Accident to the Airbus AS350 - B3E registered **F-HMFA** on 30 May 2022 at Borce, vallée d'Aspe, locality of "Belonce" (Pyrénées-Atlantiques)

Time	Around 13:00[1]
Operator	Héli Béarn
Type of flight	Cross-country flight - Non-commercial operation (NCO)
Persons on board	Pilot and 2 passengers
Consequences and damage	Body structure and tail boom substantially damaged
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.	

Vortex ring state close to the ground during approach, hard landing

1 HISTORY OF THE FLIGHT

Note: the following information is principally based on statements, the EDR computer[2] and the Appareo Vision 1000 recorder installed on board the helicopter.

The pilot took off at approximately 10.30 from a prepared helipad in a valley near Borce, known as the "Vallon de Belonce", for a cross-country flight bound for a construction site at Eylie (Ariège). He was accompanied by a second pilot seated in the rear right seat and by a flight assistant seated in the left front seat. This flight lasted around 40 minutes. It was followed by a local flight with technical staff. The pilot took off again from Eylie 45 minutes later (at approximately 12:15) bound for Borce, still accompanied by the flight assistant and the second pilot.

The approach to Borce was flown at low horizontal speed, almost overhead the landing area. A low-intensity and irregular slope breeze was blowing up the valley from behind the helicopter. About 30 metres above the ground, the pilot pulled the helicopter's nose up to slow it down, then eased the stick forward. The pilot and the rear passenger felt the helicopter sink and identified an entry into a vortex ring state. The pilot decided not to move the cyclic stick forward because of the helicopter's proximity to the ground and the presence of a group of around 10 people in front of him. He did not change path and let the helicopter fall. Just before the touchdown, he turned 90° left to avoid the mountain slope. The hard impact bent and damaged the tail boom.

The pilot shut down the engine and stopped the rotor. The occupants were unharmed and evacuated the helicopter.

[1] Except where otherwise indicated, the times in this report are in local time.
[2] Engine Data Recorder.

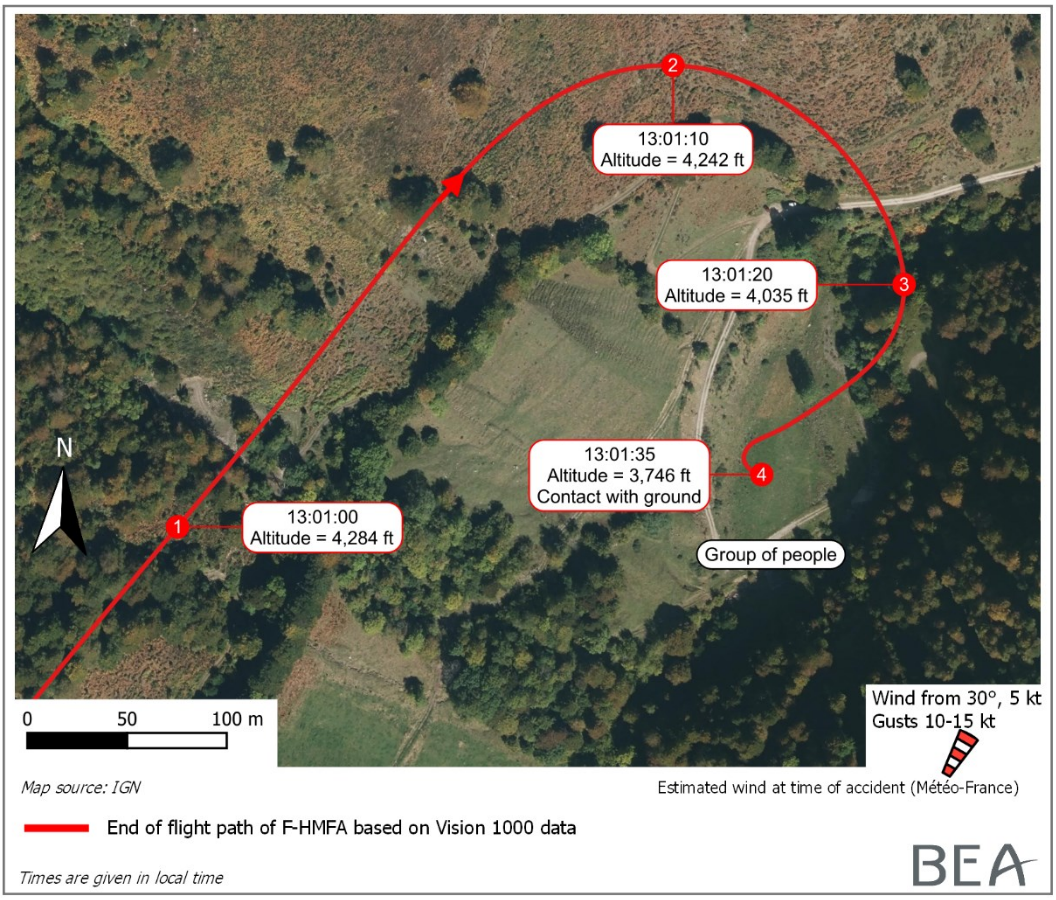

Figure 1: final approach path of F-HMFA

2 ADDITIONAL INFORMATION

2.1 Meteorological information

The meteorological conditions estimated by Météo-France at the site of the accident (altitude 1,150 m) were as follows:

- light 030° wind of around 5 kt gusting up to 10/15 kt (breezes);
- visibility greater than 10 km;
- slightly cloudy sky;
- temperature 17 °C, dew point temperature 10 °C;
- QNH 1,010 hPa.

Both the pilot and the rear passenger reported that there was a light tailwind just as they were on final approach.

The outside temperature at the helipad was 15 °C.

2.2 Site and wreckage information

The Aspe valley, where the touchdown zone (TDZ) is located, is oriented NE-SW in the upward direction. The helicopter was lying in a tall grass field.

The examination of the helicopter enabled the following observations to be made:

- all its components were present; the cabin was intact; neither the main rotor nor the tail rotor came into contact with the ground;
- the landing gear was damaged;
- the tail boom and rear body structure were distorted and folded;
- the flight control linkages were operational and the engine had no anomaly.

Visual examination did not reveal any technical malfunction that may have contributed to the accident.

Figure 2: photograph of F-HMFA (Source: Héli-Béarn)

2.3 Helicopter information

The AS350 B3e is equipped with a Safran Helicopter Engines' Arriel 2D engine. Its maximum on-board weight is 2,250 kg and its maximum gross weight is 2,800 kg in the slung-load transportation configuration.

It is equipped with a VEMD multifunction display allowing the pilot to view engine parameters, a FADEC computer which controls engine fuel flow, and an engine data recorder (EDR).

The read-out of EDR data confirmed that engine performance was nominal. Examination of the FADEC and VEMD was not necessary.

The Appareo Vision 1000 image and parameter recorder was mounted on the cockpit overhead panel. All the data it contained could be retrieved and read out (see para. 2.6).

2.4 Pilot information

The 46-year-old pilot held an American Commercial Pilot Licence - Helicopters (CPL(H)) issued in 2015 and converted to a valid European CPL(H) licence in 2019. This licence came along with R22 and AS350 ratings.

On the day of the accident, he had logged approximately 2,132 flight hours, 790 hours of which on the AS350. During the month preceding the accident, the pilot had logged five flight hours, all on F-HMFA.

The pilot had been hired 15 days earlier by Héli Béarn and was under the supervision of an experienced pilot in connection with the company's aerial work operations.

He was aware of the safety notice (SIN[3]) published by Airbus about the vortex ring state phenomenon and indicated that he knew how to react.

2.5 Vortex ring state phenomenon

The following information is an excerpt from the Airbus document referenced SIN No. 3123-S-00 rev1 dated 12 April 2022 and entitled "Useful information about the Vortex Ring State (VRS) phenomenon". The English version of the document is available on the Airbus website.

"The Vortex Ring State (VRS) is a dangerous phenomenon which can occur when flying at low airspeed with power, if the Rate of Descent (ROD) is allowed to build beyond a certain value.
It can lead to loss of lift and control of the aircraft, with potentially serious consequences.
[...]
Fully developed VRS is characterized by a rapid and substantial loss of rotor lift and control power. When VRS is not avoided (flight trajectory & power), nor detected (incipient stage), it can rapidly evolve into an extremely unstable condition with uncontrolled pitch, roll, and yaw oscillations and very high rates of descent."

2.5.1 Description of the phenomenon

"The main rotor in hover (HOGE) produces a strong downward airstream (downwash) as if it was a giant fan. On a standard day (ISA conditions) the average velocity of this airstream depends on the rotor lift - roughly equal to the helicopter (H/C) weight - and the rotor diameter. For example, a fully loaded H/C at 2250 kg (=5000 lb), with a rotor diameter of 10.7 m (=35 ft), will produce an average downwash of 10 m/s (=2000 fpm). This means that the mass of air displaced by the rotor travels downwards, or effectively descends, at a rate of 2000 fpm.
[...]

[3] Safety Information Notice.

Figure 3: description of the conditions in which a vortex ring state occurs
(Source: Airbus, SIN No. 3123-S-00)

When the H/C is still in the air (HOGE) nothing opposes this airstream from moving continuously away from the rotor disc plane. However, when the H/C descends vertically with a RoD of (say) 500 fpm (=2.5 m/sec), the opposing mass of still air does not allow the downwash to move downwards freely. When the RoD increases to a value of about ***half*** *the H/C downwash velocity in hover, i.e. 1000 fpm, then the opposing mass of still air will effectively block the rotor downwash. Without any 'escape route' the downwash will 'bend', 'brake', and unavoidably return back to the rotor disc plane, creating a giant violent recirculation. Contrary to normal operation (HOGE or low RoD) this recirculated air is highly turbulent and heavily degrades the lift generated by the blades. Under these conditions, the blades will have difficulty following the inputs (collective/cyclic) from the pilot, and the rotor will become sluggish. Moreover, the giant recirculation of turbulent air will engulf most parts of the H/C fuselage and tail, pushing and pulling it in every direction chaotically.*
This causes the overall symptoms of the Vortex Ring State *(not all symptoms may appear simultaneously)**:***

- ***Loss of average lift and severe lift fluctuations (similar to flying in heavy turbulence). This is recognised as sudden lightness in the seat (low g sensation)***
- ***Reduction of control power (commanding the rotor tilt) and/or sluggish rotor response***
- ***Erratic fuselage movements***
- ***Change in rotor vibrations***

[...]
The Vortex Ring State does not only occur in vertical descent. ***It can also happen at low speeds, roughly up to 20-25 kts****. While in low-speed descending flight the horizontal component of the airspeed (say, 20 kts = 10 m/s) will be combined with the vertical rate of descent. The angle formed by the two speeds (forward and vertical) is the flight path angle, also called the approach slope in the final approach."*

2.5.2 Aggravating factors

The Airbus SIN also presents "*some conditions or situations where the H/C and the crew can be found even closer to the VRS boundaries*", in particular:

- ***"Flying light":*** the downwash speed is reduced when the helicopter is lighter. As a result, the helicopter's rate of descent boundary before entering a vortex ring state is also reduced.

- ***"Flying with tail wind close to the surface"*:** when turning with tailwind, pilots must reduce their airspeed to maintain their aiming point on the ground and therefore get closer to the critical speed zone. If pilots do not increase engine power, the rate of descent will increase.
- ***"Small power margins"*:** the SIN specifies that "*When a H/C is heavy and/or in high-density altitude [...], the power required to sustain flight increases rapidly. The pilot has to pay special attention to his/her power management through the collective*" to prevent vertical speed from increasing and therefore avoid getting closer to the VRS boundaries.
- ***"Flying in a degraded visual environment and at night"*:** focusing on finding and maintaining external visual references may lead to a failure in monitoring the rate of descent.
- "***Rapid deceleration*"**:** rapid deceleration due to an increase in the rotor angle of attack increases the risk of vortex rings. The "*effective*" rate of descent of the rotor disc increases and the margin in relation to the vortex ring state decreases accordingly.
- ***"Confined environment"*:** contributes to increasing the approach slopes as well as air recirculation zones on near-vertical surfaces.

2.5.3 Manufacturer's recommendations for pilots

To avoid entry into a vortex ring state, SIN No. 3123-S-00 provides pilots with the following instruction: *"NEVER ALLOW AN RoD GREATER THAN 500 fpm WHEN BELOW 30 KIAS[4]. AVOID AGGRESSIVE DECELERATIONS WHILE IN DESCENT OR WHEN TURNING TO A DOWNWIND POSITION."*

Note: The standard VRS recovery technique described in the SIN is supplemented by the Vuichard technique described in SIN No. 3463-S-00.

2.6 Read-out of flight data from the Appareo Vision 1000 recorder

The read-out of the parameters recorded in the Vision 1000 revealed that during the last twenty seconds of flight, the helicopter's vertical speed was very high, with a low ground speed.
Examination of the video and recorded data showed that during the final descent, the vertical speed increased from around 1,000 ft/min to 1,600 ft/min in 11 s, without any substantial input on the collective pitch being observed.

The ground speed and vertical speed parameters could be used to assess the theoretical conditions for a vortex ring state to occur. A calculation performed by Airbus based on Froude's theory illustrated the theoretical vortex ring state envelope using the parameters of the day:

- *Weight m = 1,800 kg*
- *Rotor radius R = 5.35 m*
- *Helicopter altitude Zp = 1,170 m and Outside Air Temperature OAT = 17 °C, i.e. a density* $\rho = 1{,}06\ kg/m^3$

The speed induced by the airflow in the rotor, in hover flight, is estimated to be around 1,900 ft/min:

$$(V_{i0} = \sqrt{\frac{mg}{2\rho\pi R^2}} = 9{,}62\ m/s \equiv 1\,900\ ft/\min \equiv 18{,}7\ kt)$$

[4] Knots-Indicated Air Speed.

The theoretical envelope conducive to the occurrence of a vortex ring state is thus defined as $\begin{cases} 0 < V_x < V_{i0} \\ -V_{i0} < V_z < -\frac{V_{i0}}{2} \end{cases}$, this envelope varies depending on the tailwind speed and aircraft attitude. It is shown in red on the following graph (see *Figure 4*).

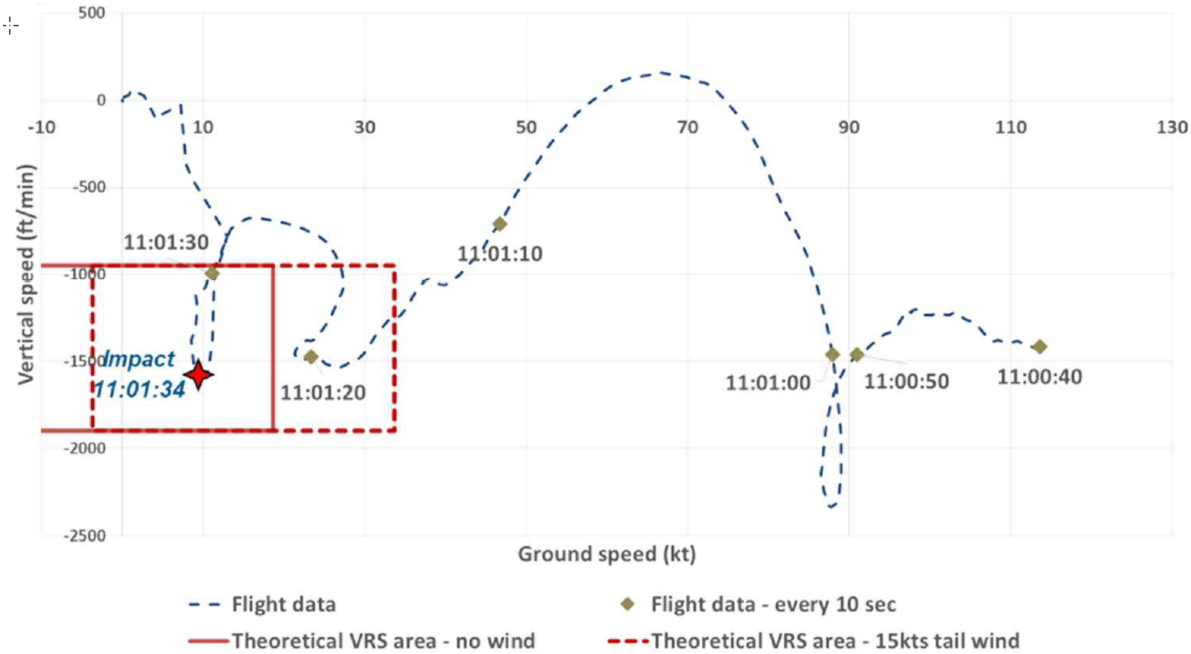

Figure 4: theoretical area where a vortex ring state may occur, with or without wind (Source: Airbus)
The helicopter's vertical speed is plotted as a function of the ground speed during the last minute of flight.

Two other video recordings, taken by two members of the group of persons on the ground (see Figure 1) showed the final approach carried out by F-HMFA until impact with the ground.

Analysis of the parameters and the video taken by the witnesses on the ground confirmed that the helicopter entered into a vortex ring state.

It is possible that the pilot was surprised and stressed by the acceleration during the descent and was slow to react and input on the collective pitch to counter an excessive rate of descent. The pilot in the rear seat noticed this late reaction and specified that he reported it to the pilot immediately, telling him that he needed to correct his approach angle.

Figure 5: extracts from videos taken from ground during final approach

3 CONCLUSIONS

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

Scenario

Following a cross-country flight to familiarise himself with the sites operated by the aerial work company Héli Béarn, the pilot made an approach with a high rate of descent under tailwind conditions. The helicopter entered into a vortex ring state and the pilot lost control of the helicopter.

Contributing factors

The following factors may have contributed to the helicopter's entry into a vortex ring state in which it remained:

- failure to take into account the effects of tailwind when managing the approach and descent;
- a rate of descent that was too high;
- the surprise and stress induced by the situation, which may have increased the pilot's reaction time and led him to make a late input on the collective control;

- the lack of any attempt to exit the vortex ring state so as not to endanger the people on the ground; the pilot did not want to input on the cyclic pitch stick, which would probably have resulted in the helicopter coming closer to them.

Safety lessons

Vortex ring state phenomenon

The vortex ring state (VRS) is a phenomenon with which helicopter pilots are familiar. Accidents which occurred in recent years with an identified VRS involved experienced pilots who were aware of this phenomenon.

The AS350 B3e is known to have a high power margin when not operated at maximum weight. These intrinsic qualities of the helicopter may lead pilots to be overconfident in the helicopter's performance and in its ability to get out of difficult situations.

Airbus has published two safety information notices explaining the risks and the actions to be taken if a VRS occurs (see para. 2.5) and has also developed an e-learning module.

The BEA investigations are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.