

Article 9a specifies that for admission of the aeroplane in the Netherlands, the competent authority that issued the certificate of registration must also have issued a certificate showing that the aeroplane is allowed to conduct flights in its state and complies with relevant Italian regulations. For I-D057, the registration document, issued by Aero Club d'Italia, allowed it to use Dutch airspace temporarily.

41 https://wetten.overheid.nl/BWBR0015237/2018-04-01
42 Founded in 1955 as an intergovernmental organisation, European Civil Aviation Conference (ECAC) seeks to harmonise civil aviation policies and practices amongst its Member States and, at the same time, promote understanding on policy matters between its Member States and other parts of the world. ECAC's mission is the promotion of the continued development of a safe, efficient and sustainable European air transport system.
43 https://www.ilent.nl/documenten/publicaties/2016/01/15/normenkader-ontheffingen-luchtwaardigheid-2015
44 In contrast, the advanced category does have comparable design requirements as the Dutch regulations.

Under article 9a of the *MLAs, MLHs and motorized paragliders Regulation* foreign-registered MLAs from ECAC countries may be granted temporary access to Dutch airspace. Such temporary access does not guarantee airworthiness and safety levels equivalent to those imposed on Dutch registered MLAs.

2.6 ILT's oversight on MLAs

Since MLAs were first introduced in the 1980s, the use of them in the Netherlands has increased. In the early years, the MLA regulations mainly aimed to restrict the use of MLAs. However, in the years following 1992, a number of these restrictions was removed. This allowed the MLA sector to grow significantly.

Today, the term 'MLA' includes simple motorized paragliders and 'trikes' as well as aeroplanes that are barely distinguishable from traditional two-seater aeroplanes. MLAs such as the Pipistrel Alpha Electro belong to this latter group of aeroplanes.

The Human Environment and Transport Inspectorate (ILT) defines an ILT-wide oversight programme for every year, aiming primarily to enhance safety and environmental protection in accordance with national and international laws and regulations. The programme specifies the number of inspections to be conducted by the ILT. The programme is compiled on the basis of risk analysis and the available safety information, such as trend analyses, inspection results, and national and international studies and investigations.

MLAs are not included in the ILT's current oversight programme, the main reason being that the ILT does not consider MLAs a risk group. In the report titled *Micro Light Aeroplanes Study* by the Dutch Safety Board[45], it was concluded that enforcement of MLA oversight was de facto an administrative operation. At that time (2007) also no actual inspections occurred in practice.

Discussions with the ILT and the aviation sector, as well as a study of the MLA regulations, revealed that innovative developments in the sector and national regulations for MLAs with a rigid wing construction are no longer congruent. An example of this is the exceedance of the maximum takeoff weight when flying with an MLA with two people on board.[46] This is not monitored by the ILT.

45 Onderzoeksraad voor Veiligheid, *Onderzoek Micro Light Aeroplanes*, 2007.
46 On 17 April 2020 the Minister of Infrastructure and Water Management mentioned in a letter to the House of Representatives of the Netherlands, that she had decided to make use of the opt-out possibility (conform the Basic Regulation (EU) 2018/1139) to put microlight aeroplanes with a maximum takeoff weight between 450 and 600 kilograms under national policies and regulations.

Innovative developments in the MLA sector and national regulations for MLAs with a rigid wing construction are no longer congruent.

In general, when innovation is introduced, like electric propulsion, one would expect the Ministry of Infrastructure and Water Management to fulfil a proactive role, prior to the first flight, in developing a system of safety demands to safeguard the use of that method.[47] The Dutch Safety Board did not observe this role. The current oversight regime does not consider developments in the MLA industry proactively.[48]

In the case of I-D057, it operated in Dutch airspace while not complying with Dutch and Italian regulations. It did not use Dutch airspace temporarily, but made 42 flights in a period of more than 4 months, and it exceeded the maximum takeoff weight of 472.5 kg.

The aeroplane operated in Dutch airspace while not complying with Dutch and Italian regulations. It did not use Dutch airspace temporarily, but made 42 flights in a period of more than 4 months, and it exceeded the maximum takeoff weight of 472.5 kg.

The Human Environment and Transport Inspectorate stated not to perform oversight on microlight aeroplanes; the main reason being that she does not consider MLAs a risk group.

The Ministry of Infrastructure and Water Management did not fulfil a proactive role, prior to the first electric-powered flight in the Netherlands, in developing a system of safety demands to safeguard the use of this new propulsion method.

47 For example: set requirements for airport equipment to charge batteries and for a program to be retrained from conventional to electric-powered aeroplanes.

48 The problems and risks pertaining to the regulation of innovation are also addressed in the report 'Safe admittance onto the public roads – Lessons learned from the Stint accident', published by the Dutch Safety Board on 16 October 2019. The Safety Board concluded that in the national decision making procedure on light motorized vehicles, vehicle safety and the consequences of admittance for road safety have been insufficiently taken into account.

3 CONCLUSIONS

The accident was caused by a low airspeed situation, close to the stall speed. This led to a stall followed by an incipient spin from which the aeroplane did not recover. Contributing factors to the accident were the aeroplane's full wing span flaperons in combination with the unusual landing configuration of +25° flaps on base leg, the aeroplane's stall properties, the lack of a stall warning system and the pilot's limited flying experience, proficiency and training with the Pipistrel Alpha Electro.

The technical investigation did not reveal any technical defect that could have been a contributing factor to the cause of the accident.

The emergency locator transmitter was not activated during the crash because the module was in OFF mode. This had no effect on alarming the search and rescue operation. Nevertheless, having the ELT system functional during flight is strongly recommended.

The fire hazard of lithium-ion batteries used in MLA propulsion is characterized by a fire with a high calorific value, the speed at which the fire develops, and the fact that such a fire is hard to extinguish. The fire departments extinguished the fire in accordance with their instructions.

An equivalent level of safety and airworthiness, as imposed on Dutch registered MLAs, is not guaranteed when foreign-registered microlight aeroplanes from member states of the European Civil Aviation Conference make temporary use of Dutch airspace.

Innovative developments in the MLA sector and national regulations for MLAs with a rigid wing construction are no longer congruent.

The aeroplane I-D057 operated in Dutch airspace while not complying with Dutch and Italian regulations. It did not use Dutch airspace temporarily, but made 42 flights in a period of more than 4 months, and it exceeded the maximum takeoff weight of 472.5 kg. The aeroplane did not comply with the requirement of a maximum stall speed of 35 knots needed for registration in the Italian basic category for microlight aeroplanes. The Human Environment and Transport Inspectorate stated not to perform oversight on microlight aeroplanes; the main reason being that she does not consider MLAs a risk group.

The Ministry of Infrastructure and Water Management did not fulfil a proactive role, prior to the first electric-powered flight in the Netherlands, in developing a system of safety demands to safeguard the use of this new propulsion method.

4 RECOMMENDATIONS

The Pipistrel Alpha Electro 167 and similar microlight aeroplanes, fall within the category of aeroplanes to which the European common rules on civil aviation do not apply (Basic Regulation, Regulation (EC) 216/2008, which was applicable when the aeroplane was registered, now replaced by Regulation (EU) 2018/1139). These aeroplanes fall under the regulatory control of the member states, in light of their limited risk to civil aviation safety, simple design, or operations mainly on local basis. However, microlight aeroplanes have become more advanced and increasingly popular over the years and they are also operated across borders. With the growing numbers and the increasing complexity of the design of microlight aeroplanes, the Dutch Safety Board believes also for these aircraft a minimum level of safety within Europe should be determined.

The Dutch Safety Board therefore issues the following recommendations:

To the Minister of Infrastructure and Water Management:

1. To improve the safety of microlight aeroplanes registered and/or operating in the Netherlands and the safety of third parties, by setting up and implementing effective oversight of the sector.

2. With regard to the innovation of microlight aeroplanes, determine additional requirements that microlight aeroplanes registered and/or operating in the Netherlands must meet and implement them within the Netherlands. Then actively strive to accept these requirements as standard within the member states of European Civil Aviation Conference (ECAC), with the aim of creating a minimum level of safety for this category of aircraft.

3. For the long term to promote that the requirements and oversight of microlight aeroplanes will be evaluated and reconsidered by European Union Aviation Safety Agency (EASA).

APPENDIX A

RESPONSES RECEIVED ON DRAFT REPORT

A draft version of this report, without recommendations, was presented to the parties involved, in accordance with the Dutch Safety Board Kingdom Act. These parties were requested to check the report for any factual inaccuracies and ambiguities.

The draft report was presented to the following parties:

- Aero Club D'Italia
- Air, Maritime and Railway, Accident and Incident Investigation Unit, Slovenia.
- Human Environment and Transport Inspectorate
- iFly Benelux b.v.
- Ministry of Infrastructure and Water Management
- Pipistrel Vertical Solutions d.o.o.
- Relatives
- Veiligheidsregio Groningen

The Board has taken note of the responses received. The responses and explanations are listed in a table which is available on the website of the Dutch Safety Board: https://www.onderzoeksraad.nl/en/.

FLIGHT PARAMETERS

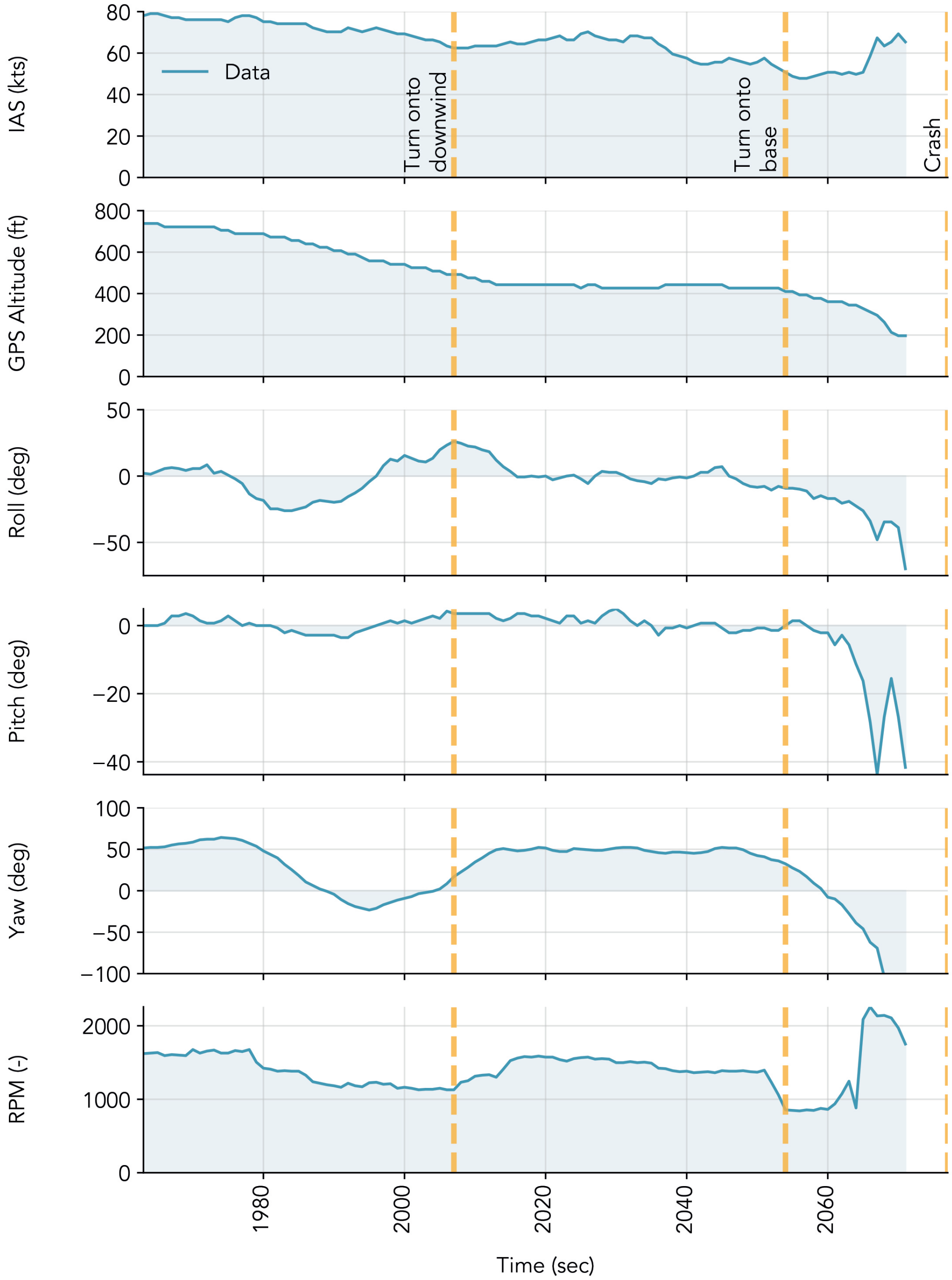

Figure 13: Flight parameters, derived from the altimeter's air data computer.

APPENDIX C

HAZARDS ASSOCIATED WITH ELECTRIC-POWERED MLAS

Fire hazard electric-powered MLAs
Lithium-ion batteries have been transported as a power supply for mobile telephones and laptops in hand luggage or cargo in aeroplanes for quite some time now. In this context, incidents in which a lithium-ion battery caught fire have occurred in recent years. Incidents with mobile telephones and other electronic devices are well-known. In addition, there have been catastrophic cases involving spontaneous combustion of lithium-ion batteries transported as cargo.[49]

The use of lithium-ion batteries as part of the technical equipment and/or propulsion system of aeroplanes is a relatively new development. Here, too, several incidents have occurred. One example is the spontaneous combustion of a lithium-ion battery in a Boeing 787 in 2013.[50] In a more recent incident, the lithium-ion battery in a glider with an electric-powered auxiliary engine caught fire.[51] The investigation into the occurrence with the Boeing 787 showed a manufacturing defect of the lithium-ion battery as the (possible) cause. The investigation into the occurrence with the glider did not identify the cause of the arcing which resulted in the electrical fire.

Due to their physical and chemical properties, lithium-ion batteries are sensitive to (spontaneous) combustion. This may be caused by:
1. Exceeding the minimum or maximum ambient temperature of the battery.
2. Exceeding the minimum or maximum charge and discharge voltages for which the battery is designed.
3. Damage to the battery, for instance due to shock or impact, causing an internal short-circuit.
4. Manufacturing defect leading to internal short-circuit.

Generally speaking, (spontaneous) combustion is initiated by a temperature rise within or outside the battery. This causes (thermal) instability of the chemical composition of the battery. Once the battery temperature rises above a specific value, the process cannot be halted and a so-called thermal runaway occurs. Eventually this leads to combustion of the individual cell. The cell may explode, releasing hot gases and flames. This generally leads to ignition of the neighbouring cells.

49 Skybrary, Accident and Incidents: https://www.skybrary.aero/index.php/Lithium-Ion_Aircraft_Batteries_as_a_Smoke/Fire_Risk#Lithium_Batteries_as_Cargo_-_NTSB_Recommendations
50 https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1401.pdf
51 See paragraph 1.18 of this report.

Batteries used in aeroplane propulsion are generally large and contain a lot of energy. As a result, the consequences of such batteries catching fire are equally significant. Should such a battery catch fire during a flight, consequently there is little time to initiate and execute emergency procedures, as the fire will develop quickly and is difficult to extinguish. Besides lithium-ion batteries generate a risk when aeroplanes are being parked, for example in a hangar. The risk of fire is greater when batteries are being charged or after they have been charged. It is foreseeable that the charging of batteries will take place at the end of a flying day, while the aeroplanes are being parked. In this case, the ignition of a battery can spread to other aeroplanes.

> The fire hazard of lithium-ion batteries used in MLA propulsion is characterized by a fire with a high calorific value, the speed at which the fire develops, and the fact that such a fire is hard to extinguish.

Fire control in electric-powered aircraft
Fire control in electric-powered aircraft with lithium-ion batteries demands a different fire extinguishing method than in aircraft using fossil fuels.
In this specific case, where the fire was a result of the crash, the fire department was aware that an electric-powered aeroplane was involved. The fire trucks were equipped with so-called focus sheets, which provide instructions for the fire extinguishing methods to be used.

The focus sheets contained amongst others instructions for extinguishing fires in electric cars. The recommendation on the sheets was to use a lot of water. In this case the recommendation was followed. Water was used for approximately 45 minutes. The extinguishing operations served to limit the scope of the fire, notwithstanding the fact that the aeroplane was largely destroyed by the crash and the resulting fire.[52]

With the existing knowledge at the time of the accident, the extinguishing method for a fire in electric cars, is to use copious water for a long time, wear full personal protective equipment and continuously monitor temperatures. This was recommended by the Dutch Institute for Safety.[53]

> The fire department extinguished the fire in accordance with instructions.

52 From conversations with experts on lithium-ion battery fires it appears that extinguishing with water is not always the preferred method. New developments in this area concern new guidelines for extinguishing battery fires and the use of newly developed extinguishing agents, such as Condensed Aerosol en Aqueous Vermiculite Dispersion.
53 In Dutch: *Instituut Fysieke Veiligheid*.

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