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INVESTIGATION REPORT

Serious incident to the BOEING - 737 - 800 registered 7T-VJM

on 6 December 2019
at Paris-Orly (94)

Time	Around 11:15[1]
Operator	Air Algérie
Type of flight	Commercial air transport of passengers
Persons on board	Captain, co-pilot, cabin crew and passengers
Consequences and damage	None

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in October 2021. As accurate as the translation may be, the original text in French is the work of reference.

[1] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC). One hour should be added to obtain the legal time applicable in Metropolitan France on the day of the event.

Loss of altitude during go-around

1 - HISTORY OF THE FLIGHT

Note: the following information is principally based on the data from the Quick Access Recorder (QAR) and the radio communication recordings. A written report made by the captain was also supplemented by a telephone interview with him, in the presence of the head of the FSB[2] for Air Algérie and a representative from the Algerian civil aviation authority.

[2] Flight Safety Bureau.

The crew took off at 08:53 from Tlemcen airport (Algeria) bound for Paris-Orly airport. A little over two hours later, on an ILS approach for runway 25, the crew pre-set an altitude of 2,000 ft on the Mode Control Panel (MCP), corresponding to the altitude to be joined in case of a missed approach. The co-pilot was then PF. The controller cleared them to land at 11:12:02. They disengaged the autopilot (A/P) at 11:14:01 and then the auto-throttle (A/T) at an altitude of around 600 ft to carry out a manual landing.

At 11:14:10, when the plane was at an altitude of 477 ft (i.e. 13 ft below the decision altitude (DA), the controller ordered the crew to go around after the activation of a Runway Incursion Monitoring and Collision Avoidance System (RIMCAS) warning. The controller did not inform the crew of the reason for this instruction to go around. The published missed approach path for runway 25 specifies climbing straight ahead and then, at an altitude of 700 ft, turning left towards the magnetic track 199° and climbing to 2,000 ft initially.

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At 11:14:14, at an altitude of 401 ft and a height of 117 ft, the crew engaged the TO/GA mode by pressing the TO/GA button on the power levers (point ❶ in figure 1 below) and set a nose-up attitude. As the A/T was not manually armed after being disengaged, it did not engage itself and the crew manually pushed forward the power levers to a position corresponding to around 90 % of N1. The aeroplane reached a minimum radio altimeter height of 73 ft before regaining altitude. The MASTER CAUTION light came on for twelve seconds[3]. The engine thrust and the automatic increase in the nose-up trim, despite the nose-down inputs on the control column[4], increased the pitch to 18°, slightly above the Flight Director (F/D) horizontal bar (15°). The vertical speed quickly increased up to 4,000 ft/min.

At 11:14:21, at an altitude of 380 ft, the crew retracted the flaps to the 15° position and then the landing gear. The control column inputs continued to follow the F/D command bars. At an altitude of 930 ft, the LNAV mode was automatically engaged, followed by, at 1,210 ft, the ALT ACQ vertical mode which took the target altitude of 2,000 ft pre-set by the crew during the final approach. The rate of climb was then at its maximum at 4,100 ft/min.

At 11:14:46, at an altitude of 1,340 ft, the A/T engaged, after being armed by the crew, following the engagement of the ALT ACQ mode. The MCP SPD mode to maintain a speed of 171 kt corresponding to the speed at the time of the engagement became active. The A/P was not re-engaged. The vertical bar of the F/D gave a left correction cue to join track 199° of the missed approach procedure. The plane was around 150 m to the right of the runway centreline probably due to the wind gradient. The crew started the left turn. At 11:14:59, the altitude was 2,000 ft and the vertical speed 1,300 ft/min. The N1 values were 72 % and decreasing. The bank angle reached a maximum value of 38° and the "BANK ANGLE"[5] alert was activated. During the turn, the crew retracted the flaps to position 2°. The aeroplane's speed, which had decreased, was 160 kt, i.e. 11 kt below the target speed of the MCP SPD mode. The maximum altitude reached during the turn was 2,070 ft. The control column inputs were consistent with the F/D command bar cues.

With a nose-up attitude of 4.0° and around 65 % of N1, the altitude started to decrease and the speed to increase. At 11:15:15, the horizontal command bar of the F/D gave a nose-up cue to reach around 10° pitch. The pitch attitude remained below 5° and the plane came out of the turn on a heading of 200°. The altitude was around 1,900 ft and the vertical speed in descent was more than 1,500 ft/min. At the same time, the controller asked the crew to climb to 3,000 ft and to turn to heading 160°. The crew modified the altitude selection on the MCP which resulted in the transition from the ALT ACQ vertical mode to the Vertical Speed (V/S) hold mode, the target vertical speed being the speed when the mode changed, i.e. 1,100 ft/min in descent (point ❷). After this mode reversion, the crew followed the F/D command bar cues which kept the plane in descent. The engines were at 45 % of N1 and still decreasing.

[3] The reason for this Master Caution was not determined.

[4] It was not possible, based on the QAR data and the statement, to determine with certitude the roles (PF or PM) of each pilot during the go-around.

[5] Alert generated by the GPWS when the bank is more than 35° and characterized by the "BANK ANGLE, BANK ANGLE" voice message.

At 11:15:34, the crew read back the altitude of 3,000 ft again at the controller's request. The crew disengaged the A/T and progressively increased the thrust to 50 % of N1. At the same time, the "DON'T SINK"[6] alert was activated. The aeroplane was at an altitude of 1,556 ft, a height of 1,260 ft with a vertical speed in descent of 1,200 ft/min (point ❸). At 11:15:37, the crew engaged the A/T in MCP SPD mode again with a target speed of 175 kt. A few seconds later, the controller told the crew that he could see the plane descending on the radar and asked them to climb to 3,000 ft. From 11:15:49, at an altitude of around 1,300 ft, the crew fully retracted the flaps, progressively increased the pitch up to 11° and thrust up to 70 % of N1 by disengaging the A/T (point ❹). At 11:15:56, the stick shaker was momentarily activated and at 11:15:57, the crew reduced the pitch. The horizontal command bar of the F/D still gave a cue to take a pitch to hold a vertical speed in descent of 1,100 ft/min in V/S mode. The "DON'T SINK" alert was activated again.

In the following thirty seconds, the crew held level flight at an altitude of around 1,300 ft during which the speed increased up to 292 kt. During this acceleration, the crew extended the flaps to the first detent at a speed exceeding the flap placard speed by 20 kt (the flaps were retracted a minute later). The crew engaged the A/T again and then climbed to an altitude of 3,000 ft with a vertical speed of more than 4,000 ft/min for ten seconds. The horizontal command bar of the F/D gave a nose-down cue until the engagement of the ALT ACQ vertical mode. At 11:17:36, the crew engaged the A/P at 3,000 ft (point ❺) and were then vectored by the controller for a new approach. They landed on runway 25 at Orly at 11:37.

[6] GPWS alert characterized by the "DON'T SINK" voice message and the **PULL UP** message on the artificial horizon.

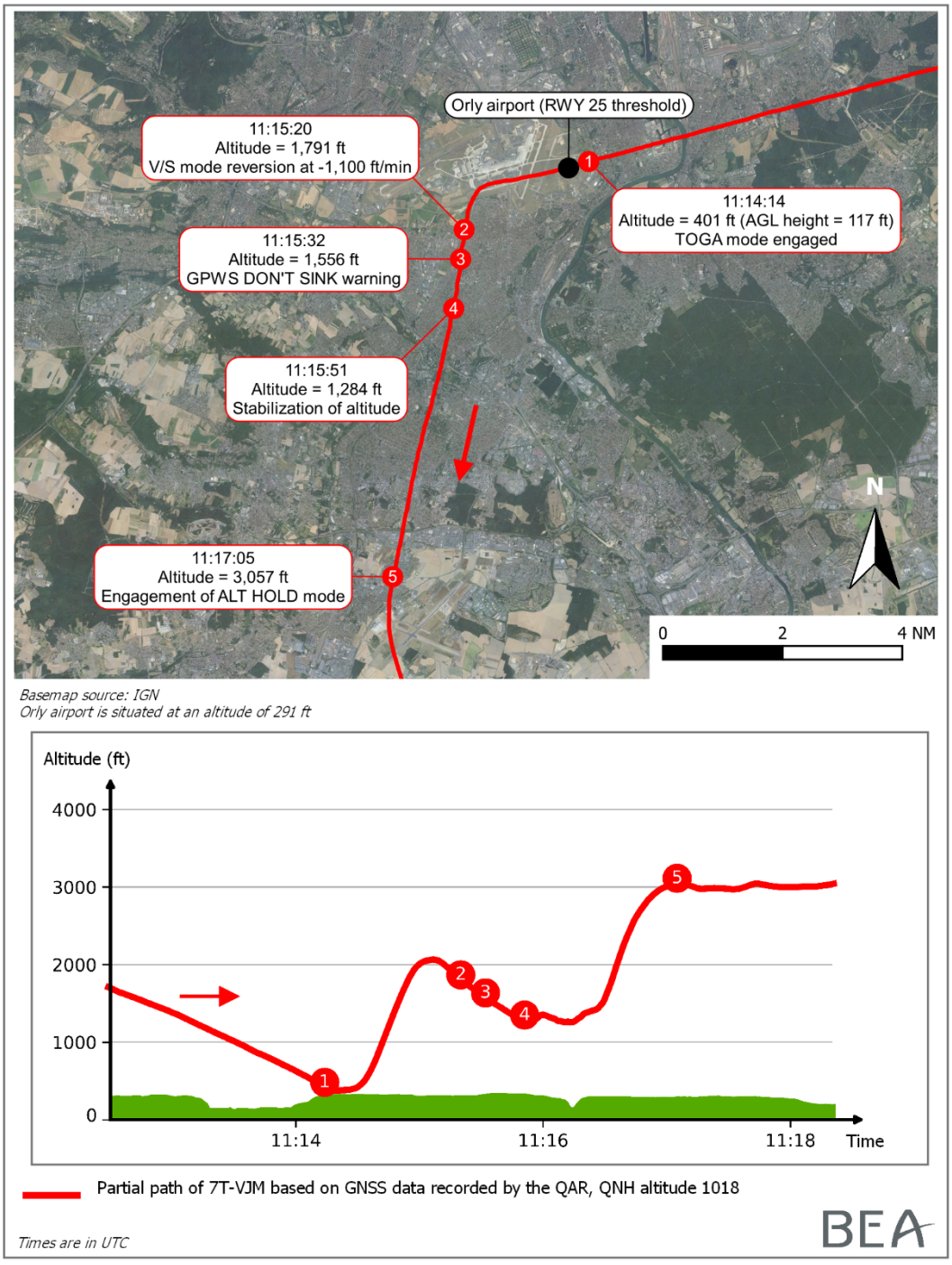

Figure 1: Horizontal and vertical paths of 7T-VJM based on QAR data

2 - ADDITIONAL INFORMATION

2.1 Crew information

The captain held a valid Airline Transport Pilot Licence (ATPL). He had logged approximately 8,000 flight hours of which 1,400 hours on Boeing 737. He had obtained his Boeing 737 type rating in May 2018 and had flown 230 hours during the previous three months.

The co-pilot held a valid Commercial Pilot Licence (CPL) and had logged around 3,700 flight hours of which 1,700 hours on the Boeing 737. He had obtained his Boeing 737 type rating in May 2017.

Due to the time which had elapsed between the incident and the telephone interview, the captain could no longer precisely recall the occurrence. However, he indicated that he and the co-pilot were preparing for the landing and that they had been very surprised by the instruction to go around. They had not understood what had caused it as they were around 100 ft from the ground with the runway in sight and clear. According to him, this was a preoccupation during the go-around. He heard the warnings but could not remember which ones. He could no longer remember the conditions which led to the loss of altitude.

2.2 Weather conditions

The 11:00 and 11:30 Orly airport METARs indicated wind from 200°, 10 kt, visibility 4,000 to 4,500 m, mist, light rain and broken clouds (5 to 7 octas) based at 500 ft.

The data recorded by the aeroplane shows the presence of a wind gradient with a 40 kt wind at 1,500 ft.

2.3 Activation of RIMCAS warning

The RIMCAS warning was triggered by the presence of a bird-control vehicle at holding point W33 (north of the runway at around 700 m from the threshold). The crew of 7T-VJM had just been cleared to land when the LOC assistant controller, over the dedicated frequency, asked the driver of this vehicle to exit the runway safety area, but the driver did not reply. The LOC controller then asked the crew to perform a go-around.

The driver indicated that he had not heard the radio message as he was in the process of scaring off birds using gun fire. Furthermore, he had ensured that he was not in the runway safety area.

The air navigation services indicated that the RIMCAS warning was generated due to an erroneous system configuration. On completion of the work carried out up to 2 December on runway 25, four days before the event, the position of holding point W33 had been modified and moved 12 m closer to the runway centreline. The RIMCAS configuration, which took into account the position of the holding points, had not been modified accordingly. The warning was therefore activated when the bird-control vehicle had not exceeded the holding point.

The RIMCAS configuration was corrected after the incident and the RIMCAS monitoring surface now corresponds to a 90 m rectangle on both sides of the runway centreline and separate from the position of the holding marks, in accordance with the runway 25 safety area.

2.4 Management of automatic systems

2.4.1 Managing a go-around with low weight or with a low published altitude

The climb performance of modern twin-engine jets tends to reduce the time given to the crew to manage a dynamic manoeuvre with a high workload[7]. As mentioned by Boeing in the Flight Crew Techniques Manual (FCTM), one of the main risks during a go-around with low weight or with a low published altitude, is the exceedance of this altitude. In order to minimize this risk, the FCTM recommends adopting a rate of climb of 1,000 to 2,000 ft/min. To do this, the FCTM suggests using the A/T but also recommends disconnecting all the automatic systems (A/P, A/T and F/D) and to level off manually if the crew considers that there is still a risk of exceeding the altitude. In particular, it is explained in this manual, that the AFDS[8] control laws limit the A/P or F/D attitude variations for the comfort of the passengers which may lead to the target altitude being exceeded without crew action.

2.4.2 Altitude acquisition

The ALT ACQ mode of the AFDS is automatically engaged when the plane approaches the selected altitude in climb or descent. The AFDS then changes to ALT HOLD mode when the aeroplane is less than 60 ft from the target altitude, provided that the vertical speed is less than the absolute value of 300 ft/min.

During the flight, 7T-VJM exceeded the altitude of 2,000 ft +/-60ft with a vertical speed of always more than 300 ft/min. The ALT HOLD mode was thus not able to engage although the PF had adopted a pitch slightly below the F/D cues. The reduction in attitude indicated by the F/D horizontal bar cues was insufficient to reduce the vertical speed and acquire the altitude. It is probable that this was due to the AFDS limiting the attitude variations (see paragraph 2.4.1).

2.4.3 Mode reversion

When the AFDS is in ALT ACQ mode and the crew modifies the selected altitude, this results in a V/S mode reversion, the target speed being the instantaneous vertical speed of the plane when the altitude was modified. The mode reversion is indicated to the crew by the mode being displayed in a box on the Flight Mode Annunciator (FMA) for ten seconds, without an audible alert. The system does not check for consistency between the vertical speed and the selected altitude. During the incident, the selected altitude of 3,000 ft corresponded to a climb but the AFDS took the instantaneous vertical speed of the plane as the target speed in V/S mode which was 1,100 ft/min in descent.

[7] This point was brought to light by the Aeroplane State Awareness during Go-Around study carried out by the BEA in 2013 (ASAGA). See paragraph 2.8.

[8] Autopilot Flight Director System: aeroplane management system composed of the autopilot, flight director and auto-throttle.

2.4.4 Display of vertical speed target

The target vertical speed can only be consulted on the vertical speed scale on the Primary Flight Display (PFD) where it is represented as a double magenta line (see Figure below).

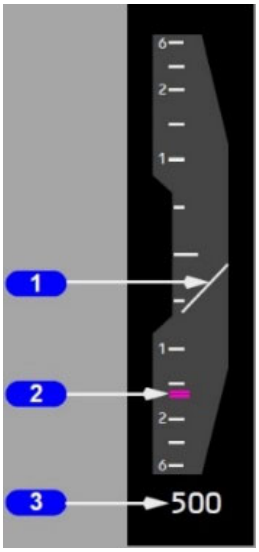

Figure 2: Vertical speed bar on B737 PFD.

1: actual vertical speed indicator.
2: target vertical speed indicator (here around -1,600 ft/min).
3: value of actual vertical speed.

2.5 Crew's management of go-around

The data from the Cockpit Voice Recorder (CVR) was not preserved for read-out due to the 2 hour recording time and the fact that another flight was scheduled after the incident flight. Despite requests addressed to the Algerian civil aviation authority to collect the crew's statements, it was not possible to organise an interview with the co-pilot.

This absence of information limited the analysis of the incident and certainly meant that it was not possible to establish all the safety lessons which could have been drawn from this serious incident. Nevertheless, it transpires from the information collected that:

- The high vertical speed, the turn, the retraction of the flaps and the sharp increase in the headwind during the approach to 2,000 ft could have constituted stabilization and levelling off conditions which were not conducive to the AFDS acquiring the altitude.
- The crew did not disconnect the A/T and the F/D as it is recommended in the FCTM when the target altitude risks being exceeded. They had perhaps not sufficiently anticipated this risk.

- The crew were surprised by the instruction to go around. This gave rise to some questioning during the phase which followed and may have absorbed numerous attention resources. The turn and the relatively low initial stabilization altitude of the missed approach procedure along with the activation of the MASTER CAUTION alerts probably led to a high workload for the crew. The surprise combined with the increase in workload may explain certain inaccuracies observed in the piloting of the plane (deviations from flight path, flight at more than 250 kt at low height for around two minutes, extending flaps to the first detent 20 kt above the flap placard speed).
- The crew probably followed the guidance cues given by the F/D command bars without having checked that the associated modes and target values were compatible with the flight path to be followed.
- The time taken to react to the "DON'T SINK" alert and to the controller's instruction and then requests to climb to 3,000 ft along with the level flight of thirty seconds at around 1,300 ft can be explained by the crew's difficulty in assessing or understanding the situation.

2.6 Go-around altitude on runway 25 at Orly

In the scope of the investigation into the incident to the Airbus A350 registered F-HREV operated by French Bee that occurred on the 4 February 2020 at Orly[9], the BEA was able to determine, with the help of the Orly air navigation services, that out of the eight go-arounds at Paris-Orly in 2019 giving rise to a deviation of more than 200 ft with respect to the cleared altitude, six had a stabilization altitude at 2,000 ft. However, the go-arounds with a cleared altitude at 2,000 ft only represent 21% of all the go-arounds in the same period[10].

At the end of the investigation into the incident to F-HREV, the BEA recommended to the DSNA (the French air navigation service provider) that it study the feasibility of increasing the published missed approach altitude at Paris-Orly airport to give crews more time to carry out all the tasks associated with a go-around procedure and limit the risk of a path deviation.

2.7 Similar event

A similar incident to that of 7T-VJM occurred on 1 June 2019 to a Boeing 737-800 on approach to Bristol airport (United Kingdom). The air traffic controller ordered the crew to perform a go-around because the plane was below the glideslope. The crew flew a missed approach with the selected altitude on the MCP at the DA of 1,000 ft whereas the go-around procedure altitude was 3,000 ft. The plane was slightly above 1,000 ft, the ALT ACQ mode activated to capture the altitude and the PF followed the F/D cues in manual control. The crew then set 3,000 ft for the selected altitude, the AFDS changed to V/S mode and thus held the instantaneous vertical speed which was in descent at this time. The descent continued for 32 s before the crew corrected the flight path. The United Kingdom Air Accidents Investigation Branch (AAIB) did not determine the reason why the crew had not detected the descent[11].

[9] https://bea.aero/en/investigation-reports/notified-events/detail/incident-to-the-airbus-a350-registered-f-hrev-operated-by-french-bee-on-04-02-2020-at-orly/

[10] The other go-arounds were initially cleared by air traffic control to climb to a higher altitude.

[11] The report is available on the AAIB website page.

2.8 Study on Aeroplane State Awareness during Go-Around (ASAGA)

In 2013, the BEA published a study on Aeroplane State Awareness during Go-Around (ASAGA[12]).

[12] https://www.bea.aero/en/safety-studies/access-to-studies/aeroplane-state-awareness-during-go-around/

2.8.1 Startle effect and degradation of crew cooperation

It transpired from this study that "*carrying out a go-around procedure and the associated workload can disassociate the two crew members for a too long period of time*". This is all the more so when the go-around is not on the crew's initiative, the instruction to carry out a go-around will then startle and may unsettle the crew.

2.8.2 Interception of go-around altitude

The difficulty of intercepting the go-around altitude is also a characteristic of the scenarios studied in the ASAGA study, both brought to light by the analysis of the occurrences and expressed by nearly half of the 831 pilots who replied to the BEA questionnaire. This difficulty particularly stands out when the published go-around altitude is low (less than 2,000 ft above the DA) as is the case for the missed approach procedure on runway 25 at Orly. The interception difficulty is partly due to a "*mismatch*" between the construction of the missed approach procedures and the available thrust on modern twin-engine jets. These planes can produce very high climb speeds especially when they are light, reducing the available time to carry out the actions and calls required for the go-around procedure before the interception.

On the Boeing 737, the thrust limitation by the A/T[13] limits the risk of an erroneous perception of the attitude (somatogravic illusion) and also offers the crew more time to carry out the go-around. However, when the crew manually manage the thrust, they do not benefit from this limitation.

[13] The TO/GA thrust remains available by pressing the TO/GA switch a second time.

2.8.3 Management of automatic systems

During the simulations carried out in the scope of the study, it was noticed that the crew's reading of the FMA was often deficient during the go-around. Up to ten undetected FMA mode changes were observed during the same go-around, although some of these had a direct consequence on the tracking of the flight path. The non-detection of FMA mode changes by the two crew members is principally linked to cognitive saturation, time pressure, the absence of a defined visual scan pattern and the workload associated with a missed approach.

Likewise, on intercepting or selecting the go-around altitude, simulations showed that mode reversions were sometimes not detected.

Based on these observations, the BEA issued the following recommendation:

"*EASA[14], in coordination with the major non-European certification authorities, ensure that aircraft manufacturers modify ergonomics so as to simplify the interpretation of FMA modes, and facilitate detection of any changes to them; [Recommendation FRAN-2013-037].*"

[14] European Aviation Safety Agency.

EASA replied in 2014 that this recommendation had already been considered by Certification Specifications (CS) 25.1302 and that the Automation Policy developed by the agency also dealt with this subject. The BEA considered this response inadequate given the various studies which showed the difficulties of reading and interpreting the FMA modes, all the more since the modification of the ergonomics on existing planes was not dealt with by EASA.

3 - CONCLUSIONS

The conclusions are solely based on the information which came to the knowledge of the BEA during the investigation. They are not intended to apportion blame or liability.

Scenario

When the plane was on final for runway 25 at Orly, a Runway Incursion Monitoring and Collision Avoidance System (RIMCAS) warning was activated due to the presence of a bird-control vehicle in the vicinity of the runway safety area. However, the bird-control vehicle was behind the holding point and outside the runway safety area. The erroneous activation of the RIMCAS warning was due to the relocation of the holding point, after work, not being taken into account in the system parameters.

Due to the RIMCAS warning and the absence of a reply from the driver of the vehicle, the controller ordered the crew to perform a go-around after they had passed through the decision altitude (DA).

The crew carried out the go-around by initially displaying a thrust and a pitch attitude which resulted in a high vertical speed. They then engaged the auto-throttle (A/T) although the autopilot (A/P) was disengaged. The left turn was started late and the high bank angle triggered the “BANK ANGLE” warning. The missed approach altitude was exceeded during the turn. Under the combined effect of a nose-down input from the PF and the A/T reducing the thrust, the plane next re-descended below 2,000 ft. The controller then cleared the crew to climb to 3,000 ft. The crew’s selection of this altitude caused a V/S mode reversion with the instantaneous vertical speed taken as the target speed (-1,100 ft/min).

The crew then followed the flight director (F/D) cues for around 20 s. During the descent, the controller contacted the crew three times, the “DON’T SINK” alert was activated and remained active for 45 s.

The crew stopped the descent at around 1,300 ft and levelled off for 30 s while accelerating up to 292 kt. They then resumed the climb to 3,000 ft. After stabilizing the plane at 3,000 ft, the crew carried out a second, uneventful approach.

Contributing factors

In the absence of a CVR recording and precise statements, it was not possible to precisely analyse the crew's actions. The following factors may, nevertheless, have contributed to the observed deviations from the procedure and tracking of the path during the go-around:

- The startle effect linked to a go-around ordered by the controller when at low height.
- The missed approach path with a low published altitude and a left turn in initial climb which creates a high workload in a short time.
- The crew's application of an initial high thrust given the stabilization altitude of the missed approach.
- Piloting based on a hybrid use of automatic systems (A/P, A/T and F/D) which was not conducive to acquiring the published altitude of the missed approach procedure.
- A breakdown in crew cooperation which may be explained by the startle effect linked to the go-around instruction and to the workload mentioned above.
- The display of the vertical speed target value on the PFD which may require a verification on the MCP. This may have contributed to the crew not detecting that the target value was not consistent with the desired path.
- The absence of a system check for consistency between the action carried out (selection of a higher altitude) and its result (mode reversion leading to a descent) along with the absence of a crew alert.

The controller's messages to warn the crew of the plane's descent, along with the GPWS warnings, probably contributed to the crew realising that they were on an erroneous path and to them levelling off the plane.

Safety lessons

Management of automatic systems

This occurrence shows that the conclusions of the ASAGA study are still relevant. In particular, the fact that the crew followed the F/D cues when the AFDS was in V/S mode with a negative vertical speed following a mode reversion, supports the BEA's recommendation FRAN-2013-037 to EASA regarding the improvement to the ergonomics to facilitate the interpretation of the FMA modes and the detection of any changes to them.

Effective crew synergy to closely monitor the FMA modes remains essential. Crews must not hesitate to disconnect the automatic systems when they no longer understand them.