BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

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SAFETY INVESTIGATION REPORT

Accident to the CM-170 Fouga Magister registered **F-AZPZ** on Friday 16 August 2024 off the coast of Bormes-les-Mimosas

Time	16:56[1]
Operator	Private
Type of flight	Air show
Persons on board	Pilot
Consequences and damage	Pilot fatally injured, aeroplane destroyed
This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.	

Pilot incapacitation under positive G-force, collision with surface of sea, during an airshow

1 HISTORY OF THE FLIGHT

Note: the following information is principally based on statements, radar data and videos taken by eyewitnesses on the ground.

The pilot took off from Cuers-Pierrefeu aerodrome at around 16:35 bound for Le Lavandou where an airshow was taking place over the sea (see paragraph 2.2.1). On arrival, he carried out seven 360° holding patterns.

At 16:52, the Flying Display Director (FDD) authorized the pilot to start his display. The pilot performed several passes one after the other, interspersed with manoeuvres to reposition him on the display axis ("wingover" with or without "Derry turns", see paragraph 2.6.1).

After a 360° turn with a high bank angle, the pilot carried out a "wingover" with a "Derry turn". In descent, in a knife-edge turn to intercept the display axis, the aeroplane stabilized for a few seconds at a height of around 400 ft, before continuing its descent until collision with the surface of the sea.

2 ADDITIONAL INFORMATION

2.1 Aeroplane and wreckage information

The CM-170 Fouga Magister was equipped with two Marboré turbojets[2]. Designed in France and produced from the 1950s onwards, it was used by the French air force between 1956 and 1996 for military training and also by the *Patrouille de France* (French air force precision aerobatics unit) between 1964 and 1980.

[1] Except where otherwise indicated, the times in this report are given in local time.
[2] The engines were built by Turboméca, which is now called Safran Helicopter Engines.

The pilot was the sole user of F-AZPZ, purchased in 1996 by a family association (the pilot's family). The aeroplane was based at Cuers-Pierrefeu aerodrome. It held a restricted certificate of airworthiness for vintage aircraft. The pilot personally managed the aeroplane's continuing airworthiness and maintenance, with the assistance of an aircraft mechanic friend for the maintenance.

The Fouga Magister is not equipped with an ejection seat. In the event of an in-flight problem, the procedure specifies jettisoning the canopy and then evacuating the aeroplane. The pilot thus wore a parachute in case of a possible in-flight evacuation.

The Fouga Magister is not equipped with an air supply system that would allow the use of an anti-g suit, designed to mitigate the effects of G-forces on the pilot's body, unlike more recent aircraft used by the French army.

F-AZPZ collided with the sea surface at a speed of approximately 200 kt (see paragraph 2.6.3). The field of debris, over a length of 50 m and a width of 10 to 15 m, was located at a depth of 14 m, 250 m off the port of Bormes-les-Mimosas. At this spot, the seabed is covered with Posidonia, an algae that can reach up to 1 m in height. Only the largest pieces of the wreckage were recovered, as a comprehensive collection of the debris was impossible. In light of the statements (see paragraph 2.3) and the analysis of videos taken by witnesses on the ground, which did not reveal any input on the flight controls or engines during the few seconds preceding the collision with the sea surface, the BEA did not examine the debris.

2.2 Air show information

2.2.1 General

The pilot was participating in the airshow organized by the municipality of Le Lavandou as part of the commemoration of the 80th anniversary of the Provence landings. It was a public airshow within the meaning of the amended decree of 10 November 2021, relating to airshows. Several tens of thousands of spectators were present. The management of this airshow was entrusted to two consultants: the Flying Display Director (FDD) and his deputy. They are both former fighter pilots in the French air and space force and had previously worked in the air force's airshow unit.

Three displays were planned during the airshow:

- a roughly ten-minute display by an Extra 330 from the French air force aerobatic team;
- a roughly ten-minute display by the Fouga Magister F-AZPZ;
- a roughly thirty-minute display by the French air force *Patrouille de France*.

Following the accident, the show was stopped.

A military delegate for the airshow and a speaker had been designated by the air force to participate in the airshow. The military delegate had also been an air force fighter pilot; he coordinated the air force's intervention with the organizers and, ultimately, with the FDD and his deputy for this event. The speaker, for his part, described the displays for the public. These individuals were positioned at the Central Point (CP) (see **Figure 1**). It was planned that the air force would only film the displays by the air force aircraft (Extra 330 and *Patrouille de France*).

2.2.2 Display axis

For its display, F-AZPZ flew along the "FOUGA" display axis, oriented 035/215°, 750 m from the public area and 230 m[3] offshore from the ports of Le Lavandou (to the north) and Bormes-les-Mimosas (to the south). The position of the axis was intended to protect the public. This axis was also used by the *Patrouille de France*. The minimum regulatory display height was 300 ft.

The "FOUGA" axis, located between the two ports (see **Figure 2**), was indicated by seven red buoys, 1.5 m in diameter and spaced 200 m apart (1,200 m in total). Two boats were used to mark the axis. One boat (South) was positioned south of the axis, and another boat (Perp) was positioned 200 m from and perpendicular to the display axis, opposite the central point (see **Figure** 1 and paragraph 2.3.4).

The air force aerobatic team axis was marked by white buoys. It was located 150 m from the swimming area (50 m wide), along the beach.

A maritime exclusion zone had been defined.

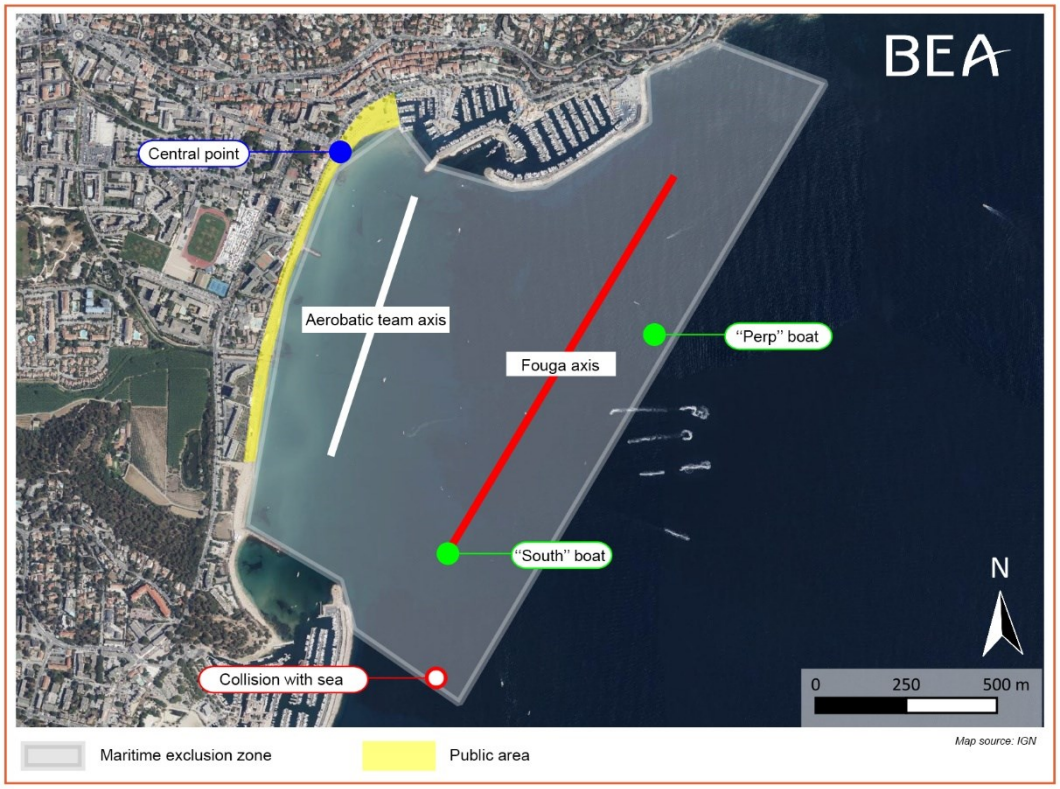

Figure 1: positions of the display axes, the area with the public, the maritime exclusion zone, the boats, the central point, and the position of the collision with the sea surface

[3] Minimum regulatory distance.

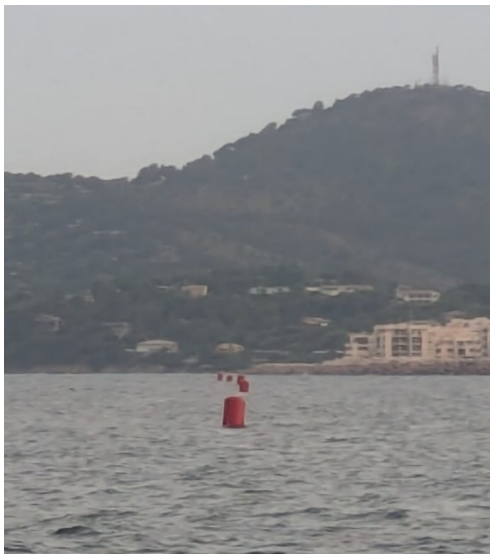

Figure 2: buoys marking the "FOUGA" axis (source: FDD)

The order relating to airshows and the guide to airshows published by the DSAC on 29 March 2024, both state that the display axis must be easily identifiable and clearly marked, even for a public air display at sea, without specifying the means according to the environment of the show venue. They do not contain any further details for displays over the sea.

2.3 Statements

2.3.1 FDD, deputy FDD and military delegate

The FDD indicated that there had been a dress rehearsal on 13 August during which the pilot performed a flight. Several aspects were discussed between the FDD and the pilot:

- flight height: the FDD considered that the aeroplane was flying low and informed the pilot on the radio, who then increased his height for the rest of the flight. During the evening debriefing, the pilot clarified that he had been flying his passes at 300 ft and that he had continued at 500 ft following the FDD's remark. The FDD asked him to maintain 500 ft during the show to improve the aeroplane's visibility from the public area, relatively far from the display axis;
- rejection of display: the pilot rejected his display and did not perform his final manoeuvre. He informed the FDD that it was too hot and that he preferred to stop there. The FDD approved this decision, which he deemed professional.

The FDD, deputy FDD and military delegate indicated that, from their position (more than 750 m from the axis), the pilot's display during the demonstration was controlled and in line with expectations. The FDD specified that it was not abnormal to see differences between the rehearsal routine and the display routine (see paragraph 2.6) for a program where the aerobatic manoeuvres simply follow on from each other. A pilot manages the aeroplane's energy in real time; he can adapt the sequence of planned manoeuvres. Furthermore, the rehearsal flight may lead to modifications to the display at the request of the FDD.

They indicated that only the few seconds of the display, before the collision with the sea surface, seemed abnormal to them, as if there was "no one on board." According to them, there was no input on the control axes of the aeroplane or on the controls of the engines delivering the power required for this phase of flight.

2.3.2 Air show speaker

The speaker knew the pilot, he had already met him during other airshows. He had been commentating on airshows for nearly ten years. Although he is not a pilot, he had the same impression as the FDD, deputy FDD and military delegate about the final seconds of the flight.

He explained that as part of his job, he trains to handle this type of crisis situation, as he is a reference for the public. After the accident, he specifically asked the public to limit the use of mobile phones to preserve the effectiveness of communication networks for the emergency services.

2.3.3 Pilot's relative

The pilot's wife stated that on the day of the accident, the pilot had taken the aeroplane out of the hangar approximately 1 h 30 min before take-off. She specified that the pilot refuelled with the fuel required for the display without an excessive margin, so as not to have an aeroplane that was too heavy.

2.3.4 Statements regarding display axis

Upon returning from the rehearsal flight, the pilot discussed with his son, the G-forces he had experienced in flight. He stated, in particular, that he had reached +4.8 g in a turn to intercept the display axis and that he had had to tighten the turn to avoid overshooting the buoys. The mechanic assisting the pilot with maintenance added that the usual positive G-forces for these manoeuvres were around +3 / +3.5 g.

The FDD stated that during the debriefing in the evening of the rehearsal flight, the pilot indicated that he had had difficulty seeing the axis marked by the red buoys, that he only saw them at the last moment and then had to tighten his turns. He mentioned that the white buoys were easier to identify.

The military delegate stated that for air displays over the sea, buoys are generally used to mark the display axes. They are fixed to the seabed and do not drift. He added that detecting them is more or less straightforward according to the light, time of day, and sea conditions. He added that pilots generally use larger references such as port entrances or the coastline to pre-align themselves. The military delegate stated that the air force pilots did not report any difficulties detecting the display axes during the rehearsal and display flights.

A display pilot who is also a FDD, and *France Spectacle Aérien* (FSA)[4], specified that if conditions allow, positioning an imposing boat or a coloured barge in the middle of the display axis as a reference can help a pilot to reposition himself more quickly.

The FDD indicated that, at the request of the *Patrouille de France* and whenever possible, he tries to mark both ends (north and south) of the display axis using boats, to facilitate the visual acquisition of the display axis. This had been done at Lavandou since the creation of the airshow. For the 2024 airshow, the FDD had chosen, in consultation with the first solo pilot of the *Patrouille de France*, to relocate the north boat, which was of little use given its proximity to the port of Le Lavandou. It was moved perpendicularly, to 200 m from the display axis, to clearly mark this position, facing the public and the Central Point, which is not easy to visualize.

[4] *France Spectacle Aérien* is a French association providing a structure for discussions and consultation around airshows.

The FDD specified that under no circumstances do these boats have a flight monitoring function, particularly with respect to compliance with the display axis. He added that the crews of these boats, given their positions, are more exposed to the risk of collision in the event of a loss of control of the aircraft. For this reason, he was not in favour of placing boats with crews in the middle of the axis.

The FDD and deputy FDD indicated that they were not able to detect any overshoot of the display axis from their positions. The flight path remained outside the public safety distances due to it extending well beyond the display axis.

The FSA specified that monitoring compliance with the display axis (at sea, but also on land), is one of the primary tasks of the FDD and that it is often difficult for a FDD to do this, particularly when the axis is located beyond the specified minimum distances, as was the case at the Lavandou airshow. The FDD must know how to differentiate between a pilot's error of judgement and systematic errors that must be addressed immediately. The FSA added that all stakeholders are concerned by this monitoring. According to the FSA, compliance with the display axis is a matter of particular vigilance for the Civil Aviation Safety Directorate (DSAC) and the Air Transport Gendarmerie (GTA) or the Border Police (PAF), when they are present.

The FDD, the military delegate, and the FSA indicated that it is preferable to overshoot the axis (controlled overshoot) rather than risk losing control. The DSAC agreed with this. Under these conditions, the pilot generally corrects their flight path and possibly aborts their display. When he is able to detect an overshoot of the axis, the FDD considered that he can inform a pilot during their display to encourage them to correct their path. The FSA considered that a FDD can inform the pilot of an axis overshoot, and that a prior briefing must define the phraseology in the event of an overshoot being detected. The briefing must specify that while overshooting the axis is inevitable, the paramount objective is to control the aircraft.

2.4 Meteorological information

2.4.1 Conditions during the rehearsal flight on 13 August 2024

The Hyères aerodrome[5] and Levant island[6] weather stations gave nearly identical information at 15:00 (at the time of the rehearsal flight) at surface level:

- south-westerly wind (230°-240°) of 7 to 10 kt - wind on display axis;
- temperature 32°C;
- relative humidity 56%.

Météo-France specified that the weather was calm and dry, with a clear sky and good visibility. The wind was light to moderate at the surface and in the lower layers, without any significant gusts (16 kt maximum recorded). There was no turbulence.

[5] Station situated at 18 km from the accident site.

[6] Station situated at 9 km from the accident site.

2.4.2 Conditions during the accident flight on 16 August 2024

The Hyères aerodrome and Levant island weather stations gave nearly identical information at 17:00 (at the time of the accident) at surface level:

- easterly wind (80°-120°) of 6 to 9 kt– crosswind in relation to the display axis;
- temperature 29°C;
- relative humidity 60%.

Météo-France specified that the weather was calm and dry, with a clear sky and good visibility[7]. The wind was light at the surface and in the lower layers, without any significant gusts (16 kt maximum recorded). There was no turbulence. According to the AROME model, at 500 ft, the wind strength was 6 kt and south-easterly at all altitudes.

2.5 Pilot information

2.5.1 Aeronautical information

The 65-year-old pilot held a commercial pilot licence (CPL (A)) obtained in 1984 along with the CM-170/CM-175 type rating. He also held the basic aerobatic rating obtained in 1992, the advanced aerobatic rating obtained in 2010, and the aerobatic flight rating obtained in 2018. In addition, he held a sailplane pilot licence and a microlight fixed wing pilot licence.

The pilot had been a fighter pilot in the French air force between 1982 and 1997. He had flown the Fouga Magister in this capacity and was also an instructor. The pilot had been a flight safety officer in his various squadrons and at the Salon-de-Provence gliding club.

According to his log book, he had totalled around 6,500 flight hours. According to relatives, he had flown more than 2,000 hours on the Fouga Magister. He had also totalled 6,000 glider flight hours.

In 2024, he logged nine flight hours on the F-AZPZ. He had taken part in two airshows:

- in Valence, on June 29;
- in Alès, on July 6.

The pilot regularly flew in airshows, at least once a year. According to statements, the pilot systematically carried out the same manoeuvres but in varying orders: roll, slow roll, inversion, barrel roll, public flypast, horizontal 360° turn, 45° loop, eight-sided roll, break, peel off. These manoeuvres were mentioned on the pilot's participation sheets for the Valence and Alès airshows, which were available to the FDD[8]. The pilot had indicated wingovers between each pass. On one of the sheets, it was indicated: replacement of wingover by a Derry turn according to sun and crosswind.

According to the airshow speaker, the pilot had little recent experience for displays over the sea.

The pilot was the sole operator of his aeroplane and had no assistant or coach (unlike the air force pilots with their military delegate) capable of monitoring his manoeuvres from the ground or detecting a possible alteration to the flight path.

[7] Information confirmed on the videos taken by witnesses on the ground.

[8] The pilot's participation sheet for the Lavandou airshow had not been given to the FDD.

2.5.2 Pilot's health information

The pilot held a class 2 medical fitness certificate. The medical certificate applications the previous two years contained no mention of illness, treatment, or hospitalization.

The pilot spent the day of August 16 with his wife. According to her, he had breakfast around 09:00 and a light lunch around noon before heading by road to Cuers. He did not engage in any unusual activity during the day. She also indicated that he drank water normally throughout the day, particularly before the flight.

Shortly before take-off, the pilot had spoken with a friend at the aerodrome. The pilot told him about the intense, "tiring" heat of the past few days. It was hot on the day of the accident; the aeroplane had been in the sun for about an hour and a half before the flight, according to relatives.

The pilot's wife indicated that the pilot had been coughing in the days leading up to the accident. He had no other symptoms. To her knowledge, he had not taken any medication for it. The airshow speaker had spoken to the pilot by telephone a few hours before the display and had noted that the pilot was coughing. They stated that the pilot had told them he was fit for the flight.

The pilot had monthly check-ups and had to take medical treatment due to a chronic illness that had developed in 2003. His wife stated that he was very discreet about his medical check-ups.

Toxicological analyses performed after the accident revealed traces of several medications, with no trace of the medical treatment for the chronic illness. The BEA traced the pilot's health history over several years and also interviewed his relatives; there was no explanation for the results of the toxicological analyses. The effects of the medications detected by the toxicological analyses are likely to reduce tolerance to the G-force (see paragraph 2.7), which is why the use of medication must always be declared to the aero-medical examiner.

2.6 Video analysis

2.6.1 Manoeuvres flown by the pilot

Between passes, the pilot performed "wingovers" allowing him to rapidly change direction in a confined space, with or without a "Derry turn":

- The "wingover" consists of breaking away by 45° from the display axis, in the opposite direction to the public, in climb with a steep attitude of around 60°, then making a knife-edge turn by banking around 80° in descent to intercept the axis at the display altitude and finally levelling the wings;
- The "Derry turn" is a 270° (three-quarter turn) roll performed during the climb, finishing on the knife-edge. This more aesthetic manoeuvre makes for a smoother "wingover" and allows the pilot to move a little further away from the display axis.

2.6.2 Rehearsal flight on 13 August 2024

The pilot had installed an *action cam* on his helmet during the rehearsal flight. This camera filmed both the external environment and the instrument panel, according to the pilot's head movements. The analysis of this video showed that the pilot performed the following sequence of manoeuvres:

- roll/wingover;
- public flypast/wingover with Derry turn;
- pass on axis then loop/wingover with Derry turn;

- pass wings level/wingover;
- 360° turn with high bank angle/wingover;
- barrel roll/wingover;
- public flypast in turn, then 45° loop/wingover;
- high-speed pass/wingover;
- eight-sided roll/wingover;
- roll/very large wingover.

The flight parameters could be partially observed on the instrument panel. During this flight, the aeroplane was manoeuvring between 300 and 2,500 ft, at indicated airspeeds of between 150 and 280 kt. The maximum vertical speeds displayed were in the order of +/-10,000 ft/min. The passes and manoeuvres were not systematically performed on the "FOUGA" axis, sometimes between the "air force aerobatic team" and "FOUGA" axes.

A maximum G-force of approximately +5 g was observed at the exit of the second "Derry turn", after the loop. The aeroplane's speed at this point was 235 kt and the vertical speed was -5,000 ft/min.

2.6.3 Accident flight on 16 August 2024

The pilot had not installed the *action cam* for the display flight. The flight of F-AZPZ was not filmed in its entirety by members of the airshow organization. Following the accident, the BEA issued a call for witnesses, which resulted in the recovery of nearly 200 videos and several hundred photos taken by witnesses on the ground. No video contained the entire flight, however, by using several videos, almost the entire flight was recovered.

The analysis of the videos showed that the pilot performed the following sequence of manoeuvres:

- pass with roll/wingover;
- barrel roll/wingover;
- public flypast/wingover;
- loop/wingover with Derry turn;
- 360° turn with high bank angle/wingover with Derry turn.

The pilot did not carry out the pass with wings level between the loop and the 360° turn as he had done in the rehearsal flight.

The BEA worked with iwiation to reconstruct the aeroplane's flight path. Position data (latitude and longitude) and flight parameters (altitude, vertical speed, ground speed, pitch attitude, roll, heading, and G-force) were estimated based on a model of the aeroplane recalibrated in real time using a selection of videos from ground witnesses. These calculations were made for the last 28 s of the flight (between points 1 and 3, see **Figure 3** below and **Figure 4**). In addition, the BEA validated, using a different method, the flight path data calculated by iwiation. The BEA also determined the flight path data of the previous figures.

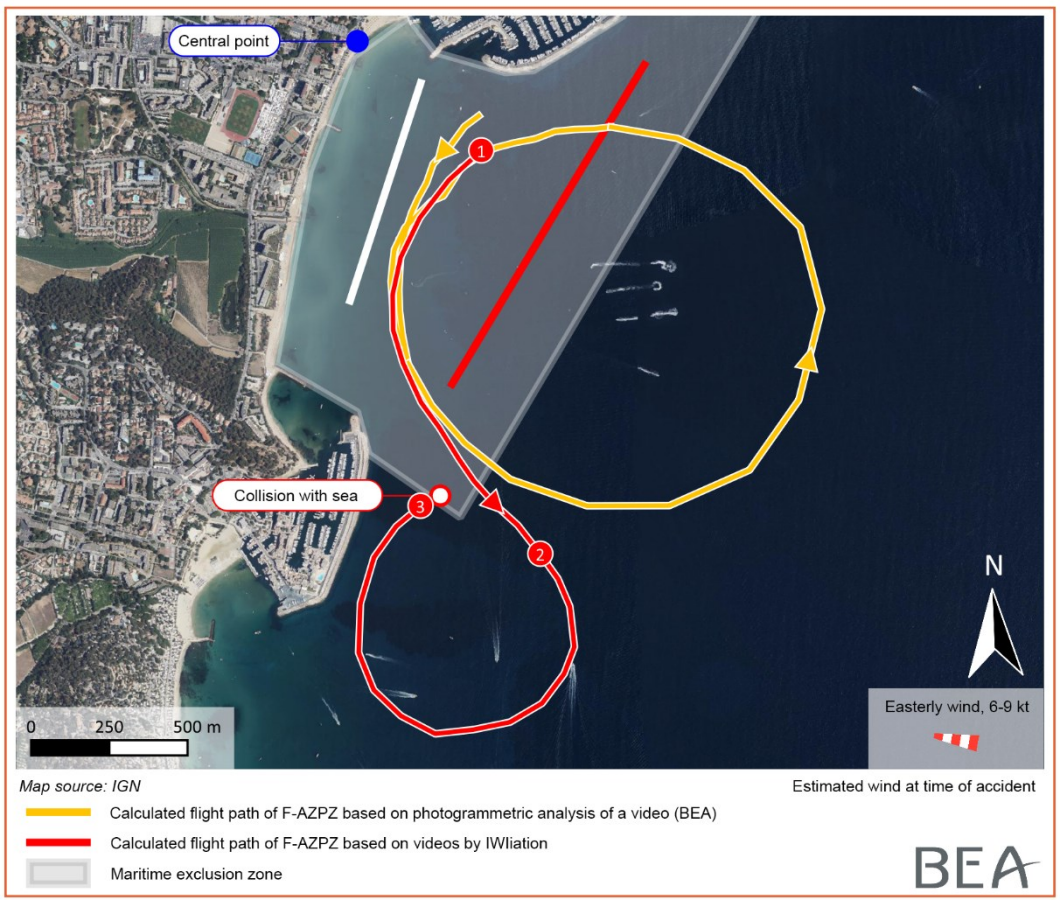

Figure 3: estimated flight path of F-AZPZ based on videos taken by ground witnesses

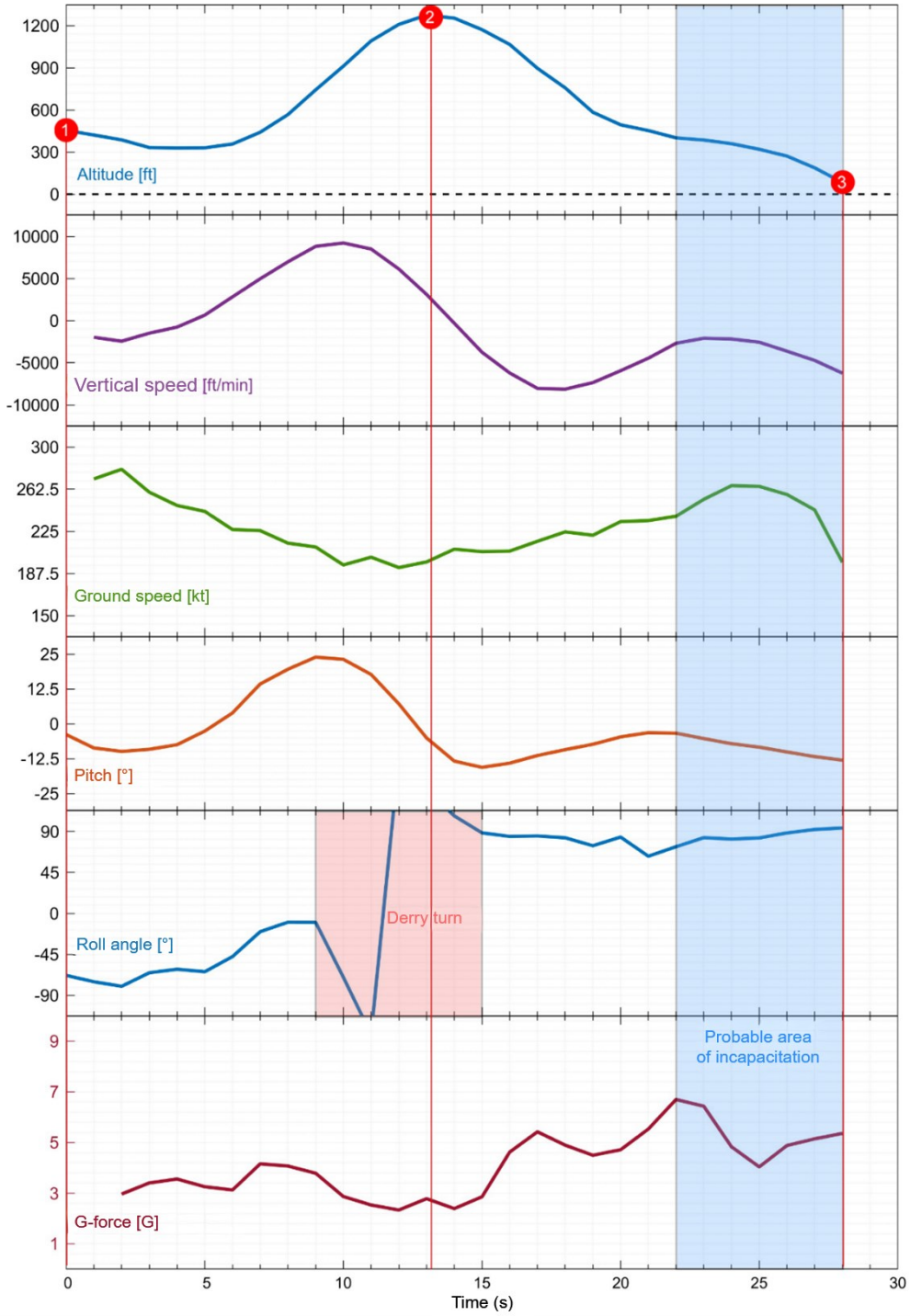

Figure 4: estimated parameters based on iwiation's videos, formatted by the BEA. The derived parameter calculations based on the aeroplane's positions and attitudes, such as the G-force, are subject to uncertainty and should be taken as orders of magnitude.

The parameters were validated in terms of quality, independently of the flight path calculations, by specialists (display pilots, two fighter pilots: the FDD and a BEA-É[9] investigator, the "aerobatics" aviation medical examiner of the French Aeronautical Federation (FFA), and the airshow speaker), based on videos.

[9] State Aviation Safety Accident Investigation authority, formerly known as BEAD-air.

The analysis of the flight path in the preceding manoeuvres showed that:

- the loop was flown along the display axis;
- the wingover followed by a Derry turn led to an overshoot of the display axis at the beginning of the following 360° turn;
- the 360° turn was performed with a steep bank (around 60°), under a G-force of around +2 g;
- the 360° turn ended beyond the display axis.

2.7 G-force information

2.7.1 General

In the book entitled "*Physiologie aéronautique*"[10], it is stated that the major risk when exposed to positive accelerations over a long period (more than five seconds) is that of G-induced partial or total loss of consciousness, which is linked to the intensity of the acceleration, the rate of acceleration (jolt[11]) and the circumstances that preceded the acceleration phase during the flight. Depending on these different factors, the appearance or evolution of the impaired consciousness has multiple characteristics.

The two most critical types of impaired consciousness[12] are described in the work:

- A-LOC (*Almost Loss of Consciousness*), more or less impaired consciousness during which the pilot is unable to act consistently and appropriately on the controls. The pilot will experience the onset of a state of confusion, combining some degree of spatial disorientation and impaired judgement. In varying form and severity, the pilot is partially conscious, dazed, able to hear and see, but unable to act, or at least act appropriately;
- G-LOC (G-*induced Loss of Consciousness*), a sudden and total incapacitation of the pilot.

It should be noted that as soon as consciousness is impaired, so is memory. As with altitude hypoxia, pilots subject to these "vascular hypoxias" generally have no memory of the disorders, which, for them, therefore do not exist.

As the positive G-force increases, the blood in the body will tend to move from the head to the feet. As the intensity and exposure time increase, the pilot may progressively experience:

- “grey-out”: narrowing of the visual field and/or blurred vision and/or decreased colour vision and/or darkening of field of vision;
- “blackout”: complete loss of vision, the pilot remains conscious and hearing is preserved;
- almost loss of consciousness (“A-LOC”);
- loss of consciousness ("G-LOC").

The intermediate grey-out or blackout states only appear if the rate of acceleration is progressive (low jolt values). If the acceleration is carried out too quickly, it does not give time for reflex cardiovascular adaptation. At a low height, these momentary effects can be fatal.

One of the most widely used G-force tolerance models is the Stoll diagram, based on work conducted in a centrifuge.

[10] Dr H. Marotte, 2004, Published by SEES.

[11] Jolt: unit measuring the speed of the increase in the G-force, expressed in g/s.

[12] Consciousness disorders are largely explained by a mechanism of brain hypoxia of circulatory origin.

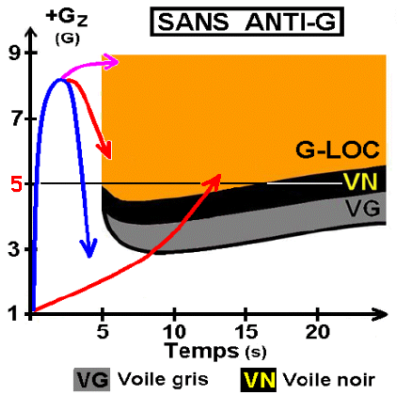

Figure 5: schematic representation of G-force tolerance, without an anti-g device (Stoll, 1956)

Analysis of the Stoll diagram indicates that a rapid and sustained acceleration lasting more than five seconds can lead a pilot directly from wakefulness to loss of consciousness (G-LOC), even in highly experienced pilots, without perceiving the warning visual cues (gray-out, blackout) that could be used as warning signals to refrain from maintaining or increasing the G-force.

It is important to note that variables are likely to modify the boundaries of the orange, black, and grey zones of the Stoll diagram. Indeed, from one person to another and, for the same person, from one moment to the next, depending on the factors listed below, intrinsic tolerance to G-forces varies greatly. Loss of consciousness (G-LOC) is possible as early as +3 g in some people, while others will withstand +8 g. The same pilot may lose consciousness as early as +5 g at a certain time of the day, while withstanding +7 g at another time.

According to the IRBA[13], the main factors affecting tolerance to G-forces are:

- use of certain drugs (particularly anti-hypertensor or cardiovascular drugs);
- consumption of certain toxic substances (alcohol for example);
- level of fatigue and possible sleep deficit;
- dehydration;
- an empty stomach or too heavy a meal;
- physical condition: not carrying out sport activities or, on the contrary, excessive and regular carrying out of physical stamina activities, especially in the hours preceding the flight;
- the absence of cardiovascular habituation, in particular under-training (e.g. pilots who only occasionally fly aerobatic manoeuvres);
- prior exposure to negative accelerations and the push-pull effect. The consequences of this exposure are likely to last for at least two hours;
- failure to adequately perform musculo-respiratory techniques known as "anti-G breathing techniques".

Other factors, such as morphology, age, or stress, can also affect tolerance of G-forces.

[13] French Armed Forces Biomedical Research Institute.

One of the most effective anti-g breathing techniques, during manoeuvres with positive G-forces, consists of the pilot holding their breath (Valsalva) ideally for 2.5 s to 3 s, while contracting their muscles (abdominals, glutes, quadriceps, hamstrings, and calves), then breathing out to evacuate the air and then taking a deep breath in lasting less than one second, while relaxing their muscles. Anti-g breathing techniques are designed to increase intrathoracic pressure to maintain sufficient blood pressure in the brain to allow gas exchange while avoiding an exaggerated vagal response. When performed correctly, these manoeuvres can provide a gain in tolerance of around 4 g.

2.7.2 Similar accidents

2.7.2.1 Reports published by the BEA

Accident to F-GZXV in 2016

The investigation report concerning the accident to the Flugzeugbau Extra 200 registered F-GZXV on 15 August 2016 at Salon Eyguières specifies that the accident was the result of the pilot losing consciousness during the flight at the end of a manoeuvre that he had carried out without having detected an impairment to his capacities. The continuation of a posture to limit the effects of a positive G-force (anti-g breathing techniques), which became counterproductive, contributed to the loss of consciousness.

The report concluded with the following safety lessons: Sports federations could address programs to pilots to enable them to learn about themselves in order to assess their ability to perform manoeuvres at any time. Such knowledge might have prompted the pilot to abort the flight. A deeper understanding of the physiological adaptation to accelerations, particularly those successively combining negative and positive accelerations, would make it possible to specify countermeasures improving the pilot's management of these constraints during flight.

Accident to F-GGYC in 2021

The investigation report concerning the accident to the MUDRY – CAP10BK registered F-GGYC on 23 May 2021 at Peyrolles-en-Provence indicated that the final flight path of F-GGYC resembled an English bunt manoeuvre continued towards the ground until collision with the surface of the lake. The investigation was not able to determine with certainty whether the action on the controls was deliberate or not. One of the hypothesis that could explain the accident was the "*occurrence of partial or total incapacitation resulting from a succession of figures under negative and positive G-forces and which ended with a high negative G-force. This incapacitation may have taken the form of G-induced almost loss of consciousness (A-LOC), G-induced loss of consciousness (G-LOC), a malaise due to a heart problem or another type of problem, or spatial disorientation* […]".

In April 2023, in its final report, the BEA recommended that "*the FFA make aerobatic pilots aware of the danger of certain manoeuvres which can lead to the physiological limits of the human body being reached. [Recommendation FRAN-2023-012]"*

The FFA replied to the BEA that it had set up a specific discussion and think-tank group on the subject. It specified that the implementation of specific training content relating to aviation medicine, combined with regular actions to raise pilot awareness, had already been in place for a long time. It added that it had implemented concrete training and refresher actions: recurrent training courses for aerobatic instructors and a seminar every two years for aerobatic coaches and instructors. Numerous documents were available to pilots; however, the FFA was unable to precisely determine the level of awareness among pilots, particularly through their instructors.

The FFA specified that the distribution of safety documents relating to the activity needed to be clarified and strengthened. To this end, a specific section was made accessible to each member who had declared they carried out aerobatics:

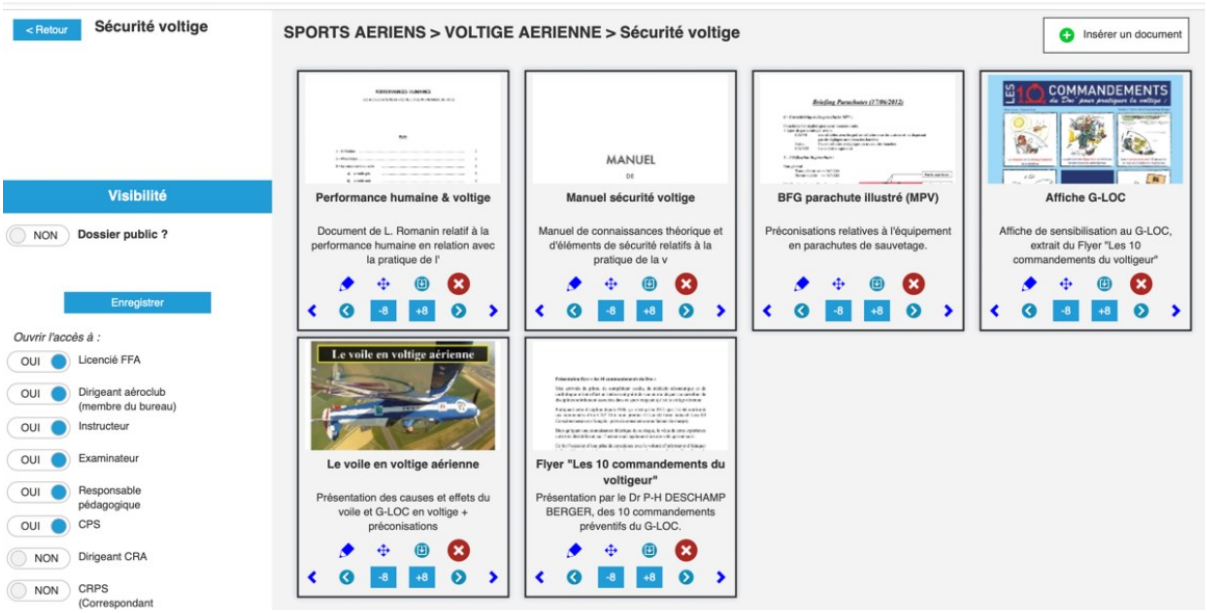

Figure 6: "Smile Documents" portal for an FFA member carrying out aerobatics (source: FFA)

In 2025, the FFA planned to:

- develop each of the points of the poster "The 10 Commandments of the Aerobatic Pilot" (see paragraph 3) through a publication distributed to aerobic pilot members;
- develop a threat and error management (TEM) tool specific to aerobic pilots, based on the IMSAFE model[14].

The pilot of F-AZPZ was not a member of the FFA.

2.7.2.2 Reports published by the BEA-É

The BEA-É has investigated several accidents in connection with G-force induced impaired consciousness.

- Investigation report concerning the accident to the Embraer EMB312F Tucano registered 502 on 19 September 2003 at Sarraud;
- Investigation report concerning the accident to the Socata TB30 Epsilon registered F-SERV on 14 March 2007 at Gente;
- Investigation report concerning the accident to the Dassault Mirage 2000 C RDI registered 116KH on 19 February 2007 at sea, 3 NM south-west of Bonifacio.

These three accidents were the result of G-induced Loss of Consciousness (G-LOC). The analysis of the conclusions of the reports and the safety recommendations issued highlights that, within the Armed Forces, at this time and previously, flight crews were insufficiently aware of the risks associated with G-forces. This patchy knowledge was accompanied by partial and essentially theoretical practice of anti-g breathing techniques.

[14] A memory aid used by pilots to self-assess their fitness to fly (*Illness, Medication, Stress, Alcohol, Fatigue, Emotion*).

Consolidated training programs were thus implemented within the Armed Forces after 2007.

2.7.3 Additional information

The pilot published videos of flights he had performed online. The analysis of these videos by the FFA's “aerobatics” aviation medical examiner showed that the pilot did not practice anti-g breathing techniques. The pilot had left the Air Force at a time when these techniques had not been thoroughly studied and when the effects of G-forces, jolt, and in particular the risk of G-LOC, were not sufficiently taken into account (see paragraph 2.7.2.2).

According to qualified aerobatic pilots, demonstration pilots and the FFA's “aerobatics” aviation medical examiner, the risks of G-LOC are, generally speaking, insufficiently known by pilots in the civilian environment.

3 CONCLUSIONS

The conclusions are solely based on the information which came to the knowledge of the BEA during the investigation.

Scenario

During an airshow over the sea, the pilot carried out a display including several passes. Approximately three minutes into the display, following a loop carried out on the display axis, the pilot carried out a 360° turn with a bank angle of 60° generating a G-force of around +2 g. This turn was started and completed beyond the display axis. From their position, the flying display director and his deputy were not aware of these overshoots.

After the 360° turn and in order to turn around and return to the display axis in preparation for the following pass, the pilot performed a wingover manoeuvre, including a three-quarter climbing roll to the right (the "Derry turn”). When he found himself facing and close to the port of Bormes-les-Mimosas and probably within sight of the port of Le Lavandou, two major references for the display axis, the pilot tightened the turn to intercept the display axis. This descending manoeuvre increased the G-force, up to approximately +5 g for about ten seconds, with a probable peak at a higher value.

The pilot most likely experienced a G-induced almost loss of consciousness (A-LOC), or even loss of consciousness under the influence of the positive acceleration experienced (G-LOC) during the manoeuvre. The flight height, approximately 400 ft, did not give the pilot time to regain his capabilities. The aeroplane collided with the sea surface.

Contributing factors

The following factors may have contributed to the pilot's incapacitation under a positive G-force during the display flight:

- executing a tight turn to intercept and avoid overshooting the display axis. The pilot had mentioned difficulties seeing the axis during the rehearsal flight. It is also possible that the pilot insufficiently took into account the "incoming" wind conditions when he was flying outbound preceding the last "wingover";
- combined physiological factors that day, including the effects of heat, fatigue, health (coughing), poor cardiovascular habituation (few flight hours in 2024 on the aeroplane), and having a relatively empty stomach;
- a probable lack of knowledge of the risks associated with positive G-forces, G-LOC, as well as a possible lack of practice in anti-g breathing techniques.

The pilot also had little recent experience with displays over the sea.

Safety lessons

Knowledge of the risks associated with G-forces and adaptation measures

Following previous accidents, several awareness-raising initiatives addressed at aerobatic pilots and instructors were implemented. The light aviation safety portal of the National Council of Aeronautical and Sports Federations (CNFAS) published an article written by the FFA's “aerobatics” aviation medical examiner, discussing G-force induced impaired consciousness, accompanied by a poster entitled "The Aerobatic Pilot's 10 Commandments," presenting the essential principles for limiting the effects of exposure to G-forces.

In parallel to this, seminars are organized by *France Spectacle Aérien* (FSA), bringing together airshow stakeholders—particularly display pilots and flying display directors—to share and promote best practices. This type of organization, working closely with front-line stakeholders, is a prime vehicle for sharing feedback.

Display axis for a display over the sea

During the 360° turn, the pilot overshot the display axis. The stakeholders involved—particularly the flying display directors and the pilot—were unaware of this. In the next manoeuvre to intercept the axis, the pilot tightened the turn, which most likely led to his incapacitation.

For displays over the sea, the axis is generally marked by buoys, which can be difficult to locate. Depending on their position, flying display directors and pilots may therefore have difficulty verifying the aircraft's position relative to the axis. The difficulties identified prior to the public display regarding the display axis could be further shared among stakeholders to determine whether specific measures should be considered, particularly to detect potential deviations.

Crossing display axis

Display pilots must, as far as possible, keep to the display axis. However, it is possible to cross it if absolutely necessary, particularly for flight or public safety reasons. Several subsequent scenarios are possible:

- the display is stopped, at the pilot's initiative or on the flying display director's orders;
- aborting the manoeuvre or taking an outbound track to allow the pilot to reposition themselves and continue the display without crossing this axis.

Special phraseology, such as the expression "stop display," is a method encouraged by *France Spectacle Aérien* (FSA) to manage this type of situation. Its implementation can be discussed during the briefing between the flying display directors and the pilots. It contributes to better coordination and the reduction of associated risks.

Role of airshow speaker in the event of an accident

Following the accident, the speaker remained calm, and no panic was observed. His messages enabled the emergency services to respond without hindrance. The speaker is the sole contact with the public in the event of a serious incident occurring during an airshow. As such, they play an important role in ensuring public safety by immediately transmitting safety instructions.