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pour la sécurité de l'aviation civile

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REPORT
INCIDENT

Undetected Decrease in Approach Speed, Triggering of High Angle of Attack Protection on Approach

Aircraft	Airbus A321 registered F-GTAN
Date and time	20 July 2012 at about 15 h 00[1]
Operator	Air France
Place	Paris Charles de Gaulle (95) Airport
Type of flight	Scheduled public transport of passengers
Persons on board	Captain (PF); Copilot (PM)
Consequences and damage	None

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.

1 - HISTORY OF FLIGHT

The crew took off from Bordeaux at around 14 h 20, bound for Paris CDG. The pilot flying (PF) stated that on departure, during taxiing, the SEC1[2] was declared unserviceable. The crew consulted the associated procedure displayed on the ECAM[3]. It specified that the speedbrakes not be used during the flight.

During the arrival, under radar vectoring, the n°1 autopilot, the autothrust and the flight directors (AP1, A/THR and the FD) were engaged. The aeroplane was in clean configuration. The crew made the descent at a speed of 250 kt[4] in OPEN DES mode.

Note: The OPEN DES mode is a descent mode selected on the AP/FD that maintains a speed or a Mach by controlling the aeroplane's pitch. When the A/THR is engaged, thrust is maintained on idle. This mode must not be used on final approach.

On descent from FL90 towards FL60, the controller told the crew *"Exit quite short, continue descent towards 4,000 ft and stable 4,000 ft from 18 to 20 NM maxi"*. At that moment, the aeroplane configuration made it possible to meet this constraint without modifying its glide[5] path. However, the PF decided to *"speed up[6] the descent"*. The speed brakes not being usable, he positioned the thrust levers on IDLE and thus disengaged the A/THR. The PF did not remember calling out this action and the PM stated that he was not aware of this disengagement.

The rest of the flight can be broken down into three phases (see graph on page 3).

[1] Except where otherwise stated, the times shown in this report are expressed in Universal Time Coordinated (UTC).

[2] The SEC (Spoilers Elevator Computer) is a computer that controls the speed brake, the elevator and the trimmable horizontal stabiliser. The A321 has 3 SEC's.

[3] ECAM: Electronic Centralized Aircraft Monitor.

[4] Except where otherwise indicated, the speeds in this report are based on the Computed Air Speed (CAS).

[5] When a controller gives a crew an altitude and distance instruction, the latter must adapt its flight path if required to follow it. To do this, the ND or the MCDU can allow the crew to check if the request from the controller can be met. The crew can also calculate the glide path requested and compare it to that followed by the aeroplane.

[6] To accelerate a descent under a speed restriction in OPEN DES mode, the pilot can extend the speed brakes, the flaps and/or the landing gear.

Phase 1: Mixed flying situation with AP ON and A/THR OFF

At about 15 h 12, the PF selected a speed of 220 kt at the request of the controller. A few seconds later, the aeroplane reached an altitude of 4,000 ft and the ALT[7] mode engaged.

[7] In ALT mode, the AP maintains the selected altitude through inputs on the THS and the stabilizer. The constraint on selected speed is no longer taken into account if the A/THR is not engaged.

The thrust at idle was not sufficient to maintain the speed in level flight. Maintaining the altitude was only then possible by increasing the angle of attack. That was why the AP gave pitch-up input orders to the trimmable horizontal stabiliser (THS) and the elevator. Under these conditions the speed decreased.

At 15 h 12 min 32, the speed dropped below the previously selected speed while the controller announced the presence of traffic *"12 o'clock, 7 NM, opposing route, 1,000 ft high, 318 for the north"*.

The PF and the PM stated that they were looking outside simultaneously, focusing their attention on searching for the aircraft.

During this phase of flight the thrust levers were on IDLE. The pitch and the angle of attack increased progressively, the speed decreased and the altitude remained stable at 4,000 ft.

Phase 2: Triggering of the high angle of attack protection

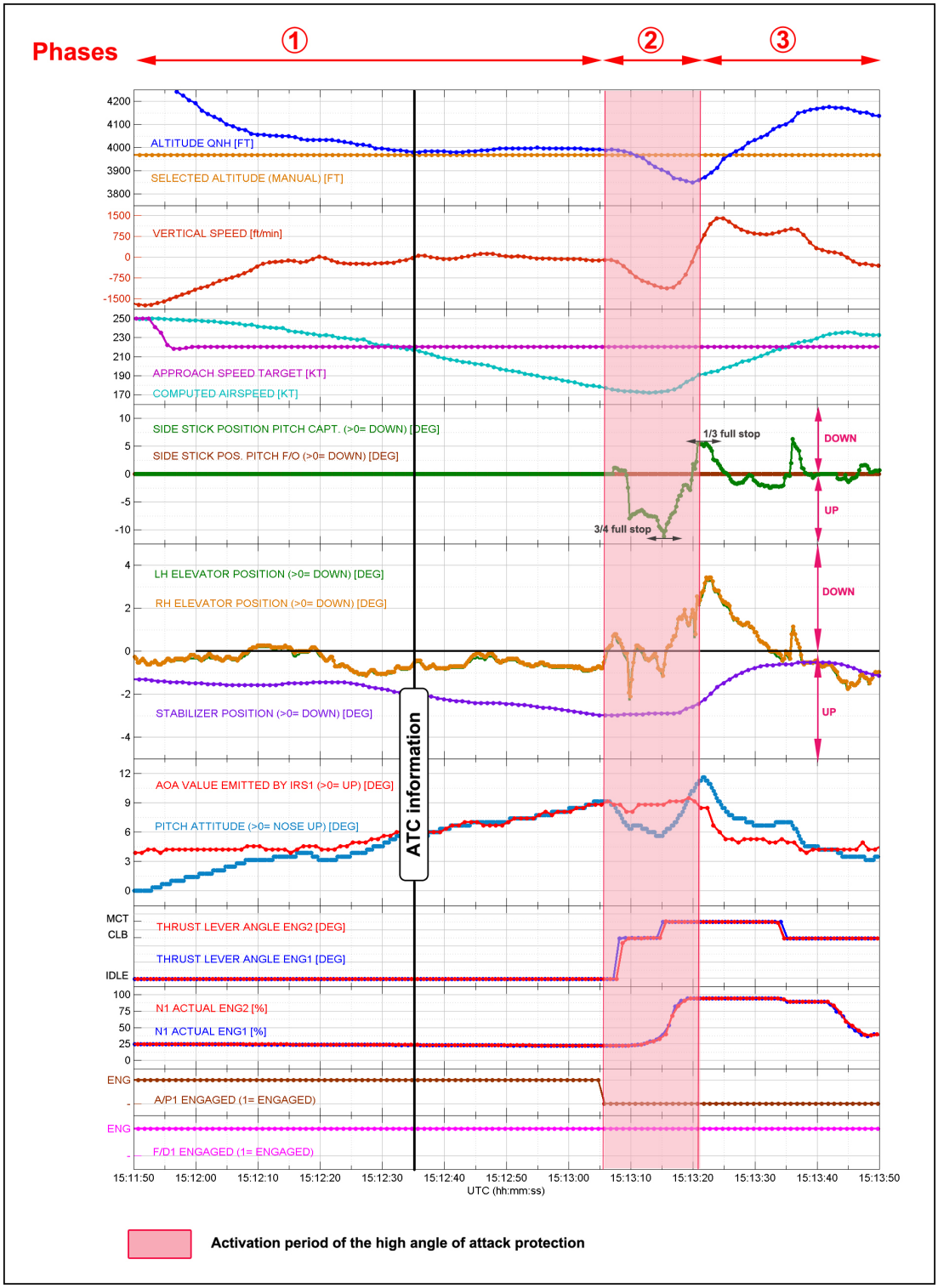
At 15 h 13 min 05, the autopilot disengaged in accordance with the angle of attack criteria. The high angle of attack protection (Alpha PROT) (see paragraph 2.6) was triggered. The speed was then 177 kt, 26 kt lower than the lowest selectable airspeed (VLS). Two seconds later, the PF pushed the thrust levers forward to CLB. Simultaneously and for about ten seconds he made a pitch-up input since the aeroplane was in descent. At that time, the thrust was not yet established, the angle of attack being limited, the speed was insufficient to develop lift equal to the weight of the aeroplane, which explains its descent. The speed reached a minimum of 172kt (VLS -31 kt) with a descent rate of about 1,000 ft/min. The PF stated that he saw the speed *"in the red"* on the speed scale and that throughout this phase of flight his priority was to maintain the altitude constant at 4,000 ft.

At 15 h 13 min 15, while the thrust was starting to stabilise, the PF positioned the thrust levers in the FLEX/MCT detent. He later explained that he did not place the levers in the TOGA detent so as to avoid too high a pitch-up moment. Simultaneously his pitch-up input on the stick reached maximum (about ¾ of the travel to stop).

The altitude reached a minimum of 3,840 ft QNH. While the thrust stabilised at about 94%, the speed increased. The aeroplane's climb gradient became positive and it pitched up. When it reached 11°, the PF made a pitch-down input for about three seconds, in order to counter the pitch-up moment generated by the engine thrust. This input de-activated the high angle of attack protection, without the PF being aware of it.

Phase 3: End of the event

The pitch and the angle of attack decreased, then stabilised at about 3°. The PF's inputs enabled the speed and the altitude to reach their respective selected values. The crew continued the approach and landed without any further issues.


Phases
①
②
③
ALTITUDE QNH [FT]
SELECTED ALTITUDE (MANUAL) [FT]
VERTICAL SPEED [ft/min]
APPROACH SPEED TARGET [KT]
COMPUTED AIRSPEED [KT]
SIDE STICK POSITION PITCH CAPT. (>0= DOWN) [DEG]
SIDE STICK POS. PITCH F/O (>0= DOWN) [DEG]
1/3 full stop
3/4 full stop
DOWN
UP
LH ELEVATOR POSITION (>0= DOWN) [DEG]
RH ELEVATOR POSITION (>0= DOWN) [DEG]
STABILIZER POSITION (>0= DOWN) [DEG]
ATC information
AOA VALUE EMITTED BY IRS1 (>0= UP) [DEG]
PITCH ATTITUDE (>0= NOSE UP) [DEG]
MCT
CLB
IDLE
THRUST LEVER ANGLE ENG2 [DEG]
THRUST LEVER ANGLE ENG1 [DEG]
N1 ACTUAL ENG2 [%]
N1 ACTUAL ENG1 [%]
ENG
A/P1 ENGAGED (1= ENGAGED)
F/D1 ENGAGED (1= ENGAGED)
15:11:50
15:12:00
15:12:10
15:12:20
15:12:30
15:12:40
15:12:50
15:13:00
15:13:10
15:13:20
15:13:30
15:13:40
15:13:50
UTC (hh:mm:ss)
Activation period of the high angle of attack protection

2 - ADDITIONAL INFORMATION

2.1 General context of the flight

The incident flight was the last flight of a four-day rotation. The two crew members had known each other for a long time before being employed by the operator.

2.2 Managing A/THR in Descent

In OPEN DES mode, the AP controls the vertical flight path so as to maintain a target speed and the autothrust maintains the thrust on IDLE, when A/THR is engaged. Thus, the fact of positioning the thrust lever on IDLE had no effect on the thrust or on the glide path. However, it led to the disengagement of the A/THR, which the PF said he was aware of when he pulled back the levers. It should be noted that the disengagement of the A/THR generates a visual Master Caution warning and a *"Single chime"* aural warning, an amber memo framed for 10 seconds on the ECAM and a mode change on the Flight Mode Annunciator (FMA).

Part A of the operator's Operations Manual (GENOPS) states that any action associated with the A/THR must be called out and checked by the crew. During the event, the PF's decision to position the levers on IDLE and thus to disengage the A/THR was not shared with the PM. The latter not having noticed the disengagement, he wasn't able to question this decision.

In addition, the GENOPS states that if it is necessary to make resources available, it is recommended to *"delegate a part of the workload to the automatic systems or other people, passing on the necessary information"*.

By disengaging the A/THR without calling it out, the PF inadvertently created a degraded crew work environment as well as a mixed *"AP ON A/THR OFF"* flying situation.

2.3 Mixed Flying Situation with "AP ON A/THR OFF"

When the A/THR and the AP are engaged, the A/THR and the AP vertical control modes are linked. When the A/THR is disengaged, the latter no longer adjusts the thrust to control the speed. The thrust has to be managed manually.

Mixed *"AP ON A/TRH OFF"* flying increases the crew's workload. Without any action from them, in ALT mode, the AP temporarily compensates the lack of thrust to maintain altitude at the expense of speed. Thus, there is a risk of forgetting speed management at the time of the change in flight phase between the descent and level flight. That is why flying with the AP engaged and the A/THR disengaged is considered inadvisable by the manufacturer.

This problem had been identified by the manufacturer and the operator. Since the beginning of 2012 that latter launched an awareness campaign on the use of automatic systems, in particular the A/THR, on Airbus-type aircraft. Specific training programmes were programmed in the context of the ECP.

In addition, following five events that gave rise to a crew report (ASR), the airline published a flight safety bulletin on 27 February 2012. The objective was to make crews aware of: *"The trap of mixed flying (AP ON + A/THR OFF), in particular after the partial re-engagement of the automatic systems"*.

Extract from the *"Flash SV"* flight safety bulletin:

> - *Remember: in mixed AP ON A/THR OFF flying, maintaining speed is the responsibility of the PF.*
> - *Mixed AP ON A/THR OFF flying must be avoided: AP ON must mean A/THR ON.*
> - *The PNF/PM's monitoring role is fundamental, in particular in mixed flying or a visual approach. Visual scan must regularly integrate the primary flying parameters (pitch, thrust, speed…).*
> - *Performing a visual approach and/or the looking for conflicting traffic again increases the risk of focusing on the external environment to the detriment of the primary flight parameters.*

2.4 Airline's Action on the Use of A/THR

Following various actions taken by the airline, the rate of overall use of A/THR on landing has progressed. It changed from 5% in November 2011 to 56% one year later according to the airline's flight analysis service.

2.5 Monitoring Primary Flight Parameters and Anti-collision Monitoring

During the event, about thirty seconds passed between the time the speed decreased below the selected speed and the disengagement of the AP. During this time, the crew explained that they focused on looking for an aircraft announced by ATC, to the detriment of monitoring primary flight parameters, in particular the speed, as well as the re-engagement of the A/THR.

The operator had identified this risk and had informed its crews in the flight safety bulletin previously mentioned. The manufacturer recommends that, permanently, one of the two crew members look at the flight instruments. The inadequate coordination between the PF and the PM, as much on monitoring conflicting traffic as on the disengagement of the A/THR, led the crew not to activate the latter.

Finally, the close proximity of traffic announced did not trigger the TCAS warning. The crew thus perhaps over-estimated the real risk of a collision and dedicated all of their resources to this, to the detriment of monitoring flight parameters, in particular the speed.

2.6 Description of the High Angle of Attack Protection (Alpha PROT)

In normal law, when the angle of attack exceeds a threshold called *"Alpha PROT"*, the elevator and the THS change to a protection mode in which the variations in the angle of attack are proportional to the movement of the stick. The commanded angle of attack cannot exceed a limit called *"Alpha MAX"*, even if the stick is pulled to the pitch-up stop. With the stick in neutral, the Alpha PROT high angle of attack protection maintains the angle of attack at an angle close to Alpha PROT.

The manufacturer's Flight Crew Training Manual[8] (FCTM) states that:

- ❒ *"The protection allows the PF to apply a full nose-up input on the sidestick in dangerous situations and thus maintain the best possible lift.*
- ❒ *The input on the sidestick described above is "instinctive" and the high angle of attack protection minimises the risk associated with a stall or loss of control."*

[8] The FCTM is a manual published by the manufacturer and intended for operators. It gives crews practical information relating to operation of the aeroplane.

2.7 Indications of Deceleration and Triggering of the Alpha PROT High Angle of Attack Protection

The aeroplane's deceleration is displayed on the speed scale by a descending yellow bar called the *"SPEED TREND"*.

The triggering of the high angle of attack protection is shown on the speed scale by a striped amber and black zone. Its triggering is not signalled by a specific aural indication.

The automatic disengagement of the AP, which follows exceeding the Alpha Prot angle of attack plus one degree, triggers a Master Warning and a Cavalry Charge warning.

The low energy *"SPEED SPEED"* warning is an aural warning that indicates to the pilot that the total energy of the aeroplane is lower than a threshold below which the thrust must be increased to maintain a climbing flight path. This warning is available in configurations 2, 3 and FULL. It is inhibited above a height of 2,000 ft. During the incident, the triggering conditions for this warning were not met.

2.8 Training and Procedure in a High Angle of Attack Protection Situation

In case of inadvertent entry into high angle of attack protection, the Flight Crew Operating Manual[9] (FCOM) and the FCTM recommend exiting it as fast as possible, as soon as other considerations allow it. These documents specify *"handing over"* to reduce the angle of attack and increase the thrust at the same time.

The FCOM states that to exit the high angle of attack protection:

- The stick must be pushed to more than a half of its forward travel, or
- The stick must be pushed for at least 1 s when the angle of attack is lower than Alpha MAX, or
- The stick must be neutral or pushed for at least 0.5 s when the angle of attack is lower than Alpha PROT.

At the time of the event, initial training as well as the recurrent training and manufacturer's checks included exercises aimed at showing the operation of the high angle of attack protection law in manual flying. However the demonstration of the consequences of the triggering of the high angle of attack protection in a mixed flying situation (AP ON A/THR OFF), when the engines are at idle, was not taught.

[9] The FCOM is a manual published by the manufacturer and intended for operators. It includes descriptions of the systems, operational procedures and performance of the aeroplane.

2.9 Flight Director

The FD consists of two bars that indicate the orders given by the AP. When the latter is not engaged, the vertical bar indicates the trend to follow in lateral control and the horizontal bar that to follow in vertical control.

During the event, the system was in HDG/ALT mode. When the AP disengaged automatically, the FD remained engaged. During the time the high angle of attack protection was triggered, the altitude fell below the selected altitude. The ALT mode being engaged, the FD indicated a pitch-up order in order to reach the selected altitude again.

3 - LESSONS LEARNED AND CONCLUSION

3.1 Crew Coordination

In the absence of a CVR recording, it was not possible to perform an in-depth analysis of crew coordination. However, it seems that it was certainly limited because of a routine approach being established between the crew members, who knew each other well and were on the last day of a four-day rotation. The desire to speed up the descent led the PF to fly in a mixed flying situation with *"AP ON A/THR OFF"*.

This situation did not allow the crew to:

- Notice their failure to engage of A/THR after establishing level flight or to pick up on the lack of management of manual thrust after interception of the 4,000 ft altitude;
- Avoid looking out together during the Traffic Advisory, without any prior consultation.

This coordination was even more necessary since flying was mixed *"AP ON, A/THR OFF"*, while the PM was not aware of it, even though this information was displayed on the FMA.

3.2 Crew's Failure to Notice the Speed Decrease

The preoccupation with searching for the traffic and the increase in workload associated with *"AP ON A/THR OFF"* mixed flying situation led to the two crew members not monitoring the speed. In addition, during the incident flight, there was no aural warning to make the crew aware of the decrease in speed, until the AP disengaged.

3.3 Studies under Way

Following several public transport accidents and incidents linked to loss of control, the FAA identified the need to improve and harmonise warning standards in low-speed situations, for type CS25 aircraft. In 2010 the FAA called on the Aviation Rulemaking Advisory Committee (ARAC) to ask it to study recommendations on additional certification requirements[10]. This study was in two phases. The first allowed a definition of new requirements. The second, still under way, aims to study the possibilities of extending these requirements to transport aircraft that are already operating. EASA was also associated with this work.

[10] http://www.gpo.gov/fdsys/pkg/FR-2011-03-03/pdf/2011-4761.pdf

3.4 Identification of and Reaction to High Angle of Attack Protection

The PF stated that on AP disengagement, his attention was drawn to the speed, but that his priority objective was not to lose altitude. Thus, he increased the thrust (CLB detent) and made a pitch-up input for more than ten seconds. The pitch-up input kept the high angle of attack protection active. This protection limited the PF's pitch-up input to maintain the aeroplane within its flight envelope while minimising the loss of altitude.

The PF did not identify this triggering of the protection and he did not make the connection with the speed scale. The investigation showed that this link was described in the manufacturer's documentation but it did not seem to be highlighted enough during crew initial training or in recurrent training. Crews might thus simply not associate the speed scale information with the triggering of the protection. They were not encouraged to apply the associated procedure to exit it.

3.5 FD Bars

The investigation did not determine whether the PF had followed the FD orders during the incident. In any event, the FD pitch-up orders were consistent with the pilot's intention to maintain level flight. However, the manufacturer's documentation states *"in case of inadvertent entry into the high angle of attack protection, and as soon as the situation at the time allows it, the pilot must exit the protection as quickly as possible, by "handing over" to reduce the angle of attack and by increasing the thrust at the same time"*. The FD's orders were thus consistent with the aeroplane's functional logic, but inappropriate for the low-speed situation.

Generally, when the AP disengages inadvertently (as in this case on the basis of high angle of attack) the relevance of keeping the FD's on should be studied.

3.6 Causes

The incident resulted from the combination of the following factors:

- The PF's pointless decision to position the thrust levers on IDLE in OPEN DES mode, in order to try to increase the rate of descent, which led to a mixed flying situation (AP ON A/THR OFF);
- The crew's limited coordination that led to a lack of thrust management to control the speed while the engines were on idle and the flight was conducted in mixed flying (AP ON and A/THR OFF);
- Both pilots focusing on the external environment, which led to their failure to detect the speed decrease until the triggering of the high angle of attack protection;
- Inadequate training on identifying triggering of the high angle of attack protection.

4 - SAFETY RECOMMENDATIONS

Note: In accordance with Article 17.3 of European Regulation (EU) 996/2010 of the European Parliament and Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation shall in no case create a presumption of blame or liability for an accident, a serious incident or an incident. The addressee of a safety recommendation shall inform the safety investigation authority which issued the recommendation of the actions taken or under consideration, under the conditions described in Article 18 of the aforementioned Regulation.

4.1 DETECTION OF LOW SPEED

The investigation showed that:

- During the incident flight, the crew concentrated on looking for traffic announced by ATC to the detriment of monitoring the primary flight parameters. This risk had been identified a few months previously by the operator, which had informed its crews about it in a flight safety bulletin;
- The crew was only aware of the decrease in speed at the time the AP disengaged. At that moment the speed was lower by 26 kt than the minimum selectable speed (VLS) and the engines were on idle;
- The visual information on the decrease in speed available on the PFD was not noticed by the crew.

During the investigation into the accident to the Boeing 737-800 registered TC-JGE[11], on 25 February 2009, it was shown that the information and warnings available in the cockpit were not sufficient for the flight crew to be aware, at an early stage, of a significant decrease in speed. Consequently the Dutch Safety Board recommended that Boeing, the FAA and EASA evaluate the use of an aural low speed warning as a way to alert the crew (reference: recommendation to EASA NETH-2010-005).

[11] http://www.onderzoeksraad.nl/en/onderzoek/1748/crashed-during-approach-boeing-737-800-amsterdam-schiphol-airport

In addition, the study conducted by the FAA, with which EASA was associated, showed the relevance of the need to improve protection systems to alert crews so as to make it possible for them to anticipate a low speed situation.

Consequently, the BEA recommends that:

- **EASA, in coordination with the other certification authorities, in particular the FAA, develop specifications aimed at making mandatory the systems intended to warn and protect crews from low speed situations in every phase of flight and aeroplane configuration. [Recommendation FRAN-2014-001]**

4.2 Training in Identifying High Angle of Attack Protection in a Mixed Flying Situation (AP ON and A/THR OFF)

The investigation showed that the crew identified an under-speed situation, indicated by the amber band, without connecting it with the triggering of the high angle of attack protection. During the recovery manoeuvre, the crew did not attempt to exit the protection as quickly as possible.

Consequently, the BEA recommends that:

- **EASA reinforce initial and recurrent training programmes in "low speed" flying situations, by improving:**
  - **Monitoring of primary flight parameters;**
  - **Identification and understanding of high angle of attack protection, in particular in a mixed flying situation (AP ON A/THR OFF). [Recommendation FRAN-2014-002]**

4.3 Flight Director Operation Following the Triggering of a Protection

The investigation showed that the orders displayed on the Flight Director indicated a pitch-up order, consistent with the selected mode. However, the manufacturer recommends, in case of inadvertent triggering of high angle of attack protection, as soon as other considerations make it possible, that the pilot exit the protection as quickly as possible by "handing over" in order to reduce the angle of attack, and at the same time increase thrust.

The FD orders were thus consistent with the operating logic of the aeroplane systems, but inappropriate for the low speed situation.

Generally, when the AP disengages inadvertently (as in this case on the basis of a high angle of attack) the relevance of keeping the FD's on should be studied.

During the investigation into the accident to F-GZCP on 1st June 2009, the BEA already recommended that EASA make it mandatory to re-evaluate the operational logic or display on the flight director so that it disappears or displays appropriate orders when the stall warning is triggered. (Recommendation FRAN-2012-048)

Consequently, the BEA completes that recommendation in the context of this report and recommends that:

- **EASA, in coordination with the manufacturer, reconsider the operational logic or display on the flight director so that it disappears or displays appropriate orders when the autopilot disengages inadvertently. [Recommendation FRAN-2014-003]**