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Mid-air collision during air display training



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The Hague, October 2018

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N.B. This report is published in the English language with a separate Dutch summary. If there is a difference in interpretation between the report and the summary, the report text will prevail.

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GENERAL OVERVIEW

Identification number:	2016059
Classification:	Accident
Date, time of occurrence:	9 June 2016, around 16.15 ¹ hours
Location of occurrence:	Airspace near Bitgum, inside Leeuwarden CTR
Aircraft type:	Northrop F-5E Tiger II
Aircraft category:	Twin engine jet fighter/trainer
Type of flight:	Display training
Phase of operation:	Re-joining of formation
Registration I:	J-3086 (number 3 in the formation of 6 aircraft)
Damage to aircraft	Destroyed
Flight crew:	One
Passengers:	None
Injuries:	Light
Registration II:	J-3088 (number 2 in the formation of 6 aircraft)
Damage to aircraft:	Medium
Flight crew:	One
Passengers:	None
Injuries:	None

¹ All times in this report are local times (UTC + 2 hours) unless otherwise indicated.

On 9 June 2016, around 16.15 hours, a mid-air collision took place between two F-5E Tiger II aircraft operated by the Swiss Air Force while flying a training mission for the Dutch Air Force Open Days at Leeuwarden air base in the Netherlands. Both aircraft were part of the Swiss demo team Patrouille Suisse and were flown by Swiss military crew.

One of the aircraft, number 3 with registration J-3086, crashed in a pond. The pilot successfully ejected just prior to the crash and landed in a greenhouse. The other aircraft, number 2 with registration J-3088, suffered damage to the right-hand horizontal stabiliser, flap and landing gear door, but landed uneventfully at Leeuwarden air base.

The accident happened because the pilot of aircraft number 3 lost sight of aircraft number 2 while manoeuvring in close distance of number 2 during a formation re-join. As a result, both aircraft collided while they had an opposite bank to each other.

Flying both operational and display flights with multiple aircraft types, limited training flights and no adequate procedures in case a pilot loses sight on other aircraft, might have played a role in the origin of the accident.

FACTUAL INFORMATION

General

On Friday 10 June and Saturday 11 June 2016, the Royal Netherlands Air Force organised its Open Air Days at Leeuwarden air base. The period from Tuesday 7 until Thursday 9 June were rehearsal days. An Air Display Permit for this event was granted by the Dutch Minister of Defence for the period of 7-11 June.

On 9 June 2016 around 16.15 hours a mid-air collision between two aircraft was reported near Leeuwarden. The collision happened between two aircraft of the Swiss Air Force's display team Patrouille Suisse. After the collision, one aircraft was able to return to Leeuwarden air base and landed uneventfully. The other aircraft crashed in a pond in the area near Bitgum after the pilot had ejected from the aircraft. The pilot fell through the glass roof of a greenhouse. He was taken to hospital for examination and treatment of injuries.

Parties involved in the investigation

On 12 April 2007 an agreement between the Swiss Federal Council and the government of the Netherlands concerning military exercises, training and education was made. According to article XII of this agreement, technical investigations into incidents or accidents with military aircraft or vehicles:

- Shall be carried out in accordance with national laws and regulations of the receiving state (the Netherlands);
- May take place either by the authorities of the receiving state or by the sending state's (Swiss) authorities in coordination with the authorities of the receiving state when the receiving state does not set up an investigation (...).

The Royal Netherlands Air Force, organiser of the Open Air Days at Leeuwarden air base decided not to investigate the accident. Investigation results of the Swiss authorities are used for both flight safety and legal purposes. For that reason, and because the accident took place in Dutch airspace, the Dutch Safety Board started an independent investigation into the accident, for safety purposes only. Beside this safety investigation a criminal investigation was started by the (Dutch) Public Prosecutor for military affairs, which did not result in further prosecution.

Flight preparation and history of the flight

Flight preparation

In the morning of Thursday 9 June 2016, Patrouille Suisse took off from Switzerland and arrived at Leeuwarden air base around 11.00 hours. After arriving, the team checked in with the Open Air Day's Display Operations and the team was given briefings about the local procedures, display programme, local weather and time schedules. At around 14.45 hours the team performed their pre-flight formation briefing, containing weather information, formation flying, formation changes, flight safety and a safety topic of the day.

After preparing their aircraft, the six aircraft of Patrouille Suisse took off from the air base around 16.00 hours for a rehearsal flight, which turned out to be the accident flight.

History of flight

The accident flight started with a standard formation take-off. All six aircraft took off from the air base simultaneously, in two formations of three aircraft. After take-off the team performed an area reconnaissance, and started the display rehearsal at around 16.10 hours. Several formations were flown in a six aircraft formation. After these formation forms, the formation split up in a four-ship formation, consisting of numbers 1 to 4 and a two-ship formation, consisting of number 5 and 6. While these two aircraft performed a solo display, numbers 1 to 4 formed a Diamond or Box formation to the east of the airfield. The four aircraft split up into two two-ship formations, subsequently flying from opposite directions, passing each other after which number 3 and 4 made a left turn and planned to join up with number 1 and 2, resulting in the Diamond formation. Appendix A provides an overview of the manoeuvres flown.

The flight was executed between 1,000 and 1,500 feet. During all of the flight, the formation leader, number 1, gave the formation commands over the radio, including altitudes and speeds to be flown.

The accident

After the opposite pass (A) numbers 3 and 4 turned to the north-west (B) to perform a left-hand turn to the west to re-join the other two aircraft. During the left turn, before forming the Diamond formation, number 3 flew under number 4 and overtook the other aircraft (C).

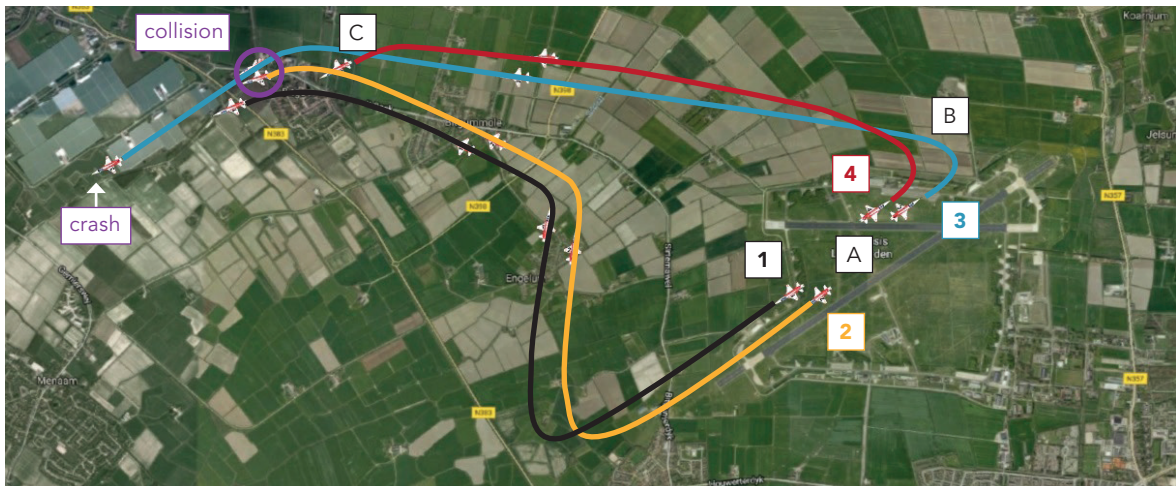


Figure 1: Tracks flown by the four aircraft of the formation and the place of collision. The black line depicts the track of number 1, the yellow line is number 2, the blue line is number 3 and the red line is number 4. (Source: Dutch Safety Board)

Realising he was out of position, flying faster than the other aircraft in the formation, pilot number 3 reduced power and banked to the right in order to fly underneath the formation. According to the pilot, this is a common procedure to reduce speed and position himself back in the vicinity of the other aircraft. While doing so, he lost sight of aircraft number 2. Pilot number 2, flying in formation with, and focussing on the position of number 1, did not see aircraft number 3. The decrease in speed of aircraft number 3,

while the pilot of this aircraft lost sight of the other aircraft in the formation, resulted in aircraft numbers 2 and 3 colliding with each other. During the collision, number 3 aircraft hit number 2 with its left main wing, thereby damaging the right-hand wing including the flap and cutting half of the right-hand elevator of aircraft number 2.

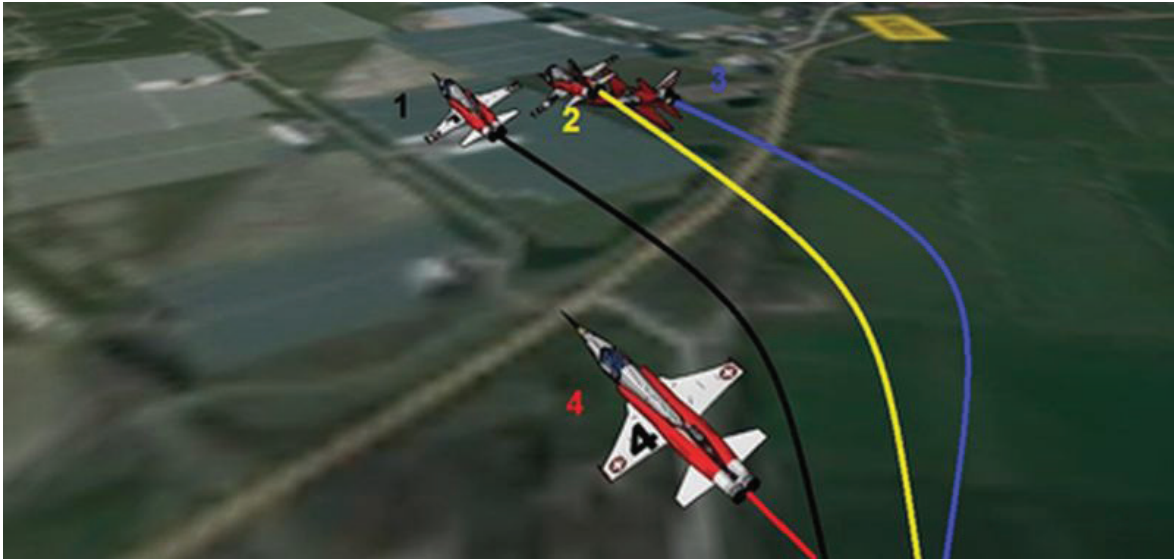


Figure 2: Close up of the situation during the collision. (Source: Dutch Safety Board)

Number 3 aircraft was damaged to such an extent that the aircraft became uncontrollable and tumbled around the longitudinal axis. After realising the aircraft was uncontrollable, the pilot ejected after the aircraft had turned more or less upright. The pilot, his ejection seat and the parachute fell through the glass roof of a greenhouse and hit the ground. The pilot sustained minor injuries. The aircraft crashed on the edge of a pond next to the farmhouse belonging to the greenhouse and came to rest under water.

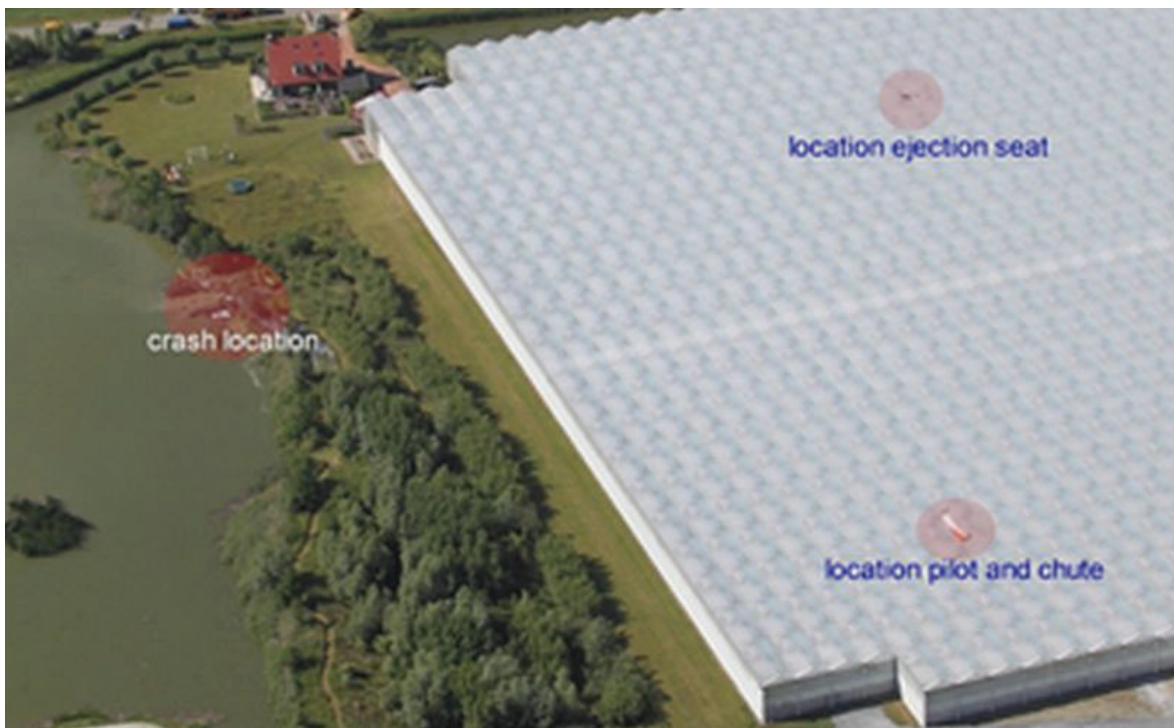


Figure 3: Impact location of accident aircraft. (Source: National Police)

The pilot of number 2 aircraft initially steered the aircraft in the direction of the sea and performed some controllability checks. After he was convinced that his aircraft was still flyable despite the damage sustained, he was able to return to Leeuwarden air base and made a normal landing several minutes later.

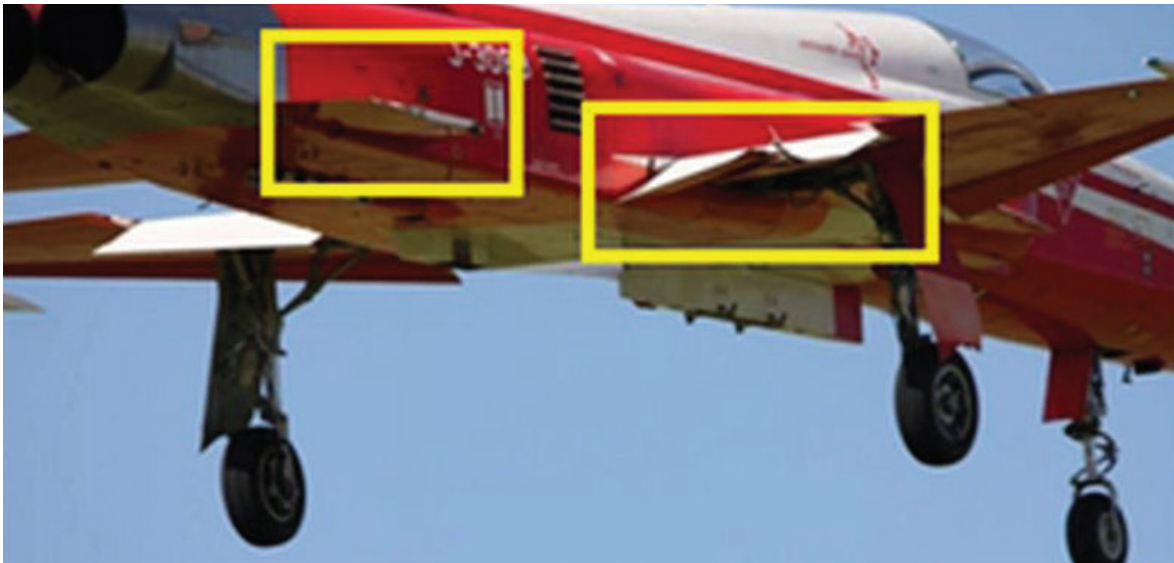


Figure 4: Damage to aircraft number 2 just prior to landing at Leeuwarden air base. (Source: Royal Netherlands Air Force)

Patrouille Suisse

Patrouille Suisse is one of four display teams of the Swiss Air Force. The team consists of a commander, seven pilots (including a reserve pilot) and supporting staff for maintenance and logistics. All pilots of the Patrouille Suisse are professional military pilots. There are no Swiss Air Force pilots performing exclusively for air shows, therefore being part of the Patrouille Suisse is an extra task in addition to their everyday jobs in the air force.

The standard fighter aircraft in the Swiss Air Force is the FA-18 Hornet. In the past, fighter pilots started their initial training on PC-7 turboprop aircraft followed by training on Northrop F-5E jet aircraft. In 2009 this was changed and all fighter pilots started their training on the FA-18 Hornet after the initial training. Also all operational flights are flown on the FA-18 Hornet only.

The air display is flown by six pilots who perform the display with F-5E Tiger II aircraft in different compositions, varying from a solo-display to a six ship formation. The F-5E aircraft was designed as a light fighter and ground attack platform, but is also used as a trainer aircraft. The F-5E entered service in the early 1960s. The aircraft is equipped with two engines and can reach a speed of 1,700 kilometres per hour. In the Swiss Air Force the F-5E Tiger II aircraft are used to relieve the FA-18 fleet. In particular, as aggressors (red air), target towing, monitoring of radioactivity and the Patrouille Suisse display team.

The Patrouille Suisse standard display consists of several manoeuvres, flown in a fixed sequence in different formations. This standard display lasts about 18 minutes and is always observed from the ground by the commander of the Patrouille Suisse. While the commander observes his team, the speaker accompanies the show with interesting facts about the team and the manoeuvres flown.

The colour scheme of the F-5E Tiger II aircraft used by Patrouille Suisse is shown in figure 5.



Figure 5: Colour scheme of Patrouille Suisse aircraft's top (left) and bottom (right).²

Crew

Pilot number 2 joined the Swiss Air Force in 2004. After his training he had been flying operational (training) missions on F-5E Tiger II and F/A18 Hornet. He joined Patrouille Suisse in 2012. He holds type ratings for: FA-18 Hornet, F-5E Tiger, PC-6 and is instructor pilot on PC-7, PC-21 and FA-18 Hornet.

He accumulated a total flying time of 1,990 hours, from which around 456 hours on the F-5E Tiger II. In 2016 he flew 120 hours F-18 and around 60 hours F-5E Tiger II. The last 30 days he made eight flights on the F-5E Tiger II. He held a valid pilot license and a valid medical certificate.

Pilot number 3 joined the Swiss Air Force in 2012. He had been an FA-18 Hornet pilot, flying operational (training) missions and also flew the PC-21 and PC-7 as an instructor pilot. In 2015 he was converted to fly the F-5E Tiger II to become a member of Patrouille Suisse. He had never flown the F-5E Tiger II before. Since 2015 he had flown approximately 125 hours on this aircraft. His second season as member of Patrouille Suisse started in April 2016. Since he joined the Swiss Air Force, he had a total flying experience of around 1,257 hours. The last 30 days he made ten flights on the F-5E Tiger II. He held a valid pilot license and a valid medical certificate.

All pilots of Patrouille Suisse have experience as operational pilot in the Swiss Air Force on the FA-18 Hornet. Their role as member of Patrouille Suisse is additional to their normal operational task. Particularly for their role as team member of Patrouille Suisse, all pilots fly the F-5E Tiger II aircraft.

² Copyright © Swiss Department of Defence, Public Defence and Sport DDPS.

Weather

The weather on 9 June 2016 was dominated by a low pressure area over Norway, and a high pressure area over the British Isles, causing a north westerly flow of polar air over the Netherlands. Below an inversion around 2,500 feet, the air was unstable. Visibility was more than 10 kilometres. Temperatures were between 15 degrees Celsius on the ground and 9 degrees Celsius at 2,000 feet and winds were about 13 knots from the north-west. The local QNH was 1020 HPa.

Salvage

Number 3 aircraft crashed on the edge of a small pond behind greenhouses. After hitting the ground the aircraft went into the pond and, apart from some small debris, most of the aircraft went under water. Several days after the accident it was decided to salvage the aircraft from the pond as evidence to the safety and criminal investigation.

Dutch military police started a separate investigation into the accident to look for any legal aspects of the accident. The investigation was strictly separated from the safety investigation performed by the Dutch Safety Board. The salvage was undertaken under authority of the Dutch military police.

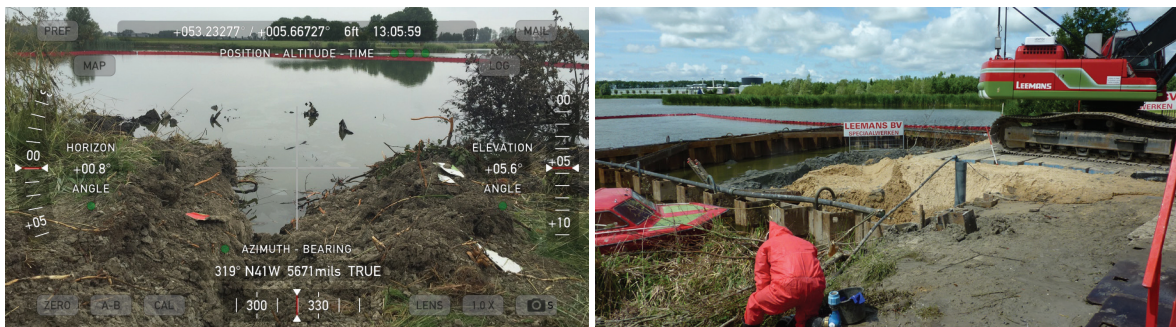


Figure 6: Impact area of aircraft number 3 and salvage operation. (Source: Dutch Safety Board)

Damage to the aircraft

Aircraft number 2 in formation:

Right wing:

- A scratch on the underside on the leading edge flap.
- A continuous scratch, starting in the middle on the underside, over the gear door, to the right-hand trailing edge flap.
- A scratch ending in an upward bended crack in the right-hand trailing edge flap.

Right-hand horizontal stabiliser:

- Cut off around the middle.
- Bended at inboard edge.

Some months after the accident, part of the right-hand stabiliser that was cut off was found on the roof of a building in the neighbourhood around 1,300 metres northeast of the impact area of aircraft number 3.



Figure 7: Damage of number 2 aircraft - underside right-hand wing (top left); right-hand trailing edge flap (top right); right-hand horizontal stabiliser (bottom left); found part of right-hand horizontal stabiliser (bottom right). (Source: Dutch Safety Board)

Aircraft number 3 in formation:

The aircraft was totally destroyed. A white coloured, left-hand missile launching rail of the aircraft was found in a field near the place of collision. The launching rail was scratched and had some traces of red paint on its surface.



Figure 8: The number 3 aircraft left-hand missile launching rail. (Source: Dutch Safety Board)

During the salvage several aircraft parts, large and small, of aircraft number 3 were found and secured for investigation. Among these parts were a part of the left-hand wing and aileron. Originally, these parts were joined together but were now cut off. The aileron was cut through and this cut was prolonged into the wing. The edge of the left part of the aileron was bent and had some red paint on it.



Figure 9: Two pieces of the left-hand aileron (left) and the left piece situated near its original place on the wing (right). (Source: Dutch Safety Board)

INVESTIGATION AND ANALYSIS

Regulations

For an air display several regulations apply which are included in the air display permit. These regulations were designed for the benefit of both aviation safety and public safety. Public safety only concerned the safety of the spectators of the displays on the air base.

The minimum display height for fixed-wing aircraft during flypasts was 200 feet above ground level (AGL). Flypasts at 100 feet AGL were approved by the display director under special conditions. Manoeuvres by aircraft exceeding 300 knots with vectors towards the crowd were to be completed no closer than 450 metres from the public. All manoeuvres had to be completed so that the aircraft did not cross the display line to prevent overflying the audience.

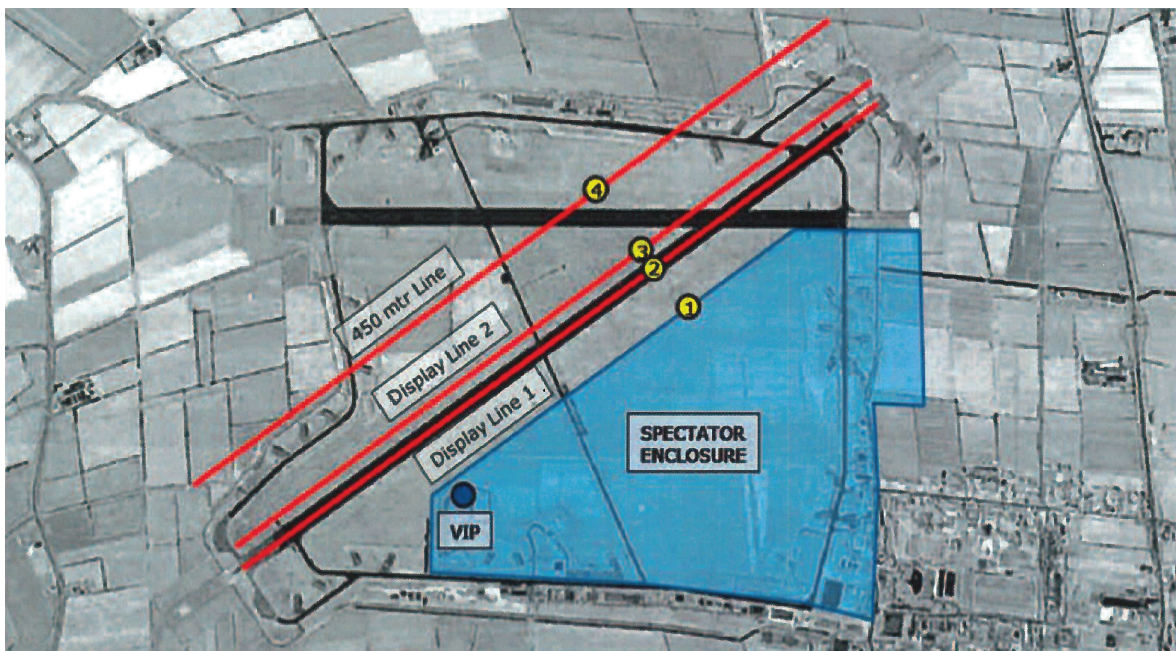


Figure 10: Display lines in relation to spectator area. (Source: Royal Netherlands Air Force)

Three special rules zones were established around the display area from ground level to flight level 095 to protect the participating aircraft from other traffic in the area. No other aircraft than participating aircraft were allowed to fly in that zone. The zones were published by NOTAM.

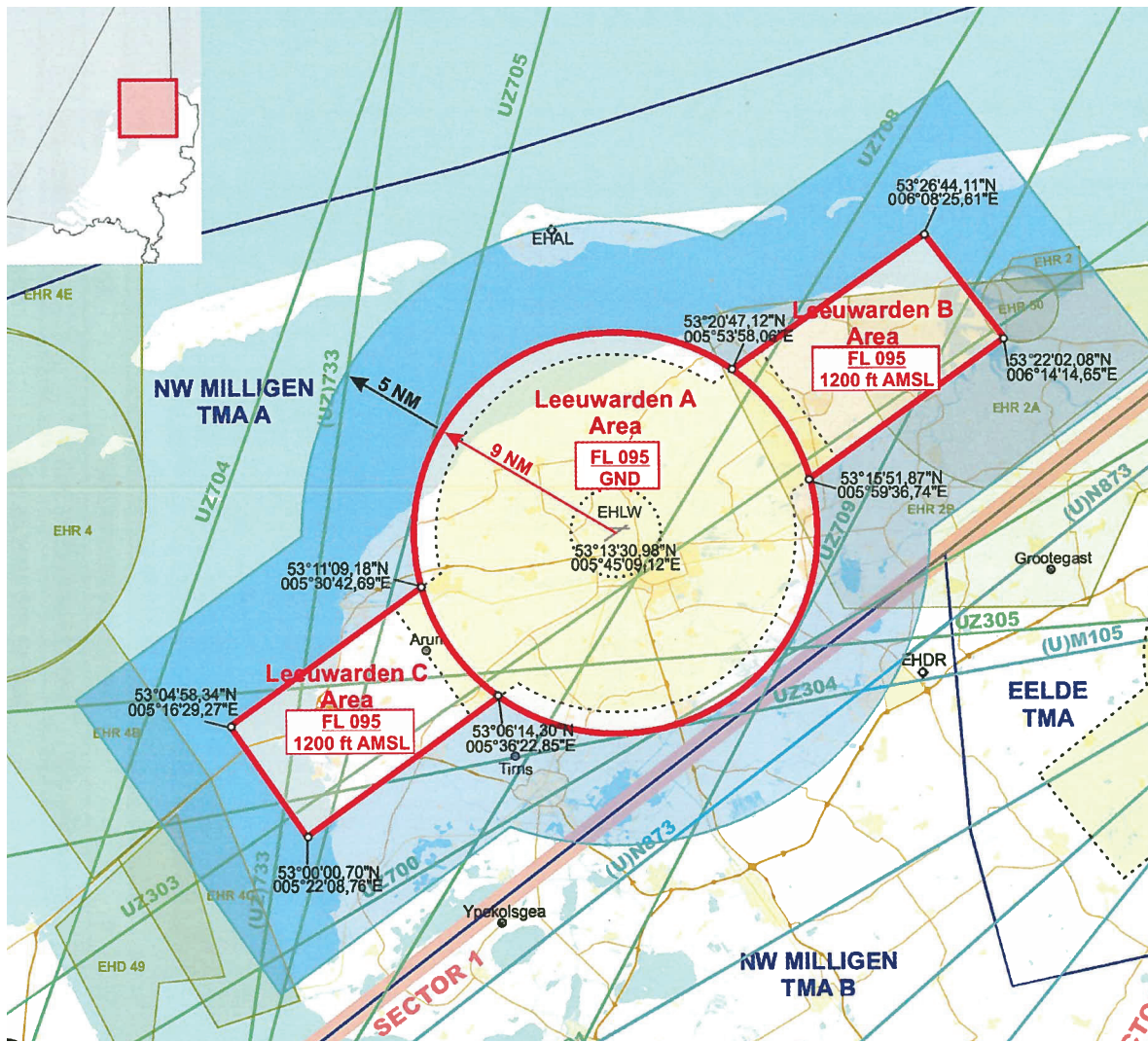


Figure 11: Special rule zones around the air base. (Source: Royal Netherlands Air Force)

With reference to the safety of people living in the surroundings no separate risk assessment had been made. However, it was concluded that the people on the ground would be at least at risk if the majority of the flight movements were to be carried out in northeast-southwest direction, parallel to runway 05-23. Those were considered to be the least populated areas. In case of an emergency, pilots had to try to reach the North Sea and avoid populated areas as much as possible. Some populated areas were designated as not to be overflowed during display flights. All information, including all regulations, rules and agreements, including relevant maps, were compiled in the Display Order that was handed over to all flying participants. Attending the display briefing was mandatory for all pilots. As a result of all those regulations the risks were deemed acceptable according to the organisation committee.

Although all reasonable measures were taken to minimise the risks, these measures were mainly focussed on the display flying and the spectators on the air base. The safety of people on the ground in the surroundings of the air base was guaranteed as much as possible. Although, a risk will always be present, as illustrated by this accident when aircraft number three crashed near a farmhouse and a belonging greenhouse. The only possibility to exclude all risks is to stop organising air displays.

Flight preparation and history of the flight

Patrouille Suisse arrived at Leeuwarden air base on the day the general rehearsal of the flying display was planned. This gave the team time to receive the general briefings from the Open Air Day organisation, execute the team's pre-flight briefings and prepare for the flight. The flying display flown by Patrouille Suisse was a standard display. Therefore, the flight, including the formation flying, changes in the formation, and join-ups were part of the standard Patrouille Suisse flying programme.

The rehearsal was flown at an altitude between 1,000 and 1,500 feet. The weather at the time of the accident flight met VFR conditions, with an inversion at around 2,500 feet. The weather posed no limitations on the flight. Since all flight manoeuvres were standard, there was no additional difficulty level or higher than normal risk involved in performing the rehearsal for the display.

Until the accident all flight manoeuvres were flown according to the conditions of the air display permit.

The accident

The take-off and first part of the rehearsal were uneventful. There was no indication of any of the team members feeling uncomfortable and the flight went normal and as planned up to the moment of the re-join after the opposite pass over the air base.

During the left turn for the re-join with numbers 1 and 2, number 3 flew under number 4 and overtook the aircraft. Number 3 took the lead of numbers 3 and 4, and closed in to number 1 and 2 for the re-join. While performing the procedure to get back into position, aircraft number 3 collided with aircraft number 2.

There was no obvious reason for the overshoot, the most likely reason was a misjudgement of speed and distance by pilot number 3, despite the speed calls of the leader. The procedure used by pilot number 3 to recover from this overshoot, reducing power and banking to the right, was a standard procedure, as used commonly by pilots of Patrouille Suisse. While performing the procedure to get back into position, he lost sight of aircraft number 2, whereby pilot number 2, flying in formation with, and focussing on number 1, did not see aircraft number 3 coming in from behind. Instead of breaking away from the formation, in order to regain visibility on the other aircraft, pilot number 3 continued to position himself back in the formation without having number 2 aircraft in sight. This resulted in aircraft number 3 colliding with number 2.

In the 'Patrouille Suisse information brochure 2016' it is stated: *"formation flying is pure manual work that requires full concentration and precision while flying only three to five metres apart. The pilots fly visually only and have no technical aids available."* Because having sight on each other and awareness of the position of other aircraft are the only ways to prevent dangerous situations when flying in close formation, adequate procedures must be in place in case a pilot loses sight of aircraft that fly at close distance. Although pilots stated that such procedures were in place, these procedures were not found. In all cases, once sight on other aircraft is lost, it is on the joining pilot to fly a manoeuvre in order to avoid a collision with his formation members. Not following the procedures when losing formation members out of sight, increases the possibility of a mishap.

The other members of the formation focus on their own position and are not always aware of the exact position and direction the joining aircraft are flying.

Recordings

Ground crew of the Patrouille Suisse filmed the flight of the display team. However, the collision was not recorded on video, only communications between the aircraft of the formation were audible. These were commands of the leader to the other aircraft referring to the formation forms. Radar information was provided by the relevant service providers. F-5E Tiger II aircraft are not equipped with any kind of flight recorders. Neither the footage nor the radar images provided information about (the cause of) the accident.

Reconstruction of the collision

The scratches on the underside of the right wing of number 2 indicate that some part of number 3 hit the underside of the wing. Because it was a single, small scratch, this part must have had a relatively small surface. This and the fact that the right-hand horizontal stabiliser of number 2 was cut off sharply, indicates that both aircraft had a relative bank, where number 2 had a bank to the left and number 3 had a bank to the right. This analysis corresponds with the statement of the pilots. The angles of the banks remain unknown.

The beginning of the scratch under the wing of number 2 was small and ended in the upward bended cut in the right-hand trailing edge flap. Because both aircraft flew almost in the same direction, this was an indication that some part of aircraft number 3 moved from the front to the back along the wing. This can only be explained by the fact that there was a relative movement between both aircraft, where number 2 flew faster than number 3. This is in line with the statement of the number 3 pilot that he slowed down to regain sight of the other aircraft.

With reference to the scratches and red paint on the left-hand missile launching rail of number 3, it is likely that this part of the aircraft caused the scratches underneath aircraft number 2's right-hand wing. Since the right-hand horizontal stabiliser of number 2 was cut off sharply, this must be caused by an aircraft part with a relative small surface. The most probable part, with reference to the damage, was the trailing edge of the left-hand wing of number 3, especially the part with the aileron that was found during the salvage. Because of the cut in the aileron with prolongation to the wing and traces of red paint on that place, it is likely that the right-hand horizontal stabiliser was hit by the left-hand wing at the height of the aileron of number 3.



Figure 12: Estimated position and relative motion of aircraft numbers 2 and 3 at the time of the collision.
(Source: Dutch Safety Board)

Flying experience versus display flying

The display season 2016 for Patrouille Suisse started in April 2016 when the team trained two to three times a day over the course of two weeks. After these two weeks the team trained once a week. This means that in that season the team had trained well over 20 times before the accident flight. Before the accident flight at Leeuwarden, the team flew three other display flights.

All display flights were flown in the F-5E Tiger II aircraft. It is common practice within the Swiss Air Force for a pilot to fly multiple aircraft types.

Flying displays in close formation with high-performance aircraft and making special manoeuvres, demands great skills and a lot of experience with the type of aircraft. This can only be achieved by extensive training and dedication. Although all pilots were experienced, extensive on-type training is needed to fly displays safely, especially when flown in other aircraft types than pilots are used to.

Most flying crew of other display teams in Europe are posted full-time to the team for a certain period of time. They do not fly operational missions, instead perform training flights almost every day and only fly the display type of aircraft during the season. Compared to those other teams, the intensity and frequency of training of the pilots of Patrouille Suisse, is low. This, combined with the fact that the pilots fly multiple aircraft types, might result in a lower level of experience and skills on the aircraft type used for the display flights. To mitigate possible resulting risks, an adapted display program is advisable. Moreover, more training and flying dedicated on the display aircraft type, is also a way to improve safety during display flights.

FINDINGS AND CONCLUSIONS

Findings

The Royal Dutch Air Force Open Air Days were held in accordance with the Air Display Permit of the Dutch Ministry of Defence.

All six Patrouille Swiss aircraft arrived in the morning of 9 June 2016. After the crew finished pre-flight briefings and preparing the aircraft, the six aircraft took off the same day around 16.00 hours for a rehearsal flight.

Due to a misjudgement of speed and distance by pilot number 3 while re-joining the formation, aircraft number 3 under flew number 2 and overtook the aircraft.

Number 3 then reduced power and banked to the right to recover from this overshoot while numbers 1 and 2 banked to the left to make a left turn as planned.

While the pilot of aircraft number 3 lost sight of number 2 aircraft, aircraft number 3 collided with number 2 because both aircraft had a bank opposite to each other.

Because number 2 aircraft flew faster than number 3 aircraft, there was a relative movement between both aircraft. Parts of the number 3 aircraft's left wing hit the number 2 aircraft's right wing underside and right-hand horizontal stabiliser from the front to the back.

Because of the damage sustained during the collision, number 3 aircraft became uncontrollable and crashed. The pilot ejected and became slightly injured.

Although damaged, number 2 aircraft could return to the air base and landed uneventfully.

Both pilots involved held valid licenses and valid medical certificates.

In the Swiss Air Force the F-5E Tiger II aircraft is used in the Patrouille Suisse display team, as well as, amongst others, for training purposes.

The pilots of the Patrouille Suisse display team are not posted full-time to the display team. They fly both operational flights and display flights with multiple aircraft types.

The frequency of training flights of the Patrouille Suisse display team is lower than those of other European display teams.

Conclusions


The accident happened because the pilot of aircraft number 3 lost sight of aircraft number 2 while manoeuvring in close distance of number 2 during a formation re-join. As a result, aircraft number 3 collided with number 2 while both aircraft had an opposite bank to each other.

Although pilots stated that procedures are in place when losing sight of the formation members, no procedures were found.

Contributing factors








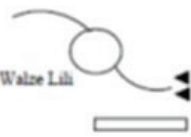





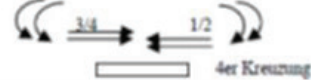
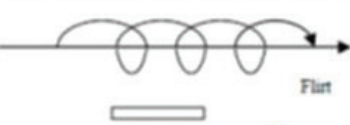

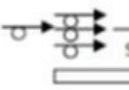
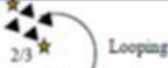










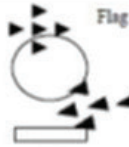









Flying both operational and display flights with multiple aircraft types, limited training flights and lack of adequate procedures in the case a pilot loses sight on other aircraft, might have played a role in the origin of the accident.

APPENDIX A



Schönwetter - Programm 2016

Stand 28.04.16

<p>1. Kreuz   Delta</p> <hr/> <p>2.  Hornet  Eiger  Hosehupf</p> <hr/> <p>3.  Melchmühl  Split 5/6</p> <hr/> <p>4. 5/6  Walze Lili  Manta</p> <hr/> <p>5. 1-4  Diamant  Split 3/4  Split 1/2  Box, Looping  4er Kreuzung</p> <hr/> <p>6. 5/6  Flirt</p> <hr/> <p>7.  Pin  Synchronrolle  Looping</p> <hr/> <p>8. 5/6  Walze</p> <hr/> <p>9.  Diamant  Shadow</p>	<p>10.  Anschl split 5  Gear down Mirror</p> <hr/> <p>11. 1-4  Rheinfall</p> <hr/> <p>12.  Solo</p> <hr/> <p>13. 5er Teil  Manta  Cloverleaf  Pfeil</p> <hr/> <p>14.  Flag  Manta</p> <hr/> <p>15.  Walze  Manta  Tango</p> <hr/> <p>16. 360 mit Derry turns  6</p> <hr/> <p>17.  Tunnel 45° 6</p> <hr/> <p>20.  Grande aus Delta  1-3/6 steigend  4/5 horizontal</p>
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