DUTCH
SAFETY BOARD

Crashed during aerobatic flight

Bussloo

Crashed during aerobatic flight

Bussloo, 19 March 2014

The Hague, June 2016

Source photo cover: Dutch Safety Board.

Dutch Safety Board

The aim in the Netherlands is to limit the risk of accidents and incidents as much as possible. If accidents or near accidents nevertheless occur, a thorough investigation into the causes, irrespective of who are to blame, may help to prevent similar problems from occurring in the future. It is important to ensure that the investigation is carried out independently from the parties involved. This is why the Dutch Safety Board itself selects the issues it wishes to investigate, mindful of citizens' position of independence with respect to authorities and businesses. In some cases the Dutch Safety Board is required by law to conduct an investigation.

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

CONTENT

GENERAL INFORMATION

Figure 1: Accident site D-EXIR. (Photo: Dutch Safety Board)

Occurence number:	2014034
Classification:	Accident
Date, time of accident:[1]	19 March 2014, around 18.30 hours
Location of accident:	Golf course near Bussloo, the Netherlands
Aircraft registration:	D-EXIR
Aircraft model:	Extra EA-300L
Aircraft type:	Single-engine propeller aeroplane
Type of flight:	Aerobatic flight
Phase of flight:	En route
Damage to the aircraft:	Destroyed
Number of crew:	One
Number of passengers:	One
Injuries:	Both occupants deceased
Other damage:	Damage to the golf course
Light conditions:	Daylight

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

SUMMARY

On 19 March 2014 the captain of a single-engine aeroplane, model Extra EA-300L with registration D-EXIR, conducted an aerobatic flight[2] from Teuge airport. On board were the captain and a passenger. Early in the flight, multiple manoeuvres were flown between about 1.000 and 3.500 feet. A climb was then initiated to about 4.100 feet, which was followed by a steep descending movement. This steep descent was not timely aborted, after which the aircraft flew into the ground. The aeroplane crashed on a golf course near Bussloo and was completely destroyed. Both occupants lost their lives. The investigation did not reveal an obvious cause for the accident. A number of possible causes was identified by means of exclusion and probability.

During the investigation it was established that the laws and regulations, as well as supervision on the performing of aerobatic flights, can be improved. Although not directly related to the occurrence of the accident, this issue is included in the report to encourage the parties concerned to implement these improvements.

2 An aerobic flight is a flight in which movements involving a sudden change in the position, an abnormal position or an abnormal change in speed of the aircraft, are performed deliberately (Article 1-l of the Regulation on Aviation Supervision (Regeling Toezicht Luchtvaart, RTL)). Aerobatic flights are also known as aerobatics or stunt flying.

1 FACTUAL INFORMATION

1.1 The flight and the accident

On 19 March 2014 at around 18.00, the captain made radio contact with the authority at Teuge airport (EHTE) to announce a local flight with D-EXIR, an Extra EA-300L, with a passenger. It was the captain's second flight with D-EXIR that day. A few minutes before the second flight, he had his aeroplane refuelled with 35.2 liters of fuel. At 18.10, D-EXIR took off and departed in a north westerly direction. The authority recorded the flight as a private flight.

Radar images show that D-EXIR performed several manoeuvres north of Apeldoorn at altitudes between about 1.000 and 3.500 feet. After about fifteen minutes, D-EXIR flew southbound between Apeldoorn and Teuge. When it reached the Sierra reporting point of Teuge airport, it changed course to the southeast. It then gradually climbed to approximately 4.100 feet (see figure 2).

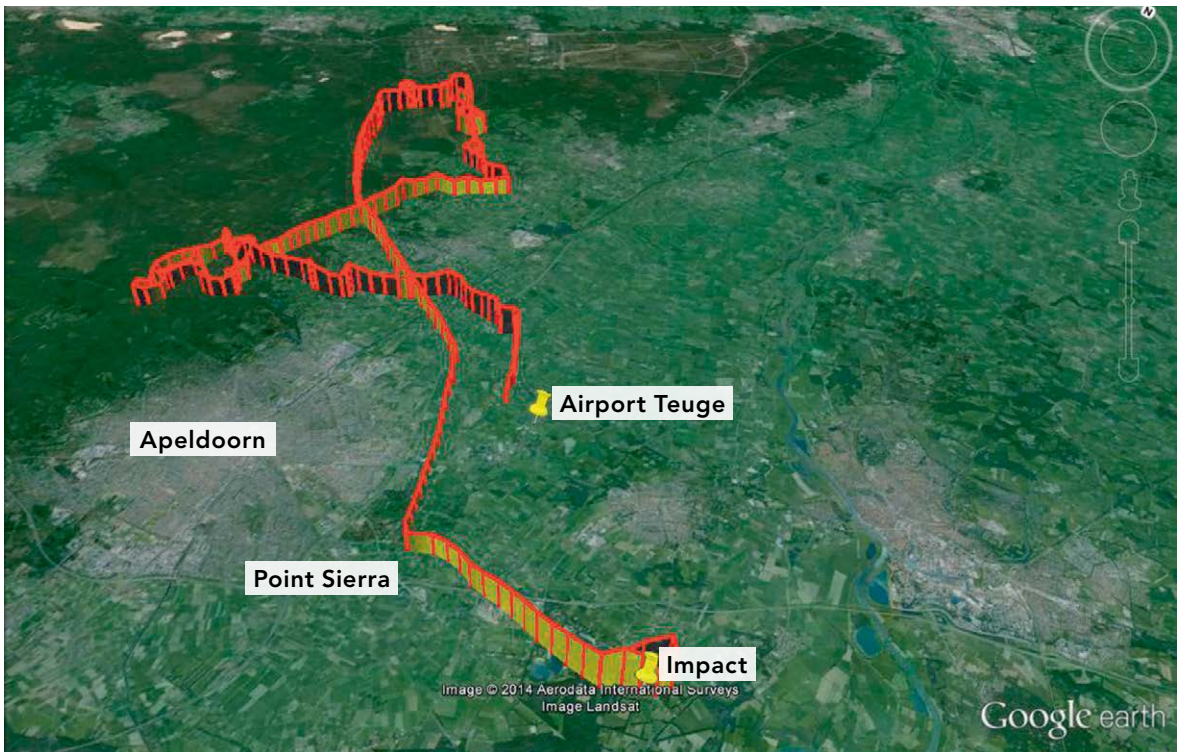

Figure 2: The flight path of D-EXIR. (Photo: Radar images from Air Traffic Control the Netherlands, as visualised in Google earth)

At this altitude, a strongly downward manoeuvre was performed. The radar images of the flight showed a continuous descent. For the last part of the flight, statements by witnesses indicate a steep descent of the aeroplane, accompanied with a lot of engine noise. This steep descent was not timely aborted, resulting in the aeroplane crashing into the ground. The aeroplane was completely destroyed and both occupants lost their lives.

1.2 On-site investigation

The aeroplane crashed on a golf course. The place where the aeroplane first hit the ground was clearly visible. An impact pit with impressions from the wings on both sides could be seen. At the ends of the wing impressions, orange metal tubes were visible, each of which stuck into the ground at an angle of approximately 20 to 30 degrees. The aeroplane had completely disintegrated, with the heaviest parts lying closest to the point of impact. From the point of impact, parts of the aeroplane parts had spread out in one direction. The direction in which the parts had spread, was approximately 30° relative to the North. The parts which had scattered furthest, were located about 88 meters from the point of impact.

Figure 3: Aerial photograph of the crash site. (Photo: National Police)

The wreckage of the aeroplane was confiscated by the police and taken to a hangar for further investigation.

1.3 Information on the occupants

The captain

The captain, a 24-year old male who was the owner of D-EXIR, had been in possession of a valid private pilot licence for aeroplanes (PPL(A)) since October 2009. He had received the training for this licence at Teuge airport. In addition, the captain was working towards obtaining his flight instructor rating (FI). From statements it appeared that the captain had the intention of getting his commercial pilot licence (CPL). For this, he completed the required theoretical examinations in June 2013.

Since August 2012, the captain had been in possession of a valid Dutch display authorization (DA). His intentions were to further develop his aerobatic flying skills. With a display authorisation, a pilot may participate at air displays.[3] This authorisation must be renewed annually. In August 2013, the captain had not renewed his authorisation, so it was expired. The reason why he had not extended this is unknown.

In addition to a display authorisation, the captain had also been in possession of an annual permit for organising and performing air displays since September 2012. With this permit he could independently, without the supervision of a display director, organise and perform air displays consisting of a number of aerobatic manoeuvres with D-EXIR. This authorization had been prolonged for another year in October 2013.

The captain had been in possession of a medical certificate class I, valid until 29 November 2014.

	Flight hours	Number of flights
Total on all types	384	394
Total at time of purchasing D-EXIR	154	225
Total on the type involved	85	173
During the last 90 days on all types	21	45

Table 1: flying experience of the captain.

The passenger

The passenger did not possess any pilot licence. He had flown on D-EXIR as a passenger once before.

3 An air display is an event with one or more demonstration aircraft in the air, organised to provide entertainment to an audience. (Art. 1 h. of the Air Display Regulation).

1.4 Information on the aircraft

Figure 4: Archive photo of D-EXIR. (Photo: J. Hage)

D-EXIR was of make and model Extra EA-300L. This is a single-engine propeller tail-wheel aeroplane, designed in 1987, intended mainly for flying unlimited aerobatic manoeuvres. The aircraft is powered by a Lycoming engine producing 300 brake horse-power at an engine speed of 2.700 rpm. Fuel is stored in two wing tanks (both with a capacity of 60 liters), and in an Acro & center tank (51 liters). In the cockpit, with room for two people, the seats are installed behind each other. The rear seat is intended for the pilot/captain.

D-EXIR was registered in the German aircraft register and had a valid airworthiness certificate on the day of the accident. The aeroplane was maintained by an approved maintenance organisation at Teuge airport. The last maintenance work on D-EXIR had been carried out on 19 February 2014 (100-hour inspection) and there were no known defects on the aeroplane. Until the day of the accident, the aircraft had 450:15 flying hours.

The aeroplane is designed so that the flight characteristics of a normal horizontal straight and level flight, are identical to those when flying inverted. The Extra EA-300L manual states that when flying with one occupant, the G-limits are ± 10G, while with two occupants these limits are ± 8G.[4] Such G-loads may only be used if the Acro & center tank is filled and the two wing tanks are empty. With these features, the aeroplane can make virtually unlimited manoeuvres, placing it in the highest performance category of aerobatic aircraft.

4 'G' represents gravity and indicates gravitational acceleration (for example, +3G means that gravity becomes three times as large). Positive G's are involved when an object becomes heavier than its weight on the ground, due to a force working against the direction of gravity (e.g. a climbing aircraft). Negative G's are involved when an object falls towards the earth faster than the force of gravity, making it lighter than its weight on the ground, due to an additional earthward force (e.g. a descending aircraft). See annex A.

Beneath the ailerons, the aircraft is equipped with so-called 'spades' (see figure 5). These are installed to reduce excessive forces on the pilot's steering column, so that movements around the longitudinal axis can be made with much less effort. Both wing tips are equipped with a construction of bars that help the pilot to determine the position of the aeroplane relative to the horizon (see figure 6).

Figure 5: 'Spade'. (Photo: Dutch Safety Board)

Figure 6: Construction of bars on the wingtips. (Photo: J. Hage)

1.5 Weather

According to a report from the Royal Dutch Meteorological Institute (*Koninklijk Nederlands Meteorologisch Instituut, KNMI)*, there was a strong westerly current of dry air. At ground level, the temperature was about 13 degrees Celsius. The wind came from a direction of 240 degrees at a speed between 12 and 20 knots, in the altitude veering and increasing in strength to 30 knots at 3.000 feet. Visibility was over 10 kilometers and there were no clouds below 8000 feet. Atmospheric pressure was 1019 hPa. On 19 March 2014, the daylight period at Teuge airport ended at 19.02.

2 INVESTIGATION AND ANALYSIS

2.1 The flight and the accident

After D-EXIR took off, there was no further radio contact between the Teuge airport authority and the pilot of the aeroplane. The aircraft had no recording equipment on board from which it can be reconstructed how the flight developed and what manoeuvres were made. However, a so-called action camera of the type GoPro was found at the scene of the accident, which probably had been attached to the left wing. The memory card of this camera, on which any flight footage would have been recorded, was also found at the crash site. This card was seized by the police, but was then lost in the salvage of the wreckage, which means no images recorded with the GoPro were available. The known information about the final phase of the flight was obtained from radar images provided by Air Traffic Control the Netherlands (LVNL)[5] and witness statements.

A witness at Teuge airport made video recordings from the moment of engine start-up until take-off of the accident flight. These recordings do not show any abnormalities that can be linked to the accident.

After the accident the Dutch Safety Board conducted a technical examination of the wreckage. Here the aeroplane construction and the components of the control system were examined, but the aeroplane was destroyed to such an extent that this did not yield any useful information. However, an airspeed indicator dial was found. Examination thereof showed a mark that was very likely an impression from the airspeed indicator needle (see figure 7). This impression had apparently been formed at the moment of impact. From the impression it could be concluded that the speed of the aircraft at that time was about 110 knots.[6] It was also concluded that the safety belts of both the pilot and the passenger were still closed.

5 Data provided by the Airfee software programme, which records flight movements at Teuge airport, could not be used for this investigation.

6 A knot is one nautical mile (1.852 meters) per hour. Hence, 110 knots is equivalent to approximately 204 km/h.

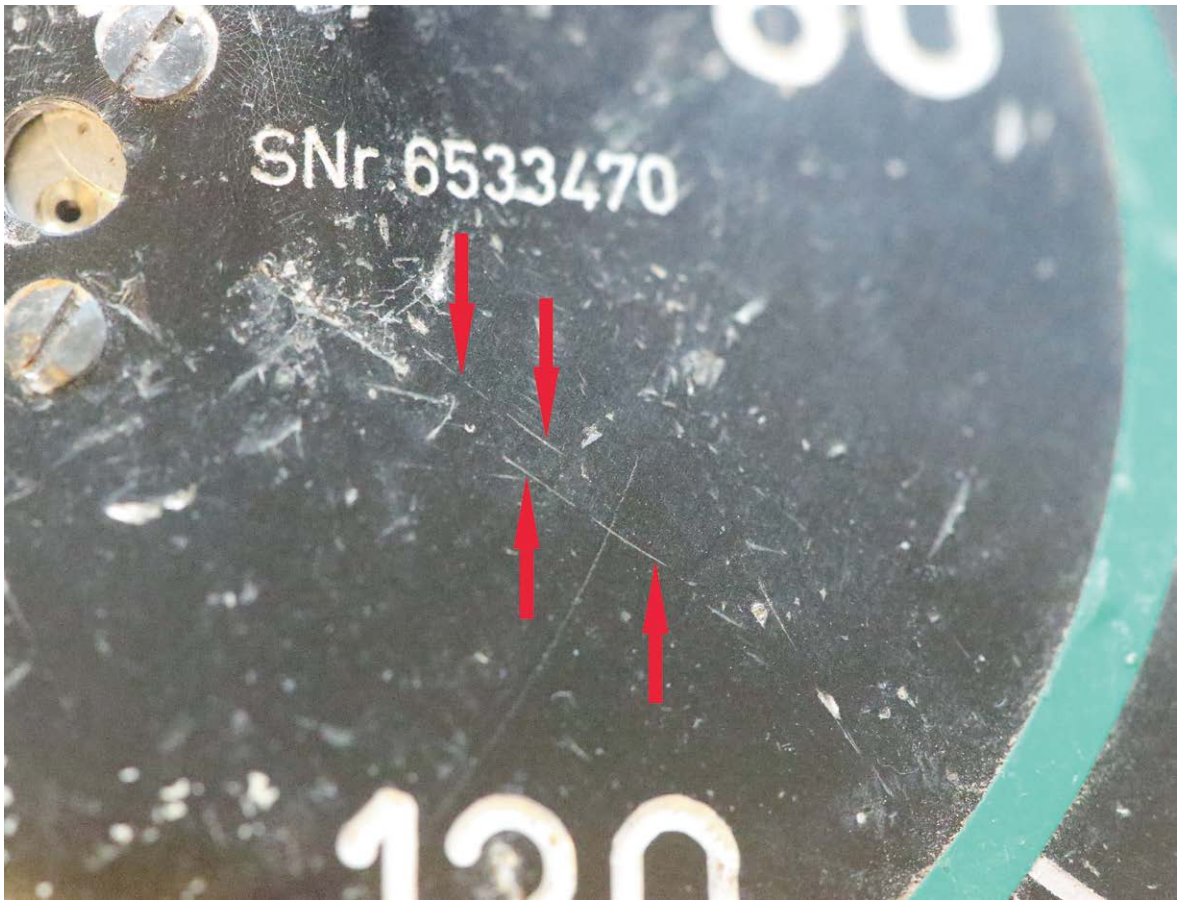

Figure 7: Detailed photograph of the airspeed indicator with the impression of the needle. (Photo: Dutch Safety Board)

The impression marks of the aeroplane and its wings in the ground indicate that the aeroplane's nose hit the ground first, and that both wings impacted the ground at almost the same time. This is confirmed by the marks that the 'spades' beneath both ailerons left in the ground. At the moment of impact, D-EXIR had little or no bank (see figure 8).

The orange metal tubes, which were found at an angle in the ground, proved to be the reference bars that had been mounted at the wingtips. These bars stuck into the ground at an angle of approximately 20 to 30 degrees. As the bars were mounted parallel to the longitudinal axis of the aeroplane, it can be concluded that D-EXIR impacted the ground at an angle of approximately 20 to 30 degrees.

Figure 8: Impression marks of the aircraft in the ground. (Photo: National Police)

The available radar images were examined and analyzed. Due to the fact that: this radar generates one image per 5 seconds,[7] the rate of the D-EXIR's movements is very high, the radar does not have coverage all the way to the ground and the system rounds off all altitudes, only a global analysis rather than an accurate analysis could be made based on these radar data. The following table lists the times and the observed altitudes during the last part of the flight.[8] Based on these, the rate of descent was calculated.

Time	Radar altitude, in feet[9]	Altitude gain/loss, in feet	Rate of descent in feet/minute
18.28:08	4.000		
18.28:13	4.100		
18.28:18	4.000	-100	1.200
18.28:23	3.200	-800	9.600
18.28:27	2.800	-400	6.000
18.28:32	2.500	-300	3.600

Table 2: Overview of recorded radar altitudes.

7 The radar antenna rotates at about 12 revolutions per minute, therefore an image is only generated every 5 seconds, which means that a continuous presentation of the flight data is not possible.

8 The radar calculates the height with respect to the standard pressure altitude of 1013,2hPa. After conversion to the current air pressure of 1019 hPa, the height is 48 meters. The actual altitude is therefore 48 meters lower than stated in the table. In one case, the interval between two observations is 4 seconds.

9 A foot is 0.3048 meters.

From this data it can be deduced that D-EXIR descended from about 4.100 feet to about 2.500 feet (the last more or less reliable recorded altitude) in 19 seconds. This corresponds to an average rate of descent of 5.052 feet per minute. The rate of descent per five seconds shows that the rate of descent was reduced towards the last part of the manoeuvre.

The radar system also recorded the aeroplane's position at these times. These recordings are too imprecise to draw conclusions, but it is clear that the aircraft flew around the golf course during these 19 seconds. This suggests that, during this period, the aeroplane did not carry out a flight involving a large horizontal displacement.

Witness statements revealed that a number of witnesses had seen the aircraft before it hit the ground. Most witnesses mentioned a steep angle of descent, some even said it was perpendicular to the ground. One witness stated that he saw the aeroplane coming down spiralling. He saw the aeroplane come down in at least four spirals, after which it disappeared behind the trees.

Based on a combination of the analysis of the radar images, the marks on the ground and the witness statements, it can be concluded that D-EXIR flew towards the ground from about 4.100 feet in a strong vertical motion, probably rotating, in a transition from vertical to horizontal flight. Although during this transition the rate of descent was reduced, this was not enough to fully stop the descent and proceed into a horizontal or climbing flight path; the aeroplane hit the ground at a speed of about 110 knots at an angle of about 20 to 30 degrees. Because the wings touched the ground almost simultaneously, it is likely that the rotating movement had ended by that moment. The heaviest part of the aeroplane, the engine, penetrated into the ground, after which the aircraft disintegrated and its parts spread in the direction of flight. It can therefore be concluded that the manoeuvre to change the vertical movement into horizontal flight was initiated at such an altitude that timely recovery was not possible. The pilot apparently did manage to stop the rotation, but the aeroplane had come too close to the ground to take it out of the vertical movement in time. Why a timely recovery was not possible, has remained unknown.

A similar flight was carried out using the same type of aircraft. A flat spin and a normal spin were flown to identify the manoeuvre D-EXIR might have made, based on the rate of descent. However, the data was too imprecise to draw conclusions.

Although a reconstruction could be made of the last part of the flight, the information does not provide sufficient support to determine the cause of the accident with certainty.

2.2 The captain

At the time of the accident, the captain had over 380 hours of flying experience, including 85 hours on the type Extra EA-300L. Since the spring of 2012 he had been the owner of D-EXIR, an aeroplane capable of flying unlimited aerobatic figures. From his logbook it can be seen that he flew regularly and also performed aerobatics. In August 2012 he obtained his display authorisation and in September 2012 he came into the possession

of an annual permit to independently organise and perform air displays. Since demonstrations and air displays are primarily conducted in summer, it can be concluded that he had just over one year of experience in performing demonstration flights and air displays. In addition, he had flown about 85 hours on the applicable type in two years. Given the complexity of some of the manoeuvres flown [10] this means that the captain was relatively inexperienced in the type and nature of the flights he conducted.

2.3 Possible causes

Several possible causes were investigated and analysed.

1. **Miscalculation, pilot error or other causes**
   The accident may have been caused by pilot error or miscalculation when executing a manoeuvre. This is not unique when performing aerobatic flights. Investigations by other safety boards into accidents during aerobatic flights [11] has shown that in a number of these accidents, a manoeuvre could not be recovered in time after which the aeroplane hit the ground. In a large number of cases, the reason why the manoeuvre was not recovered in time remained unknown. Investigations in more recent accidents had not yet been completed, which meant that it was not yet known why the manoeuvre could not be recovered from in time. In some accidents, a technical malfunction was involved or the obstruction of a control surface by an object. There are also cases in which the controls (pedals or stick) got blocked by objects or passenger body parts, specifically legs and feet, which meant that the controls could not be fully deflected.[12] This made it impossible to recover the aircraft from a particular (aerobatic) movement.

   Studies and research[13] show, among other things, that performing aerobatic manoeuvres is the most important risk factor in accidents with fatalities and/or serious injuries in the United States. Over 80% of the 494 investigated accidents involving aerobatics were fatal. The main reason for these accidents was a lack of sufficient altitude.

2. **Status D-EXIR**
   The investigation revealed that D-EXIR's documents were in order. The aeroplane had a valid Certificate of Airworthiness and a valid Certificate of Registration. Statements by the maintenance organisation responsible for the maintenance of D-EXIR, and the aeroplane's documents, indicate that there were no known defects. On 19 February 2014, the aeroplane received its last maintenance, a 100-hour inspection. After that, it was flown without complaints for a number of hours. The statement by the passenger who had flown with D-EXIR earlier in the day, indicates that no defects had been detected on the aircraft. Statements by witnesses at the crash site indicate that D-EXIR was flying at high engine power at the time of the accident. Engine failure can therefore almost certainly be ruled out as the cause of

10 Such as tumbles; a certain type of auto-rotation figure in which use is made of the engine torque.
11 For example 12-10-2013, accident Extra 330 ZS-BUL; 7-3-2014 accident Zivko Edge 540T N149WA; 21-9-014 accident XtremeAir Xtreme 3000 D-EYKS, 22-4-2015 accident Zivko Edge 360 G-EDGJ and 22-8-2015 accident Hawker Hunter T7 G-BXFI.
12 There are cases where the foot of the pilot got stuck between or beneath a pedal.
13 De Voogt, van Doorn (2009) Accidents Associated with aerobatic maneuvers in US Aviation.

the crash. Moreover, engine failure need not result in a crash; normally it will be possible to make an emergency landing. Fuel samples were taken at the fuel station at Teuge airport. No peculiarities emerged from the examinations of these samples, so that it can be concluded that fuel composition did not contribute to the accident.

Statements from people who have experience in flying the Extra EA-300L indicates that loose safety belts may prevent free movement of the controls. Upon examination of the wreckage of D-EXIR, is was concluded that the safety belts of both occupants were properly fastened at the time of the accident.

It can be concluded that there is no evidence that a technical problem of the aeroplane contributed to the crash. However, as it was not possible to conduct a complete technical investigation because of the degree of damage, this cannot be ruled out entirely.

3. Structural limits of D-EXIR

Before the flight, the captain had refuelled D-EXIR at the airport's pump with 35.2 litres of fuel. The statement by the passenger of the first flight indicated that, with the addition of 35.2 litres, only the Acro & center tank was filled while the wing tanks remained empty. It was common practice to perform this type of passenger flights with only the Acro & center tank filled, so as to not have any restrictions with regard to manoeuvring. Calculations showed that the estimated total take-off weight of the aeroplane was about 862 kg, with the centre of gravity lying about 75.57 cm from the reference point. Because the aerobatic flight was performed with two people on board, the maximum take-off weight according to the flight manual was 870 kg and a G-load of up to ± 8G applied. The above indicates that the weight and balance of the aircraft throughout the flight were within the limits in the flight manual.

The manufacturer's data showed that, at a speed of about 110 knots during impact, the maximum possible load would have been approximately 3,5G.[14] At higher G-forces, the wings will start losing lift (high speed stall).

It is unlikely that the structural limits of the aircraft were exceeded. It is therefore unlikely that the load of the aircraft had an effect on the flight or the cause of the accident.

4. Weather

The flight took place entirely under visual meteorological conditions (VMC). With respect to the weather, no factors were identified that could have had an effect on the course of the flight and the cause of the accident.

5. Condition of the captain

The captain had a valid medical certificate, and statements by people who were in contact with him on the day of the incident did not provide any indication to doubt the health and condition of the captain. After the accident, a pathological examination

14 The manufacturer provided the so-called V-n diagram of the Extra EA-300L.

was conducted. This examination did not yield any observations either with respect to the cause of the accident. It was concluded that the health and condition of the captain can almost certainly be ruled out as the cause of the accident.

6. **High G-forces**
   High G-force manoeuvres may result in insufficient blood flowing to the brain, which may cause a temporary loss of awareness or consciousness (see Annex A). The captain regularly performed aerobatic flights, in which he was exposed to high G-forces. Despite this proficiency, it cannot be excluded, also due to the high rate at which G-forces can be built up with the Extra EA-300L, that a temporary loss of awareness or consciousness occurred early in the manoeuvre, which could have caused the accident.

   This loss of awareness or consciousness probably did not occur during the final phase of flight, just before reaching the ground. In this last phase of the flight, the captain was apparently consciously trying to recover from the steep descent. This is concluded from the fact that the aircraft hit the ground practically 'wings level', at an angle of about 20-30 degrees. Moreover, according to the manufacturer, the maximum possible G-load at a speed of 110 knots is 3.5G. Given the captain's experience with G-force exposure, this is not enough to cause loss of awareness or consciousness.

7. **Influence by the passenger**
   Accidents have been caused by passengers consciously or unconsciously having an effect on the aeroplane controls. Especially when performing manoeuvres, passengers can brace themselves against the pedals or hold on to the stick. In addition, statements made by persons who had previously flown with this captain, indicated that passengers were regularly given the opportunity to take over the controls.

   Given the above, it cannot be entirely ruled out that the passenger consciously or unconsciously had an effect on the operation of the aircraft during the last part of the flight.

2.4 Regulations and supervision

The crash of D-EXIR does not show a direct link between the cause of the accident and regulation and supervision. Nevertheless, the Dutch Safety Board feels that it is important to elaborate on both points, because the investigation has revealed deficiencies at certain points.

Those active in aerobatic aircraft should be aware of how to safely perform aerobatic flights. In addition to their own safety, the safety of people on the ground and any passengers are also at stake. In order to ensure this safety as much as possible, regulations have been developed for performing aerobic flights.

1. **General regulations regarding aerobatic flights**
   Specific regulations for performing aerobatics under normal circumstances are limited. Article 16 of the Dutch Air Traffic Regulations (*Luchtverkeersreglement*)[15] states that it is prohibited to perform aerobatic flights. This prohibition does not apply (among others) to:

   …flights conducted under visual meteorological conditions if the captain of the aircraft exercises intensified vigilance with the aim of being able to timely recognize a collision risk, and being able to take the required measures in order to avoid collisions in a timely manner, and if:

   1°. flying takes place at such a horizontal or vertical distance from areas with consecutive buildings or groups of people, that persons or property on the surface cannot be compromised by the performance of the flight specified in the first paragraph, and (…)

   To carry out aerobatic flights, the purpose of the flights determines which regulations are applicable. When practising as the sole occupant, or when aerobatic flights are carried out with passengers, the flight is considered a private flight, and general flight rules and the aforementioned Article 16 of the Air Traffic Regulations apply.

2. **Regulations at air displays**
   During aerobatics at an air display, a large number of rules apply. The Dutch Air Display Regulation (*Regeling Luchtvaartvertoningen*) states, among other things, that an aerobatic flight during an air display shall not have any passengers on board, and minimum dimensions are specified for the display area and distance to the spectators. Flying may only take place in parallel to the audience, i.e. not in a direction towards or over the spectators. The difference is that at air displays usually a lot of spectators are present, who are protected as much as possible by these regulations if something should go wrong.

3. **Regulations on flight altitudes during aerobatic flights**
   For the conducting of VFR flights[16] in general, the minimum flying altitudes stated in the Air Traffic Regulations[17] apply. These are (in short) 300 meters (1.000 feet) over buildings and groups of people, and 150 meters (500 feet) over other areas. These altitudes apply in relation to the highest obstacle within a 600 meter radius around the aircraft. This also applies to the performing of aerobatic flights, in which the aforementioned Article 16 of the Air Traffic Regulations remains fully applicable.

   One of the exceptions to this rule is the performing of flights during an air display for which a permit has been granted, in which case the minimum altitude indicated in the permit shall apply. Performing aerobatic flights outside of displays or the practising

15 This article was replaced on 5 December 2014 by Article 13 of the Air Traffic Decree 2014 (Besluit Luchtverkeer 2014, Decree of 5 December 2014 laying down new rules on air traffic in compliance with Regulation (EU) 923/2012 establishing common air traffic regulations).
16 VFR flights are flights in which the visual flight rules apply in addition to the general flight rules.
17 The Air Traffic Regulations expired on 12 December 2014 and were replaced by the 2014 Air Traffic Decree.

for displays is not listed as an exception, meaning that the general minimum altitudes apply.

4. Nature of the flight operations

The accident flight was registered as a private flight with a passenger. The D-EXIR logbook indicates that the captain had made many private flights with passengers. This is permitted under the condition that no payment is made for these flights.[18] From the monetary amounts listed in the log with these flights, it is clear that several flights had been carried out at a fee. Statements revealed that passengers often were offered the opportunity to take over the controls. The captain then gave instructions and directions to the passenger to control the aircraft. The D-EXIR logbook showed that a number of passengers made multiple flights with the captain. This makes it likely that the captain was giving paid instructions.

The payments and the giving of instructions change the nature of the flight operation. In the laws and regulations, this change is recognised by classifying such a flight as a commercial flight. Although the aforementioned rules of the Air Traffic Regulations are still applicable, to commercial flights other regulations and other requirements also apply. Many parameters, including aerobatical parameters such as minimum altitudes, preparation and completion are recorded in approved courses and operations manuals. Thus, additional margins are created to improve safety.

5. Pilot authorisation for performing aerobatic flights.

Special pilot authorisations for aerobatic flights were not required at the time of the accident. In the past, this was considered a shortcoming. The European Aviation Safety Agency (EASA) implemented new regulations on licences (FLC.800) in EU Regulation 1178/2011. Aerobatic flights may only be performed if the captain has an aerobatic rating. The conditions for this rating are:

1. at least 40 hours of flight time as pilot in command in the appropriate aircraft category, completed after issuance of the pilot licence;
2. a training course at a qualified training organisation, including:
   i. applicable theoretical instruction for the pilot license;
   ii. at least 5 hours or 20 flights of aerobatics instruction in the appropriate aircraft category.

This Regulation has been in force since 8 April 2015. For the Netherlands, the Regulation shall apply from 8 April 2018. Until then, it is possible to record the aerobatic rating in the pilot licence on a voluntary basis.

6. Locations

The Netherlands has not made airspace explicitly available for practising aerobatic flights. This means that aerobatic flights may be performed everywhere in the Netherlands, if the legal requirements with regard to altitude and distance to

18 EU Regulation No. 965/2012 has since been modified, making it possible for passengers to contribute to the flight costs, under certain conditions. However, this change did not apply at the time the accident occurred.

buildings and groups of people have been met. These requirements prevent persons and property on the ground from being exposed to risks. As a condition, pilots are to comply with these legal requirements. However, there is no airspace available for training for air displays at low altitude. Where authorisations for such displays allow to perform aerobatic flights at very low altitude, there is no legal possibility to exercise at low altitude outside of air displays. In other countries, this problem was solved by arranging aerobatic days or evenings at aerodromes or by establishing an area where aerobatic flights can be practised (dedicated aerobatic airspace blocks designated in advance). Here, people from the field come together, creating an opportunity to support and / or correct each other. By indicating locations where aerobatic flights can be executed, whether or not in combination with certain time slots, the possibility is created to practise within legal limits. In the Netherlands, options are being explored to find one or more designated locations where aerobatic flights can be practised at low altitudes, by pilots in possession of a display authorisation. However, this has not yielded any results yet.

7. Authorities responsible for the regulation of aerobatic flights.

The Air Display Regulation specifies that participants in an air display will only be admitted if they are in possession of a display authorisation issued by the Royal Dutch Aeronautical Association (KNVvL). In this it is assisted by the Air Display Association (ADA). Up to 2011, ADA was an independent organisation responsible for the review and issuance of display authorisations. An amendment to the Air Display Regulation specifies that the ADA as an independent organisation will cease to exist and will merge with the KNVvL. The allocation of tasks and responsibilities after the merger remains unclear and has not been not recorded. There are only a few draft contract documents that have not been signed by any authority. The display authorisations, for example, still mention the ADA as the issuing body.

The captain obtained his display authorisation in August 2012. Directly associated with this was the category 'Unlimited', with an altitude restriction of 200 feet (about 60 meters). This means that there were no limitations with regard to the type and nature of manoeuvres, and that these manoeuvres could be flown at an altitude of 200 ft. Because the regulations were only implemented to a limited extent, the captain, as an inexperienced aerobatic pilot (in 2012), was subject to little or no restrictions while practising for, and executing manoeuvres at, air displays. Within the ADA, the issuance of this authorisation to this captain resulted in significant discussion, but did not result in an initiative from the KNVvL to eliminate the uncertainty with regard to the categories. It was only decided that, upon renewal of the captain's authorisation, which was valid for one year, the assessment would be critically re-examined. However, the captain did not renew his authorisation in August 2013. This was not noticed by any of the parties involved.

In the meantime, the KNVvL has become of the opinion that additional training should be required to perform so-called 'advanced aerobatic manoeuvres' such as tumbles/ auto-rotation figures. This idea has already been put into practice by a few parties like aircraft lessors.

The (former) members of the ADA are the most experienced people available from the field for making assessments for the issuance of display authorisations. However, they are currently basing this assessment on their own experience and have incomplete regulations at their disposal, which are also still in a conceptual phase. An important element which is not clear, are the categories[19] associated with a display authorisation. CAP403, a British document containing the regulations with regard to air displays in the United Kingdom, is used as the basis for the interpretation of these categories. It is currently unclear whether the categories are associated with the type of aircraft or with the kind of manoeuvres that may be flown. In the absence of adequate regulations, the possibility remains that unequivocal decisions cannot be made when issuing display authorisations. With these qualified people, KNVvL has sufficient expertise to further develop these regulations for display authorisations.

Meanwhile, the aerobatic flying branch of the KNVvL has taken measures to resolve the problems regarding the issuing of display authorisations. Its members are working on establishing a set of requirements and regulations on aerobatic flying, with the English system as an example.

8. Supervision

As indicated earlier, in addition to a display authorisation, the captain had also been in possession of an annual permit for the organising and performing of air displays since September 2012.[20] This permit, granted by the Environment and Transport Inspectorate (Inspectie Leefomgeving en Transport, ILT), had been extended by one year in October 2013. During the investigation, the ILT indicated that it did not supervise the organising and performing of air displays held on the basis of this permit. The reason for this was that the ILT had opted for risk-based supervision, resulting in other displays having been selected for inspection. In the period 2013-2014, one display was inspected which was attended by the captain. The air display was not covered by the permit issued to the captain. Because the focus of the inspection was on another field, no report was made on flight performance.

The ILT also indicated that it had received no indications that the captain did not always keep to the rules when carrying out aerobatic flights.

The ILT indicated that the intention was to carry out an inspection in the 2014 season during an air display that was organised and would be performed by the captain.

Besides the fact that it was exceptional that such a permit was initially issued without significant restrictions to someone with little experience, specifically in the area of air displays, it is surprising that there was no supervision during the year on the organisation and performance of the independent air displays in the context of the issuance of this annual permit, for the extension of this permit.

19 There are four categories: Standard of Sportsmen, Intermediate, Advanced and Unlimited.
20 Air displays, where the display program consists only of a single standardized component.

The Dutch Safety Board feels that this may be expected from a regulatory and licensing authority. It can be said that the ILT was not careful in the granting of the permit in September 2012, and did not adequately supervise in the context of the renewal of the captain's permit to independently organise and perform air displays, in October 2013.

3 CONCLUSIONS

1. The recovery manoeuvre to pull the aeroplane out of its descent into horizontal flight or climb, was deployed at such an altitude that a safe recovery without flying into the ground was no longer possible. The Dutch Safety Board was unable to determine why timely recovery was not possible.

2. With regard to regulation and supervision, the following was established:

    a. Specific regulations for performing aerobatic flights, other than air displays, are limited. Only requirements related to visibility, altitude and distance from buildings and groups of people, are mentioned. These requirements are sufficient to guarantee the safety of third parties, as long as the pilots comply with the regulation.
    b. Stringent requirements are set for air display participants, and many rules apply, while it is not possible to legally practise for them with regard to the minimum flying altitude.
    c. With regard to the issuing of a display authorisation, it can be concluded that the regulation is insufficiently specified by the KNVvL. This shortcoming has been identified and the KNVvL is working to correct this.
    d. The ILT has failed to adequately supervise the permits granted to the captain.

APPENDIX A

G-FORCES AND THEIR IMPACT ON MAN

The human body reacts to G-force. There is a clear difference in feeling between positive and negative G-forces, but their effect on awareness and consciousness is the same. The effects that G-load has on the body varies from one person to another, and are related to a good condition and posture. Being well trained and knowing one's body are important features to prevent loss of awareness or consciousness. Another important factor is the rate at which G-forces are accumulated in time (G-onset rate).

Positive G-forces

The increase in weight of the extremities and the body as a whole is responsible for the emergence of symptoms, even at relatively low positive G-forces. At +2G, one experiences subsidence of the soft tissue of the face, and an increase of weight of the torso and extremities is very clearly noticeable. It's difficult to raise one's body when seated at +2.5G, and impossible at +3G. At +8G it is impossible to move upper extremities. From +8G one can't even get one's head up if it is down with the neck bent. Repeated exposure to a longer period of positive G-forces may cause fatigue, pain in the neck and swelling. An unexpected and sudden exposure to high positive G-forces can cause the head to fall forward so hard that it may even cause injury to the spine.

Exposure to positive-G accelerations causes visual impairment prior to loss of consciousness. At lower positive G-forces, one sees less clearly and peripheral vision is reduced, creating a kind of tunnel vision. This is also called a 'grey-out'. Exposure to +4.5G causes complete vision loss, the so-called 'black-out', while hearing and mental activity will continue to function properly. Exposure to positive G-forces larger than required to cause a black-out results in loss of consciousness. For example, with acceleration of +5G to +6G, black-out occurs prior to unconsciousness. At higher accelerations, it is also possible that loss of consciousness occurs before any other visual symptoms. If one is unconscious, the muscles relax and the body collapses. While someone is still unconscious, regular convulsions occur which cause the blood to flow back into the brain. It takes approximately 15 seconds before consciousness is regained, and another 15 seconds in which one is very confused, before turning back into one's former self.

Negative G-forces

The human body tolerates negative G-forces much worse than positive G-forces, and at as little as -2G, symptoms are unpleasant and disturbing. Low negative G-forces also cause serious performance degradation. The feeling of heaviness and thereby the movements of the extremities resulting from exposure to negative G-forces are the same as with positive G-forces. The specific effects of negative G-forces are mainly in the head and neck. Exposure to -1G creates a feeling of fullness and pressure in the head. At -2G, this becomes very unpleasant, causing an intense throbbing headache that can last up to

several hours after exposure. Exposure to -2.5G or more for a few seconds causes bleeding of the skin in the face and neck. The eyes are also irritated quickly and at -2.5G to -3G feel as if they are protruding. Exposure to accelerations which are greater than -4G to -5G for more than 6 seconds will result in mental confusion and loss of consciousness.

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