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Report A-029/2017

Accident involving a Boeing 737-800 aircraft, registration EI-FJJ, operated by Norwegian Air International, at FL190 in the vicinity of the CLS VOR/DME (Valencia) on 18 October 2017



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DE ESPAÑA

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Notice

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n° 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1., 4. and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

00° 00' 00"	Degrees, minutes and seconds
°C	Degrees centigrade
AEMET	Spain's National Weather Agency
ACAS	Airborne collision avoidance system
ACC	Area control center
ATC	Air traffic control
ATPL	Airline transport pilot license
CAS	Calibrated air speed
CPL	Commercial pilot license
CVR	Cockpit voice recorder
DME	Distance measuring equipment
EASA	European Aviation Safety Agency
FA	Flight attendant
FCOM	Flight crew operating manual
FL	Flight level
fpm	Feet per minute
ft	Feet
g	Acceleration due to gravity
IFR	Instrument flight rules
IR	Instrument rating
kt	Knots
min	Minutes
NM	Nautical miles
PAC	Conflict alert prediction
s	Seconds
STCA	Short-term conflict alert
TCAS	Traffic alert and collision avoidance system
TCAS RA	Traffic alert and collision avoidance system resolution advisory
UTC	Coordinated universal time
VAC	Conflict alert violation
VOR	VHF omnidirectional range

Synopsis

Owner and operator:	Norwegian Air International
Aircraft:	Boeing 737-800, registration EI-FJJ
Date and time of accident:	Wednesday, 18 October 2017 at 13:50 UTC ¹
Site of accident:	Vicinity of CLS VOR/DME (Valencia) at FL190
Persons on board:	Crew: 6 (1 with serious injuries and 1 with minor injuries) Passengers: 178 (uninjured)
Type of flight:	Commercial air transport - Scheduled - International - Passenger
Flight rules:	IFR
Phase of flight:	En route - change in cruise level
Date of approval:	26 February 2020

Summary of accident

On Wednesday, 18 October 2017 at 13:50, the two flight attendants located at the rear of a Boeing 737-800, registration EI-FJJ, operated by Norwegian with callsign IBK1CH, were injured during a flight from Oslo (Norway) to Alicante (Spain).

In complicated weather conditions resulting from a phenomenon called *convective training*, the aircraft, diverted from its initial route, triggered a conflict alert as it approached another aircraft that had been instructed to hold. The conflict was identified by both ATC's short-term conflict alert system (STCA) and by the on-board traffic collision avoidance system (TCAS), which issued avoidance maneuvers. During the execution of these maneuvers, aircraft EI-FJJ recorded swings in vertical acceleration that were consistent with the general convective activity in the area.

These swings caused the two flight attendants to fall, resulting in serious injuries detected afterward.

The investigation has determined that flight attendants 2 and 3 fell as a result of the failure of controllers in two adjacent sectors to plan and coordinate, which led to a conflict alert. While maneuvering to clear the alert, the aircraft entered an area of turbulence.

This report does not contain any safety recommendations.

¹ All times in this report are in UTC.

1. FACTUAL INFORMATION

1.1. History of the flight

On Wednesday, 18 October 2017, a Boeing 737-800, registration EI-FJJ, operated by Norwegian with callsign IBK1CH, took off from Oslo (Norway) en route to Alicante (Spain) with 184 people on board. It was the second and final flight of the day for the crew, which had started its duty period that morning flying in the opposite direction: Alicante - Oslo.

The aircraft took off from Oslo at 10:32:21 and climbed normally to its cruise altitude of FL370 and 260 kt². Toward the end of the cruise phase, the aircraft entered the airspace of the Barcelona ACC via reporting point ANETO, located in the Pyrenees.

The planned route (dashed line in Figure 1) had the aircraft descend on a practically southerly course to Alicante over Valencia, but due to bad weather throughout the east and northeast of the Iberian Peninsula, the crew requested a change in route (solid red line in Figure 1), which ATC authorized.

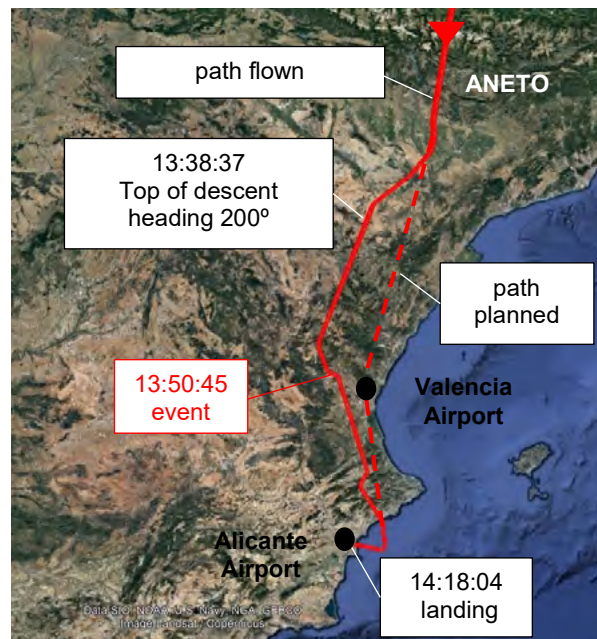


Figure 1. Flight path in the Barcelona ACC airspace

At 13:38:37, the aircraft, already diverted, began its descent at a vertical speed that remained practically constant, around -1700 fpm. The initial course was 200°, with a subsequent turn to heading 163°.

At 13:50:21, 12 minutes into the descent, at 20075 ft, with a selected altitude of FL190 and following ATC's instructions to avoid a conflict with another aircraft, the crew entered 90° as the selected course. The aircraft began the turn at 13:50:28 and two seconds later, at 13:50:30, a TCAS resolution advisory (TCAS RA) was received that lasted 18 s.

² Unless otherwise specified, all speeds in this report are calibrated airspeed (CAS).

The TCAS initially commanded a DESCEND maneuver, which it later changed to LEVEL OFF. While executing these maneuvers, the aircraft increased its bank angle to the left and its vertical speed, and the vertical acceleration recorded swings between 0.81 g and 1.78 g. Between 13:50:40 and 13:50:42, maximum values were recorded for left bank angle (-28°), vertical speed (-3536 fpm) and vertical acceleration (1.78 g), which caused two flight attendants (FA) located at the rear of the aircraft to fall.

At 13:50:49, the TCAS advisories cleared and the aircraft resumed its navigation to the destination airport, where it landed without further incident at 14:18:04.

The pilots became aware of the flight attendants falls after the flight, once they were in the terminal at the Alicante Airport. The injuries of the FA were initially thought to be minor, but it was later discovered that one had a fractured tibia.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal				
Serious	1		1	
Minor	1		1	
None	4	178	182	
TOTAL	6	178	184	

1.3. Damage to aircraft

None.

1.4. Other damage

None.

1.5. Personnel information

1.5.1. Captain

The captain, a 46-year-old Norwegian national, had an airline transport pilot license (ATPL) and B737 300-900 and instrument flight (IR) ratings that were valid until 30 April 2018. He had a total of 8933 flight hours, 3763 of them on the type. He had been working for the operator for 3 months, but he had previously worked for Norwegian Air Shuttle for 6 years and for Luftransport for 9 years.

His activity prior to the flight had been as follows:

- 4 days before the event: rest in Alicante.
- 3 days before the event: Alicante - Hanover. Hanover - Alicante.
- 2 days before the event: Alicante - Oslo. Oslo - Alicante.
- 1 day before the event: Alicante - Helsinki. Helsinki - Alicante.
- Day of the event: Alicante - Oslo. Oslo - Alicante (accident flight).

The operating schedules in the days before the accident had been similar to that of the day of the event, making two long-distance flights every day, starting in the morning at around 07:00. On the day of the event, the first flight had lasted about 3h 30 min. He had flown into and out of the Alicante Airport frequently since 2011.

1.5.2. First officer

The first officer, a 28-year-old Dutch national, had a commercial pilot license (CPL) and B737 300-900 and instrument flight (IR) ratings that were valid until 31 July 2018. He had a total of 2060 flight hours, 1710 of them on the type. His activity on the day of the event had been the same as the captain's.

1.6. Aircraft information

The aircraft, a Boeing 737-8JP, S/N 41148, was registered in Ireland in January 2017. There were no deferred items of relevance to the accident. It had a valid certificate of airworthiness at the time of the event. The aircraft had installed a TCAS II (TTR-921), version 7.1.

1.7. Meteorological information

1.7.1. AEMET's assessment of the meteorological situation

Two cold fronts were traveling across the Spanish mainland from west to east. One of them (of relevance to the flight) exhibited significant convective activity over the east and northeast of the peninsula, with a slowly advancing line of storms (*convective training effect*), causing strong, and in places persistent, rainfall. The forecast condition, according to the significant weather maps, was conducive to convective activity, especially in areas near the front, which after crossing the peninsula, was heading out into the Mediterranean.

Remote sensing images (satellite, lightning and radar) showed that there was significant convective activity in the area at the time of the event. There was a slowly moving structure whose behavior was similar to that of convective training. A characteristic of this structure is the storm cells it generates are propagated in a line such that successive storms are unleashed over said line over the course of several hours.

1.7.2. Dispatch meteorological information

The dispatch information had been compiled on the morning of the day of the flight (03:55), and contained the significant medium/high-level map forecast for 12:00 that was applicable to the return flight, Oslo-Alicante. This map forecast the following for the area of the event:

- Embedded isolated *cumulonimbus* up to FL320.
- Turbulence between FL140 and FL200.
- Moderate icing up to FL140.

1.7.3. Meteorological information displayed on the on-board radar

The information displayed on the aircraft's weather radar was, as per the crew's statement, similar to that shown in the photo in Figure 2 (right display). This photo was taken by the crew 2 minutes after the event, and it shows a radar return that indicates clouds with intense rain and turbulence³.



Figure 2. Photo taken by the crew at 13:53 (2 min after the event)

1.8. Aids to navigation

The information on the navigation aids used during the event has been included with the information on the flight recorders to provide a more complete picture of the event.

³ Rain is shown in red, yellow and green, with red indicating the highest intensity and green the lowest. The magenta indicates strong turbulence.

1.9. Communications

Because the investigation was opened a month after the event, the cockpit voice recording was not available; however, the communications held with air traffic control stations were, and they provided enough information to analyze the event. These communications are presented alongside data from the flight recorders and navigation aids in order to make it easier to follow the event.

1.10. Aerodrome information

Not applicable.

1.11. Flight recorders

This section integrates the information from the aircraft's data recorder, the ATC radar and ATC communications. The event took place at 13:50, but the most relevant events from the 5 minutes leading up to it are also provided due to their significance. Also included are the data from the aircraft involved in the TCAS alert, referred to in what follows as VLG (callsign VLG3968⁴). The accident aircraft is referred to as IBK (callsign IBK1CH) to simplify the description.

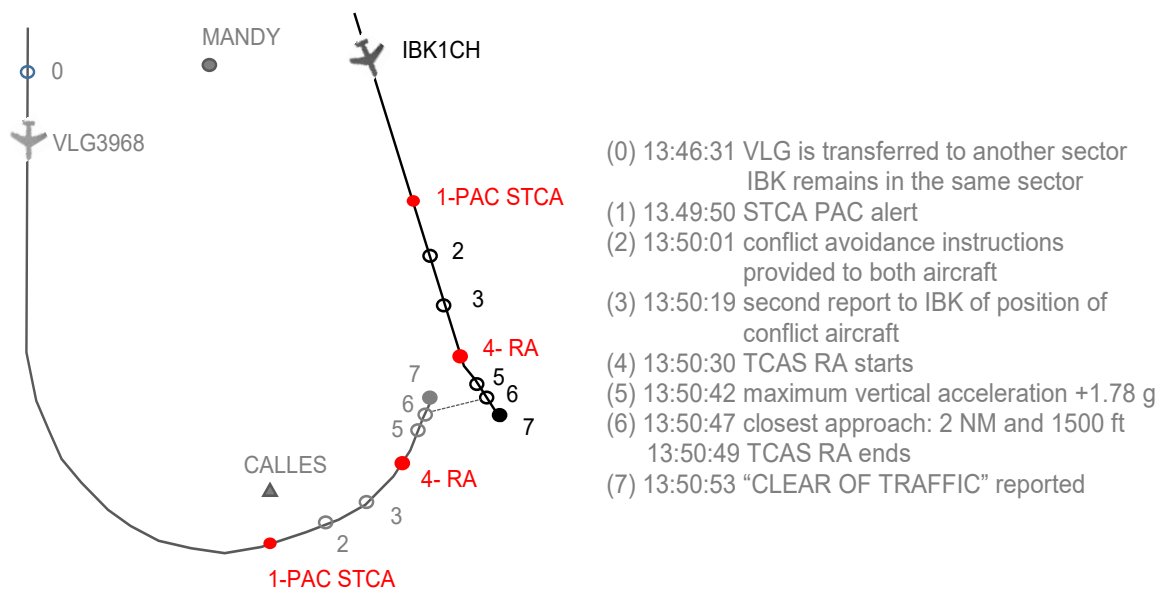


Figura 3. Relative positions of the aircraft during the event

⁴ Vueling A320 from Bilbao to Valencia.

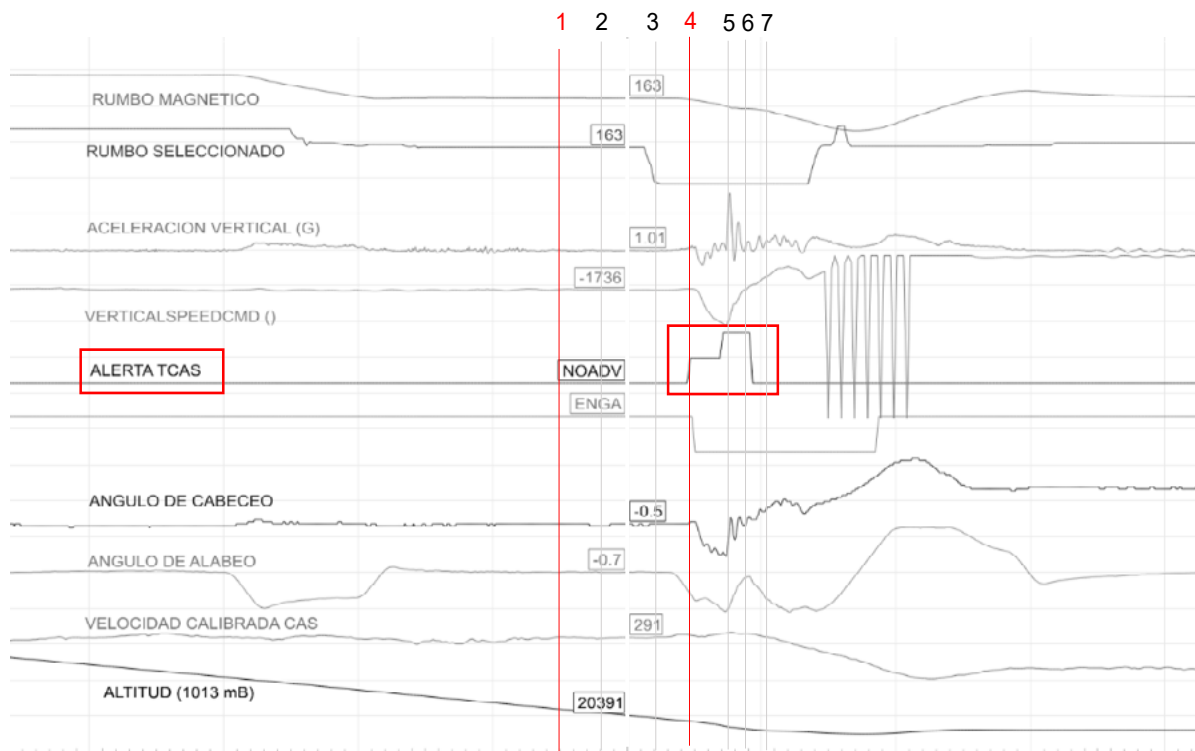


Figure 4. Parameters from IBK during the event

13:45:

The crew of IBK first contacted sector SUW⁵ of the Valencia TACC, as did the crew of VLG, which it would later have the conflict with. Both had deviated from their original routes due to adverse weather conditions.

13:46-13:47 (0):

The SUW sector controller confirmed to VLG, which was descending through FL270, that it could expect runway 12⁶ at Valencia, after which he transferred the aircraft to the lower sector VAP, while it was still in the airspace of sector SUW. Once transferred, the VAP controller cleared it to hold at CALLES and descend to FL150. There is no record of any communication between the controllers of sectors SUW and VAP to coordinate.

IBK, which was also at FL270 and descending to FL190, stayed with the sector SUW controller.

⁵ The sector layout of the area where the event took place was as follows:

- a lower sector (ground-FL145), designated VAP, airspace C, and
- an upper sector (FL145-FL245), designated SUW, airspace C.

⁶ Given the altitude and position of VLG with respect to Valencia, the wait and descent at CALLES was highly likely.

13:49:50 (1):

The STCA PAC⁷ alert between the two aircraft was activated when they were 10.8 NM and 600 ft apart. Both were descending to FL210 (21700 ft and 21100 ft), with VLG above IBK. Each aircraft was in contact with a different sector.

13:50:01 (2):

As a result of the PAC activation, both controllers issued the following instructions to their aircraft to avoid the conflict:

- To VLG (13:49:57): "Turn left 305 and speed up descent to flight level 150". The crew replied they would start the turn and increase their vertical speed.
- To IBK (13:50:01): "Traffic at two of your position, eight miles descending through your level, please turn left heading 090". The aircraft were 8.6 NM and 800 ft (21500 ft and 20700 ft) apart, descending, with VLG above IBK, which did not start to alter its heading until 27 s later.

13:50:13-13:50:14:

At 13:50:13, the aircraft were 7.1 NM and 900 ft (21300 ft and 20400 ft) apart and descending, with VLG remaining above IBK, which was still on heading 163°. The controller amended his previous instruction to VLG to descend and instructed it to hold its current flight level ("Amend instructions and hold FL210, 210"), which the crew immediately acknowledged.

At 13:50:14, IBK informed ATC that "Left 090, this is really a bad heading for us". After this exchange, which lasted 5 s, the crew began to alter their heading as requested, selecting it on the instrument panel. Heading 090° was selected by the crew at 13:50:21, 20 s after receiving the initial instruction from ATC.

13:50:19 (3):

The aircraft were 6.2 NM and 900 ft (21100 ft and 20200 ft) apart, both descending. IBK, which was below VLG, was flying with level wings on heading 163° (although the crew were inputting a new heading) when it received the following communication from ATC:

- To IBK: "Traffic at 2 of your position, 6 miles, crossing from right to left".

⁷ The PAC alert is shown on the Air Traffic Controller screen.

13:50:28

At 13:50:24, IBK recorded an increase in the left bank angle, and 4 s later (13:50:28), it began to change course to the left, with the crew reporting to ATC at 13:50:26: "We are turning".

13:50:30 (4):

- t=0 Activation of the TCAS RA DESCEND DESCEND, which was active for 9 s. The aircraft was 4.5 NM and 700 ft away (20600 ft and 19900 ft) from VLG, which was above IBK. The aircraft was at 292 kt with a left bank angle of 18° and descending at 1656 fpm. The value of the vertical acceleration was in the normal range (1.04 g).
- t=+1 Autopilot and autothrust disengaged. Crew reported "TCAS RA TCAS RA" to ATC.
- t=+2-8 The bank angle and vertical speed increased during this period. The pitch angle increased from -0.4° to -3.2°. Vertical acceleration fluctuated, with maximum values between 0.81 and 1.11 g. At t=8 s, the two aircraft were 2.8 NM and 800 ft apart, with both aircraft descending.
- t=+9 End of DESCEND DESCEND advisory. The aircraft had increased its vertical speed to -3336 fpm and its bank angle was -27.1°. Its speed was 294 kt and the pitch angle had recovered to -0.9°.
- t=+10 Activation of TCAS RA LEVEL OFF, which was active for 8 s. The maximum bank angle, -28.5°, was reached at this time. During the 8 s that the LEVEL OFF advisory was activated, the crew leveled the wings.
- t=+11 Maximum vertical speed of -3536 fpm registered, which would start to decrease from this moment on.
- t=+12 Maximum vertical acceleration recorded: 1.78 g (5). The aircraft were 2.3 NM and 1500 ft apart.
- t=+17 Point of closest approach: 2 NM and 1500 ft (6).
- t=+19 TCAS LEVEL OFF advisory cleared. The aircraft was on course 145° with a bank angle of -9°, a vertical speed of -1448 fpm and a CAS of 293 kt.

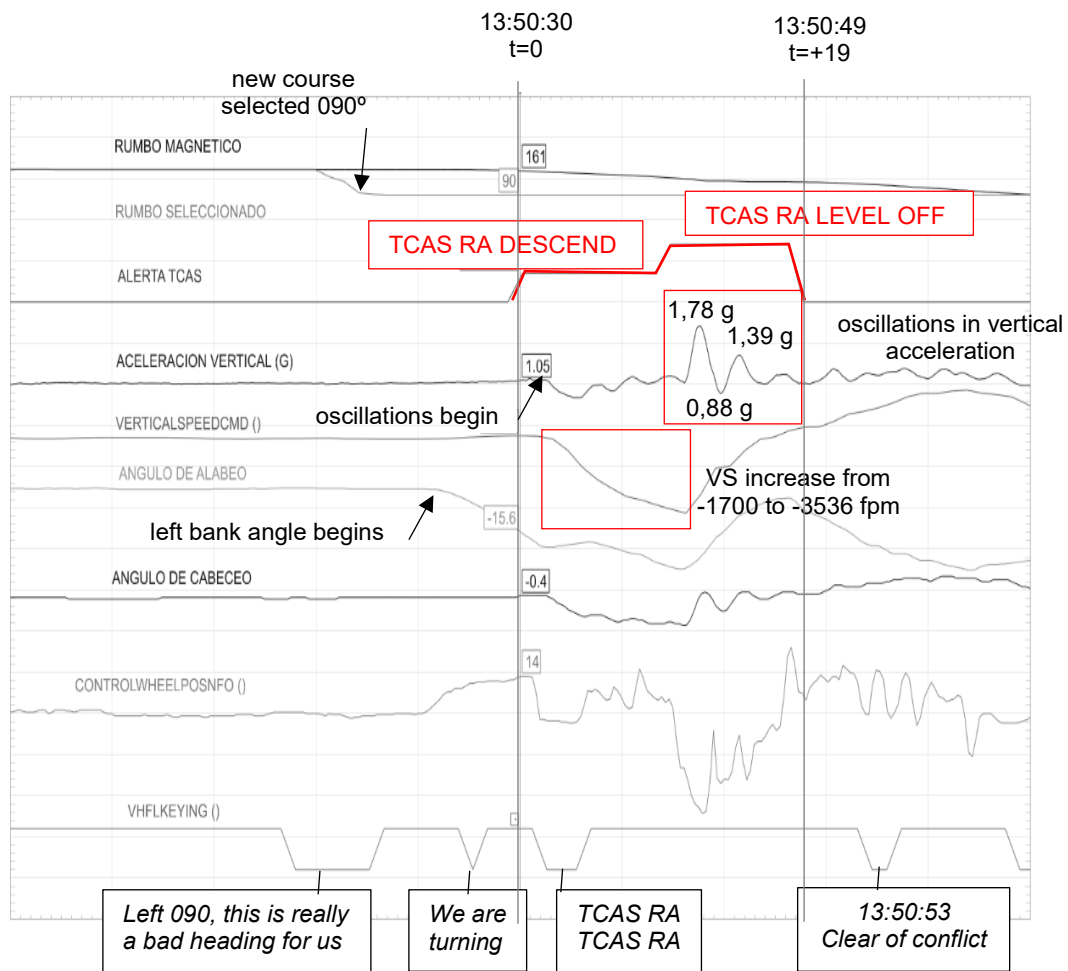


Figure 5. Timeline of TCAS RA

13:50:53 (7):

5 s after the TCAS RA cleared, IBK reported "Clear of traffic" to ATC.

13:51:01

VLG, which had not made any previous reports to ATC, informed ATC they had received an RA.

13:51:03

IBK resumed using the automatic systems after having disengaged them during the TCAS maneuver. The autopilot and autothrust were engaged at 13:51:03 and 13:51:27, respectively. The descent speed was 0 fpm. The rest of the flight was uneventful.

1.12. Wreckage and impact information

Not applicable.

1.13. Medical and pathological information

The fall to the floor of flight attendants 2 and 3 resulted in a fractured tibia, which was diagnosed two weeks after the flight.

1.14. Fire

Not applicable. There was no fire in the aircraft.

1.15. Survival aspects

Not applicable.

1.16. Tests and research

1.16.1. Statement from the captain

In his statement, the captain informed that they had held a briefing before each flight that day. Concerning the weather, he stated that they had information beforehand, but that it turned out to be worse than forecast. He turned on the seat belt sign as they were crossing the Pyrenees and he instructed the flight attendants to remain seated. He also made an announcement for the passengers in this regard.

With ATC's approval, they diverted from their initial route due to the presence of *cumulonimbus*. A few minutes before the event, the captain spoke with the purser and informed her that he would leave the seat belt sign on, but that they could prepare the cabin if they had to.

He saw a traffic on the display and, to his left, a *cumulonimbus* directly on the course instructed by ATC. They carried out the maneuver instructed by ATC as he informed the controller that it was a bad heading for them. The advisories displayed on TCAS were DESCEND DESCEND, then INCREASE DESCENT or MONITOR VERTICAL SPEED (he did not recall which), and lastly LEVEL OFF.

They did not have visual contact with the other aircraft during the accident. He was informed of the injuries to the flight attendants after they had exited the aircraft. The flight attendants exited the aircraft without medical help.

1.16.2. Statement from FA2 (right rear position)

She stated they had had a briefing with the crew before the flight, where they received information on the weather forecast for the flight. She recalled there were clouds when the event occurred. Her position in the aircraft was in the right rear seat.

She was standing, securing the carts and boxes when the event took place. The seat belt sign was on. With the exception of one passenger who had to use the lavatory, the other passengers were seated. Suddenly, a jolt lifted her and she fell to the floor on her left side. She rated the turbulence as strong. They were 12 min out from their destination and it was the last flight of the day, so she decided not to report anything to the FAs located in the front of the cabin or to the pilots at that time. At the end of the day, she went to a doctor, along with FA3.

1.16.3. Statement from FA4 (right front position)

They had had a briefing in Alicante before starting the first flight of the day. She did not recall having been warned of turbulence in the last 30 min of the flight. They were halfway down the aisle, near row 10, with the cart collecting the trash. She was with the purser (FA1). She recalled that the seat belt sign was on and that there were a couple of people standing in line for the lavatory. As for the severity of the turbulence, it was unlike anything she had experienced before. They found out about the injuries to FA2 and FA3 after the passengers deplaned, and recommended that they go to the doctor.

1.17. Organizational and management information

1.17.1. TCAS procedures

The documentation of both the manufacturer and operator contain procedures (in the abnormal maneuvers section) on how to act if a TCAS TA or RA is received. The information of interest to the investigation, taken from the FCOM (*Flight Crew Operations Manual*) and FCTM (*Flight Crew Training Manual*), is provided below:

- For TA:
 - Attempt to identify and locate the traffic.
 - Maneuvering is not recommended as it could reduce the separation.
- For RA:
 - The RA maneuver has priority over ATC instructions.
 - Disengage the autopilot and autothrust.
 - Gently adjust the pitch angle and thrust to carry out the RA maneuver.
 - RA maneuvers only require small changes in pitch angle, which must be executed smoothly and quickly.
 - No sudden or long maneuvers are required. Remember that flight attendants or passengers may not be seated during these maneuvers.

1.18. Additional information

1.18.1. Information on TCAS from Eurocontrol and EASA

On the date of the event, the required standard in Europe was TCAS II, version 7.1⁸. TCAS is independent of similar systems used by ATC (STCA – short-term conflict alert). Its purpose is to provide the final barrier to avoid mid-air collisions between aircraft. It classifies surrounding aircraft as potential intruders and issues two types of alerts: traffic advisories (TA) and resolution advisories (RA), but only vertically, never horizontally. Some data contained in the Eurocontrol *ACAS Guide*, published in December 2017, and in EASA guidelines that are of interest to the investigation are provided below.

The resolution maneuvers in TCAS version 7.1 are designed for:

- Pilot reaction times of 5 s.
- Vertical speeds of -1500 fpm for DESCEND DESCEND advisories.
- If a higher descent rate is needed (-2500 fpm), the advisory will change to INCREASE DESCEND.
- Changes in vertical speed will be carried out with an acceleration of 0.25 g.
- Achieving a descent rate of -1500 fpm from level flight requires a pitch angle of:
 - 6° if the TAS is 150 kt
 - 4° if the TAS is 250 kt
 - 2° if the TAS is 500 kt
- If the aircraft is turning, the turn must be stopped to achieve the vertical speed needed. In fact, controllers should keep in mind that if an aircraft is executing an RA, it will not be able to carry out ATC instructions at the same time. The ICAO, however, specifies that both RA and ATC instructions are to be followed to the extent possible.

A TA is generally issued 10 to 13 s before an RA, although it depends on the geometry, and an RA may be issued without a preceding TA. The same thing happens with similar ATC systems (STCA), which are designed to provide an alert to ATC some 30 s before an RA is issued on-board an aircraft. Sometimes, however, ATC will be alerted after an RA is issued, or an RA may be issued with no alert being issued at all for ATC.

As concerns communications with ATC, the guidelines include a requirement to inform ATC when an RA maneuver is being executed and when the conflict is clear. If an instruction is received from ATC that contradicts an RA, the crew must inform ATC that its instruction is not being followed.

⁸ The TCAS is the implementation of the ACAS concept or standard defined by the ICAO, which is why they are usually referred to interchangeably. ACAS I did not issue RA. ACAS II issued TA and RA, and in the wake of several accidents, version 7.1 has improved some of the RAs that were in previous versions of ACAS II.

1.18.2. Actions taken by ENAIRE after the event

ENAIRE conducted an internal investigation of the event, as a result of which it laid out the following reinforcement measures: include the accident in the training activities to “recall the importance of the use of immediately in evasive maneuvers to convey urgency, the importance of weather-related coordination in sectors of adjacent airspace and to recall the importance of transferring the traffic clear in situations when traffic is diverted due to weather”.

1.19. Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

The fall of flight attendants 2 and 3 on aircraft EI-FJJ on 18 October 2017 during an Oslo-Alicante flight occurred in the following circumstances:

- On the one hand, complicated weather conditions involving strong turbulence due to a phenomenon called *convective training*, which was present in the east of the Spanish mainland.
- On the other, due to the proximity between two aircraft, which led to instructions from ATC to increase separation while also generating a TCAS RA on board the aircraft.

2.1. Meteorology

The weather was a factor during the event, and had an influence both initially and during the event. The weather conditions affected the entire area where the flight was to take place. These conditions had been forecast and were included in all the reports issued. This forecast was correct and on the day of the event, remote sensing images confirmed the very intense convective activity.

The dispatch information provided to the crew for this flight included this information and allowed the crew to adapt the flight to this factor. The request to deviate from the planned flight path indicates that the crew were considering this factor. In addition, the crew monitored the weather throughout the flight using the on-board radar, which confirmed the presence of significant convective activity and storm cells. The crew were engaged in this monitoring activity when the event occurred, as is reflected in the comment that the crew made in response to the left turn that ATC requested. The crew were hesitant to make the turn since it brought them closer to a meteorologically active area.

The swings in the vertical acceleration, which caused the flight attendants to fall, occurred as the aircraft started to make the left turn, thus confirming the presence of the problematic area that had been identified by the crew, as reflected by their reticence in executing the maneuver instructed by ATC.

From the point of view of the passengers, the seat belt sign had been on since entering Spanish airspace, confirming that the weather factor had been anticipated by the crew. Despite keeping this sign on for the passengers, the captain had allowed the cabin crew to stand if necessary. In fact, before the event took place, the vertical acceleration was stable and the cabin crew that had been standing did not suffer any adverse effects. In other words, the preventive measures taken by the crew involving the weather are deemed to have been adequate and proportionate.

ATC was perfectly aware of the weather situation, and controllers had been managing traffic that had diverted precisely for this reason. However, despite being aware of the

general situation, it is difficult to know the exact location of every phenomenon that can affect each of the flights under ATC's control. Such was the case in this event, where ATC instructed an aircraft to turn left, unaware that said turn would bring the aircraft closer to a problem area. The crew also did not report why the turn was unfavorable for them, they simply reported that it was a bad course. If they had explained the reason for their hesitation to carry out the maneuver, ATC may have provided a different instruction.

2.2. Start of the event

The instruction from ATC to turn left was intended to resolve a conflict with another aircraft (VLG). Both had been in the same control sector on parallel headings for more than one minute. When VLG was transferred to the lower control sector, the aircraft were not in conflict. Immediately after being transferred, VLG was instructed by the new controller to hold, which conflicted with the flight path of IBK, thus triggering the sequence of events that followed.

Since VLG was still at FL270 and very close to Valencia when it was transferred to the lower sector, it was very likely that it would be instructed to hold at CALLES, as in fact happened. VLG received this instruction (hold at CALLES) from the controller of the lower airspace while the aircraft was still in the airspace of the upper sector. There is no record of any coordination between the two controllers.

It may be concluded that there was:

- A lack of planning in the transfer out of sector SUW, which was made without considering the likely flight path of VLG.
- A lack of coordination between the VAP and SUW controllers when instructing VLG to hold at CALLES, considering the aircraft was still in the airspace of sector SUW.

The event thus resulted from a lack of planning and coordination between the controllers in adjacent sectors SUW and VAP.

2.3. Conflict detection

The conflict between the two aircraft was identified by the two protection systems: STCA and TCAS. Both worked correctly and in the intended sequence.

The first alert was generated in the STCA 40 s before the RA was generated by the TCAS. This alert was issued when the aircraft were 10.8 NM and 600 ft apart. This period of time (40 s) satisfies the design criteria of the STCA system, which is to provide this alert 30 s before the RA, thus allowing ATC to take measures to try to avoid the loss of separation so the aircraft do not have to execute evasive maneuvers. Since the aircraft were being handled by different controllers, the alert was issued to both, who

handled it simultaneously. The response times from the appearance of the PAC until an instruction was issued to the aircraft were 7 s for VLG and 11 s for IBK.

The instructions included proper evasive maneuvers for both aircraft, although the terminology employed in both cases did not include appropriate information on the urgency and reason for the instructions:

- In the case of VLG, the phraseology did not state that the instruction was due to a conflict with another traffic, or the urgency of the maneuver.
- In the case of IBK, the controller did specify that the maneuver was for conflicting traffic, but the urgency was not specified.

The fact that the two controllers each issued instructions to their respective aircraft involved shows that they were monitoring the progress of the conflicting traffic: in fact, the second instruction to VLG was amended in response to the changing situation. In all, two messages were provided to each aircraft before the TCAS RA was issued.

The resolution instructions provided by ATC to the aircraft were unable to avoid the conflict. The times between the execution of ATC's instructions until the TCAS RA was issued were 33 s (VLG) and 29 s (IBK). The flight paths were not changed during this time. By the end of this period, VLG was starting to change its course and vertical speed, and IBK was just then starting to change its course, since the crew did not select the new heading until 20 s after receiving the instruction from ATC.

The maneuvers of the aircraft did not avoid the conflict and the TCAS issued an RA when the aircraft were 4.5 NM and 700 ft apart. The RA maneuver was executed as per the airline's operating procedures, with the crew disengaging the autopilot and autothrust and adjusting the pitch angle to achieve the descent ordered by the maneuver. The reaction times expected (under 5 s) following the appearance of a TCAS RA were also satisfied in this case. The resulting flight profile was as follows:

- A descent at a rate that reached -3536 fpm.
 - This value exceeded the -1500 to -2500 fpm range recommended by Eurocontrol and EASA guidelines to carry out TCAS maneuvers.
- A descent as the aircraft increased the left bank angle to -28.5° , as a result of the instruction issued 29 s earlier by ATC.
 - As regards the compatibility of banking while executing a TCAS maneuver, EASA and Eurocontrol guidelines state that the bank must be stopped to achieve a descent rate that is as precise as possible. In contrast, the ICAO states that the ATC and TCAS instructions should be followed to the extent possible. The fact that the aircraft was turning could have affected the crew's ability to adjust the descent rate.

The geometry of the two flight paths during the descent maneuver caused the TCAS to issue a new instruction to stop the descent of IBK and level off at its current altitude. This new instruction was executed immediately by the crew, which decreased the descent rate, and the pitch and bank angles. All the RAs cleared after 9 s. The fall of the two cabin crew and the closest point of approach of the two aircraft (2 NM and 1500 ft) occurred during this second stage, after which the aircraft increased their separation as they continued in opposite directions.

As concerns the communications with ATC that are required during a TCAS event (report the execution of an RA, clear of conflict and resuming navigation), they were made immediately by the crew, with reaction times of 1 and 5 s.

3. CONCLUSIONS

3.1. Findings

General:

- The aircraft and crew were on their second and final flight of the day. The previous leg had transpired normally.
- The area where the aircraft was to travel through was affected by very intense convective activity called *convective training*.
- The weather conditions were known to and were being monitored by the crew.
- The aircraft had requested to deviate for weather.

Fall of the flight attendants:

- Flight attendants 2 and 3 fell at the same time as the swings and increases in vertical acceleration.
- Similar oscillations were not recorded before or after the event.
- The flight attendants were standing when the turbulence occurred.
- The seat belt sign was on for the duration of the event.

Start of the event:

- The flight attendants fell while the aircraft was maneuvering to clear a conflict resolution caused by an approaching aircraft in the vicinity of a turbulent area.
- The conflict involved another aircraft that had been instructed to hold at CALLES.
- The other aircraft in the conflict had been transferred to a lower adjacent sector, VAP, even though it was in the airspace of a higher sector, SUW.
- Due to its altitude and position, the other aircraft in the conflict was expected to hold at CALLES and descend.
- The hold at CALLES was in conflict with IBK.
- The instruction to hold at CALLES was issued by the VAP controller without coordinating with the controller of airspace SUW, where the aircraft was still located.
- The two aircraft were under the responsibility of different controllers at the time of the conflict.

Detection of the event:

- The conflict was identified by the STCA 40 s before the TCAS RA was received.
- The two controllers involved identified it and issued evasive maneuvers.
- The maneuvers provided by ATC were unable to prevent the issuance of a TCAS RA.
- The TCAS RA lasted 19 s.
- The execution of the TCAS RA instructions overlapped the execution of ATC's instructions.

3.2. Causes/Contributing factors

The investigation has determined that flight attendants 2 and 3 fell as a result of the failure of controllers in two adjacent sectors to plan and coordinate, which led to a conflict alert. While maneuvering to clear the alert, the aircraft entered an area of turbulence.

4. Safety recommendations

None.