DATA SUMMARY

LOCATION

Date and time	**27 March 2013 at 13:36 UTC[1]**
Site	**Alicante airport (Spain)**

AIRCRAFT

Registration	**EI-DLE**
Type and model	**B 737-800**
Operator	**Ryanair**

Engines

Type and model	**CFM56-7B**
Serial Number	**2**

CREW

	Pilot in command	First officer
Age	**49 years**	**24 years**
Licence	**ATPL(A)**	**CPL(A)**
Total flight hours	**16,500 h**	**960 h**
Flight hours on the type	**8,100 h**	**800 h**

INJURIES

INJURIES	Fatal	Serious	Minor/None
Crew			**6**
Passengers			**175**
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**Commercial air transport – Scheduled – International – Passenger**
Phase of flight	**Take-off**

REPORT

Date of approval	**28th May 2014**

[1] All times in this report are UTC.

1. FACTUAL INFORMATION

1.1. History of the flight

During the take-off rotation from runway 28 at the Alicante Airport, the tail section of the aircraft made contact with the runway. The captain and first officer noted that they had felt something strange and mentioned the possibility of having suffered a tailstrike[2], though they were unable to confirm at the time that it had in fact occurred.

During the initial climb after take-off, the purser called the captain to inform him that her colleagues in the rear of the aircraft had heard a strange noise at the end of the take-off run.

After speaking twice with the flight attendant (FA) and suspecting that the tail of the aircraft had indeed struck the asphalt, the captain decided to halt the climb at FL220 and return to the departure airport. The crew informed ATC of its intentions and suggested that the runway be checked for any debris that may have been left by the airplane. After this message and before the runway could be checked, another aircraft was cleared to take off on the same runway, which it did so without any incident.

The airplane was cleared to commence its descent. While descending through 13,600 ft, the crew, after consulting the QRH, depressurized the cabin, which activated the cabin altitude alarm. The pilot and first officer made use of the oxygen masks until they reached a safe altitude. The approach and landing were made without further incident.

A subsequent inspection revealed marks on the aft part of the fuselage that confirmed the contact with the runway, though the extent of the damage was limited enough that the airplane was dispatched without needing repair.

1.2. Personnel information

All of the crewmembers were based in Alicante and reported to the operator's office at the airport on time. It was their first flight of the day, which would see them fly to Baden-Baden and then return to Alicante.

The captain had flown in the two previous days in the afternoon, on two-way flights from and to Alicante. The day before he had completed his duty day at 19:15. Before these flights he had had three days off. The first officer was returning to duty after four days off. In both cases the total duty time accumulated in the previous month was

[2] This term refers to a situation in which the lower part of the tail cone impacts the surface of the runway on take-off or landing as a result of an excessive nose-up attitude during the rotation or flare.

within the legal limits. Neither one reported any fatigue-related problems and their medical certificates were valid.

In January 2012 the captain had passed a module in the tri-annual refresher training program that reviewed techniques to avoid tailstrikes and the procedure to be used if a tailstrike was suspected. This same module developed into CRM hazard and error management concepts by analyzing an actual tailstrike incident involving one of the company's airplanes.

The first officer completed the type rating course in December 2011 and an integrated SEP/CRM[3] course in November 2012. This second course had also been successfully completed by the four flight attendants[4] in June, September and October 2012.

The tower controller had twenty years of experience as an ATC. He had been stationed at the Alicante tower since 2004. He had worked at four other towers in the AENA network. He had just started his shift for that day.

The route controller, who was the first to gather the information on the problem detected by the crew, had twenty-five years of experience as a controller, six of them in the tower. He had been a transport pilot.

1.3. Aircraft information

The incident B737 has serial number 33587 and a total of 23,744 flight hours. It had an Airworthiness Review Certificate, issued on 9 February 2013 and valid until 8 February 2014, and it had undergone a maintenance inspection on 8 March 2013.

The aircraft has two CFM56-7B engines. This is a constant thrust engine, meaning that the thrust it provides is constant regardless of the ambient air temperature up to a limit of ISA+15°. It has a standard static thrust value at take-off of 26,000 lbs. The engine has two fixed reduced thrust values (24,000 lbs-24K and 22,000 lbs-22K), which can be selected by the crew to prolong engine life if allowed by conditions.

The B737 has four flight spoilers located on the top surface of each wing. In addition to braking the aircraft by increasing drag and reducing lift, they also enhance the bank control provided by the ailerons. When a bank angle in excess of 6° of control wheel input is commanded, the low-wing flight spoilers start to deploy in proportion to the deflection of the ailerons.

[3] Course on safety and emergencies for both flight and cabin crews that integrates CRM (Crew Resources Management) concepts.

[4] The Ryanair B737-800, given its cabin configuration with seating for 188 passengers, requires four flight attendants. The purser (n.° 1) and the most junior FA (n.° 4) were seated at the front of the aircraft, while the other two (n.^{os} 2 and 3) were at the rear. FAs 2 and 3 had seven and five years of experience, respectively.

1.3.1. *Rotation technique and tailstrikes*

The B737 FTCM (Flight Crew Training Manual) chapter on take-off and initial climb provides the appropriate technique to be used on rotation. An optimal take-off and initial climb requires rotating smoothly and reaching a 15° pitch angle. This technique is used to achieve the initial take-off attitude (typically about 8º) in approximately 3 or 4 seconds. A proper rotation rate is between 2º/s and 3º/s.

According to this manual, with the airplane on the ground and the struts fully extended, the pitch angle that results in the tail of the aircraft contacting the runway is 11°. For each take-off configuration (flap position), table 1 shows the corresponding minimum separation margin between the tail of the aircraft and the runway. This margin increases as the flaps are extended. The standard take-off configuration is Flaps 5.

Tabla 1. Excerpt from Boeing FCTM for the 737-800

Flaps	Attitude at Vlof (º)	Minimum tail-runway margin (cm)
1	8.5	33
5	8	51
10	7.6	58
15	7.3	64
25	7.0	73

The manual underscores the importance that starting the rotation at the proper time[5] has on climb performance, noting that rotating before the proper speed is reached can lead to a tailstrike.

Roll control should be minimal at the start of the run and be increased gradually with speed as needed to offset any effects from a crosswind. An excessive roll command during rotation and the first few seconds in the air will cause the spoilers to deploy, increasing aerodynamic drag and reducing lift. This translates into reduced tail-runway separation margins as well as into a longer take-off run and a slower acceleration of the aircraft.

[5] The rotation speed (Vr) is calculated by the crew from performance tables (see Section 1.7.1).

A crosswind is thus one factor that increases the risk of a tailstrike. To combat a strong crosswind situation, the crew can consider using thrust close to maximum take-off thrust, as well as increasing the rotation speed to that associated with the maximum take-off weight. In any event, the crew should try to avoid rotating during a gust and delay the rotation if a gust is detected near Vr.

The B737 has a tail skid mounted on the lower outer section of the tail cone that contacts the runway during a tail strike (Figure 1). This system features a support fairing, a skirt and a shoe. When the tail skid strikes the runway, the skid moves upward and the frangible honeycomb cartridge located inside the skirt may be crushed.

A green and red indicator can be used to visually evaluate the magnitude of a tailstrike and determine when the cartridge has to be replaced (green band not visible).

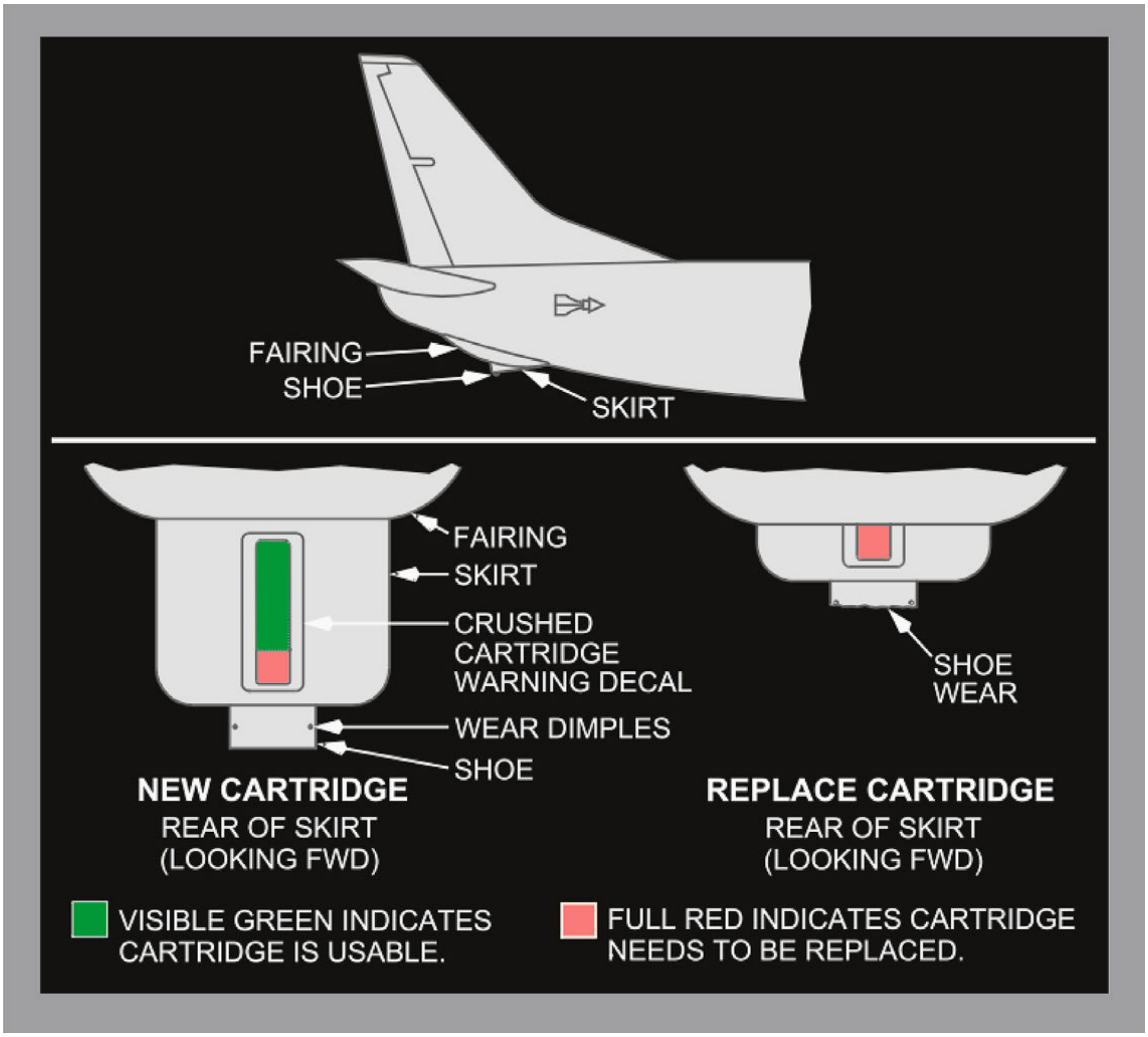

Figure 1. Boeing Flight Crew Operations Manual Tail skid Diagram. Copyright © Boeing September 23, 2010. Reprinted with permission of The Boeing Company

The abnormal operations section in the Boeing 737NG FCTM describes in detail the problems associated with tailstrikes, and lists the following factors as potential triggers for this type of event (Copyright © Boeing June 30, 2013 Reprinted with permission of The Boeing Company):

- Error in the position of the horizontal stabilizer trim.
  Normally results from incorrect take-off data (e.g., weight or center of gravity) or from improperly entering said data into the aircraft (FMS, trim wheel). The crew must use its experience to challenge the reasonableness of the data used.
- Rotating at improper speed. Normally below the speed required as determined by the weight and flap configuration.
- Trimming during rotation. Due to the loss of feel for the pilot flying (PF) that this action entails.
- Excessive rotation rate. Pilots unfamiliar with the aircraft type are particularly vulnerable to this type of mistake. The amount of control input required during rotation depends on the aircraft type.
- Improper use of the Flight Director (FD). The information provided by the FD is only reliable once the airplane is airborne. With the proper rotation rate, the airplane reaches 35 ft with the desired pitch attitude of about 15°. However, an aggressive rotation into the FD pitch bar immediately at take-off can cause a tailstrike.

1.3.2. *Description of the pressurization system and its control panel*

In keeping with the certification regulations for transport airplanes[6], the pressurization system on the B737 guarantees that under normal conditions the cabin altitude does not exceed 8,000 ft at any time during flight. The airplane also has a (visual and aural) warning system that alerts the crew when the cabin altitude exceeds 10,000 ft, in which case the crew is required to use the oxygen masks, since the prolonged lack of oxygen at that altitude can have adverse effects on humans. The certification regulations also specify that oxygen masks must automatically be made available to passengers if the cabin altitude exceeds 15,000 ft. On this airplane model, the masks drop when the cabin altitude reaches 14,000 ft.

Two valves control the bleed air pressure from stages 5 and 9 on each engine compressor. This air is sent through two air conditioning packs before it is routed to the cabin.

Usually, cabin pressure is controlled during every phase of flight by a pressure control system that includes two automatic cabin pressure controllers. Each one alternates as the main controller on each new flight, with the other controller remaining in stand-by in case it is needed. A fault condition is immediately announced by means of a light on the pressurization panel (figure 2, item 1).

[6] FAR (Federal Aviation Regulations) Part 25 (Transport Category) in the USA and EASA CS-25 (Certification Specifications: Large Airplanes) in the EU (former JAR 25).

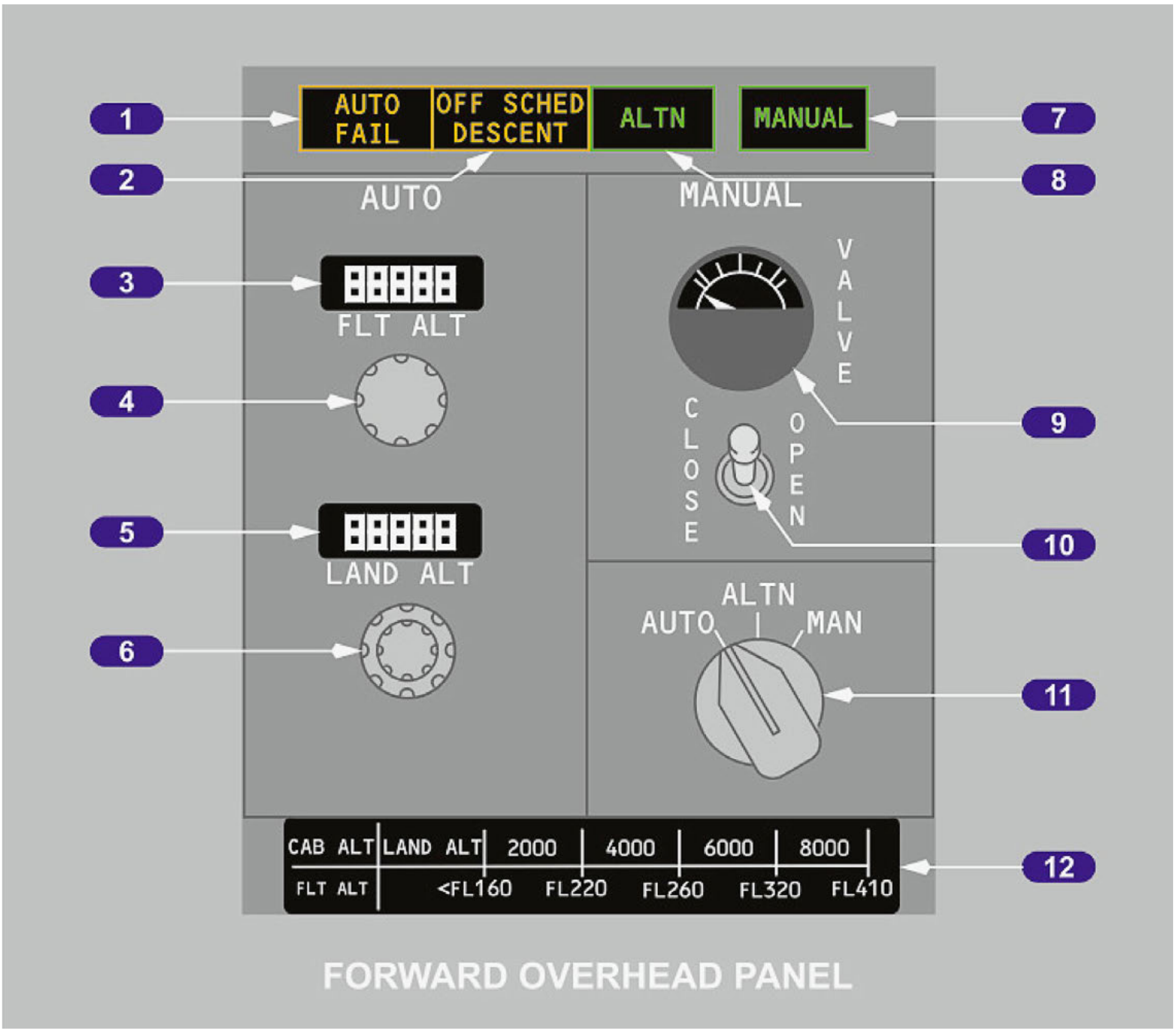

Figure 2. Pressurization system control panel. Copyright © Boeing June 11, 2010. Reprinted with permission of The Boeing Company

Ventilation and pressurization in normal flight conditions are controlled by modulating the opening of the outflow valve either automatically by the active controller when the system is in automatic mode, by the alternate controller if set by the crew or manually if the crew selects manual operation (figure 2, item 11: AUTO, ALTN and MAN modes).

In automatic mode, with the airplane on the ground and the throttle lever fully retarded, the outflow valve opens and the airplane is depressurized (ground mode). As the throttle lever is pushed forward, the cabin starts to pressurize (take-off mode). This makes the transition to pressurized flight more comfortable for the passengers and crew and allows the system to better handle the ground effect during take-off.

In flight the automatic controller adjusts the differential pressure depending on the applicable law for the phase of flight (climb, cruise or descent mode). To do so, the system has to know the planned cruise flight level and the elevation of the destination airport, which must be entered by the crew by using the relevant controls on the pressurization panel (FLT ALT and LAND ALT, items 3, 4, 5 and 6).

During the climb the cabin altitude is increased proportionately to the climb rate within the seleted cabin rate climb limit. Just prior to reaching cruise altitude, cruise mode is activated, which will maintain a constant differential pressure depending on the flight level. Descent mode is activated when the airplane descends just below the value selected as the cruise altitude. Cabin altitude will drop proportionately to a value slightly below that selected for the destination airport (LAND ALT) within the selected cabin rate descent limit.

Upon landing, the controller opens the outflow valve, depressurizing the cabin. Once on the ground, if the system detects a thrust demand at or in excess of take-off thrust limits lasting more than a second and a half the system transitions to take-off mode, restarting the pressurization process.

In general the automatic operation of the system will keep pressure variations in the cabin within a certain limit that can be configured by the operator. In the case of the incident airplane, these limits are 600 slfpm[7] during the climb and 500 slfmp during the descent. These limits are reduced to 350 slfpm during cruise flight and on the ground. The system can, however, exceed these limits in certain cases involving rapid transitions in cabin pressure (when the air conditioning packs are connected or during engine regime changes, for example). The automatic control provides protection against structural damage due to differential overpressure (either positive or negative), which takes precedence over the aforementioned pressure gradient control, whose purpose is to improve passenger comfort.

Manual operation activates the associated green indicating light (item 7). During manual operation, the crew directly controls the movement of the valve (item 10) and monitors its position (item 9). Control of the valve is by means of a spring loaded toggle switch that allows the outflow valve to be controlled to an open, closed or intermediate position. The valve has 119^0 range of travel which takes 20 seconds to motor from open to closed – approximately 6^0 a second. There is no modulation of this rate available to the pilot. Once the toggle switch is activated, the full rate of movement is applied to the valve. Control of the valve position is therefore determined by the length of time that the toggle switch is held in either position.

The crew can monitor the cabin altitude (in feet), its climb/descent rate (in ft/min) and the differential pressure (in psi), all of which are shown on gages installed for this purpose on the cabin altitude panel (figure 3). This panel also has a button to silence the cabin altitude alarm (item 3).

[7] slfm (Sea level feet per minute) is the unit used to measure the variability range for cabin altitude, and corresponds to the pressure gradient equivalent to a climb rate of 1 ft per minute at standard atmospheric pressure at sea level.

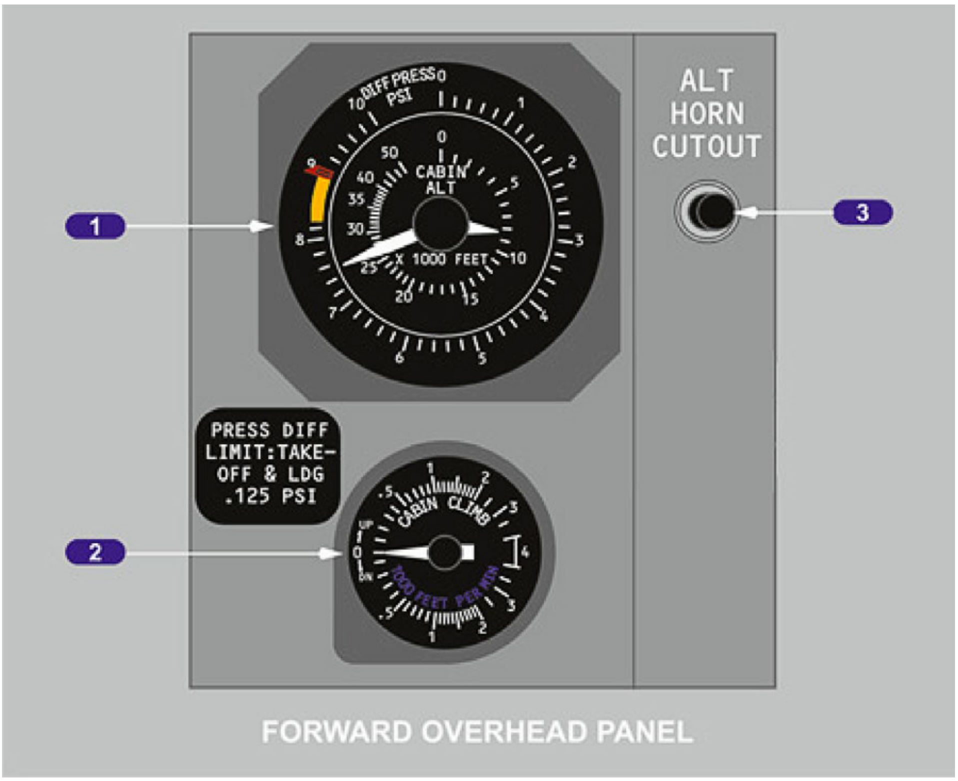

Figure 3. Cabin altitude panel. Copyright © Boeing June 11, 2010. Reprinted with permission of The Boeing Company

As a last resort to avoid structural damage, there are two relief valves that limit the differential pressure between the cabin and the outside to a maximum of 9.1 psi, and another valve that limits the external pressure to 1 psi above the internal pressure (negative differential pressure).

1.3.3. *Procedure after a tailstrike*

The 737NG QRH has a procedure to be used after a tailstrike (Appendix I) [8]. The procedure warns flight crews not to pressurize the aircraft Its main objective is to keep the stresses resulting from pressurizing the aircraft from aggravating any potential structural damage suffered due to the strike and the friction with the runway. To do so, the crew must manually inhibit pressurization by opening the outflow valve and then land at the nearest suitable airport. The Boeing 737NG Flight Crew Training Manual (FCTM) guidance on tail strike events instructs flight crews to accomplish the non-normal checklist anytime a tail strike is suspected or known to have occurred.

[8] The original checklist published by Boeing stated that the condition for executing the checklist was a tailstrike, with no additional stipulations. In 2009 Ryanair modified the list to establish the condition for executing it as the mere suspicion of a tailstrike. The list in the appendix is the company's version.

According to Boeing, about 5% (2 of 43) tailstrikes reported to Boeing in 2011 were detected late, either well into the climb or even during the cruise phase. As a result of this incident, Boeing has initiated a procedure review process aimed at analyzing and, if necessary, improving its applicability in cases like this one. As of this writing, the process was still ongoing.

1.4. Meteorological information

The last aviation routine weather report (METAR) before take-off indicated wind from an average direction of 210° (varying between 170° and 250°) at 11 kt.

The ATIS[9] reported average wind speeds of 13 kt gusting to 23 kt and varying in direction from 200° to 280°.

The 10-minute wind speed readings recorded by the anemometer at the airport around the time of the take-off (13:36) are shown in the following table:

Time (UTC)	Direction (°)	Average speed (kt)	Maximun speed (kt)
13:20	250	13	20
13:30	210	11	19
13:40	180	10	18

1.5. Communications

The aircraft was in normal communications with ATC in both the control tower and in the various terminal control centers in the Valencia area (TACC). The airport tower was in contact with the TACC.

At 13:36 the aircraft, call sign RYR9054, was cleared to take off with a reported wind from 200° at 10 kt. The crew acknowledged the clearance and did not contact the tower again until three minutes later, to sign off and to be transferred to the TACC approach sector.

At 13:39 during its initial contact with the TACC they were cleared to continue climbing to FL120.

[9] Automatic terminal information service. A transmission containing essential flight information that is broadcast automatically so as to reduce the amount of communications on VHF land-air frequencies.

At 13:40 they were transferred to the next sector (route sector), which cleared them to FL220.

At 13:46 the crew requested to hold at FL220 before being cleared to a higher flight level (their cruise level as per the flight plan was FL340).

At 13:50 they contacted the route controller once more to report their suspicion that they may have touched with the tail on take-off (the literal report heard through the interference was, "We may have touched the tail on take-off in Alicante"), and that they wished to return to Alicante so that their maintenance service could check the aircraft. They also suggested that the airport tower be informed so they could have the runway checked for debris from the aircraft. They were cleared to descend to FL130.

At 13:51 the TACC called the airport tower to convey the information received from the aircraft. The approach controller literally said, "they don't know if they impacted or lost something, there must be something on the runway".

The tower controller confirmed receipt of the information and replied that they would check the runway. He then cleared a take-off from runway 28 and informed the ground crew of the need to check the runway for debris.

At the same time the route controller requested more specific information from the crew about their problem, asking explicitly if they had suffered a birdstrike. The crew replied "we suspect a light tailstrike we had... on rotation we had a sudden upset and we heard a noise at the back of the aircraft. So we are not sure about it but we want to be sure before we continue, that's why we want to return to Alicante".

The approach controller contacted the tower once more, informing of the possibility that the aircraft may have struck a bird on take-off ("they felt an impact on take-off... it may have been a bird"). The controller was surprised by the delay in reporting the strike. The tower controller asked about what to do with another airplane that was on approach, to which the approach controller replied that it could land ("send him in, we're not removing him, he's not declaring an emergency or anything").

At 13:55, after clearing the other approaching aircraft to continue with the descent, the tower controller cleared ground personnel to enter the runway and proceed with the inspection.

At 13:56 the approach controller cleared RYR9045 to continue descending below 6000 ft on approach to runway 28 at the crew's discretion.

At 13:58 the signalman reported the runway clear and the tower controller immediately cleared another aircraft, already on final, to land. The controller then asked the runway personnel about the inspection, to which the personnel replied that they had not found anything. The tower controller relayed this to the TACC, who in turn reported it to RYR9054.

At 14:11:45 RYR9054 was cleared to land.

1.6. Flight recorders

The data stored in both the flight data recorder (FDR) and quick access recorder (QAR) were downloaded and then analyzed with help from the manufacturer. The data taken from the FDR were used to reconstruct the rotation geometry, the contribution from relevant parameters and identify the moment when contact was made with the runway. The QAR data were used to reconstruct the cabin pressure conditions and the actions taken by the crew involving the pressurization system.

The most significant parameters are shown in figures 4 and 5.

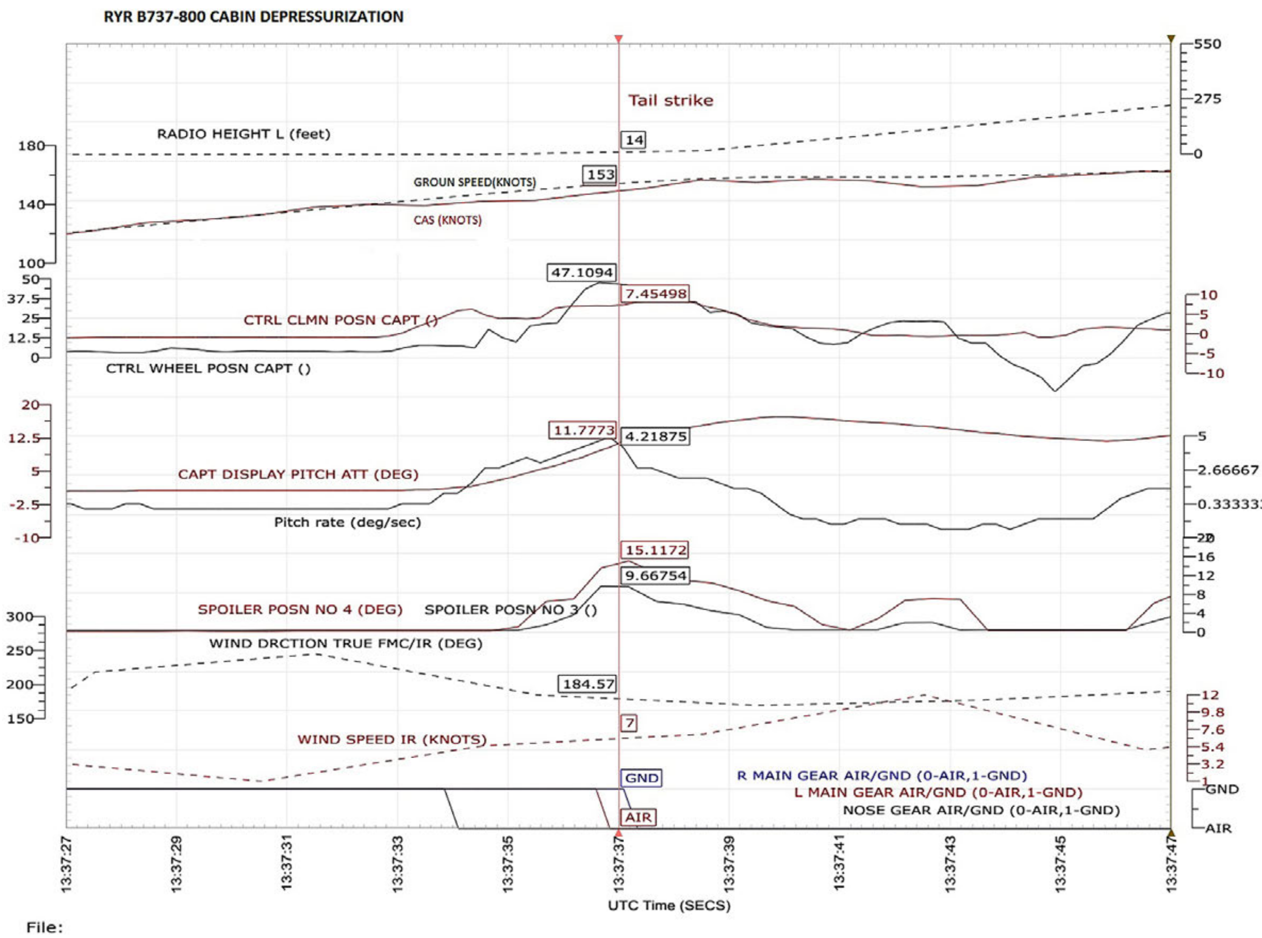

Figure 4. Relevant parameters during the take-off run and rotation

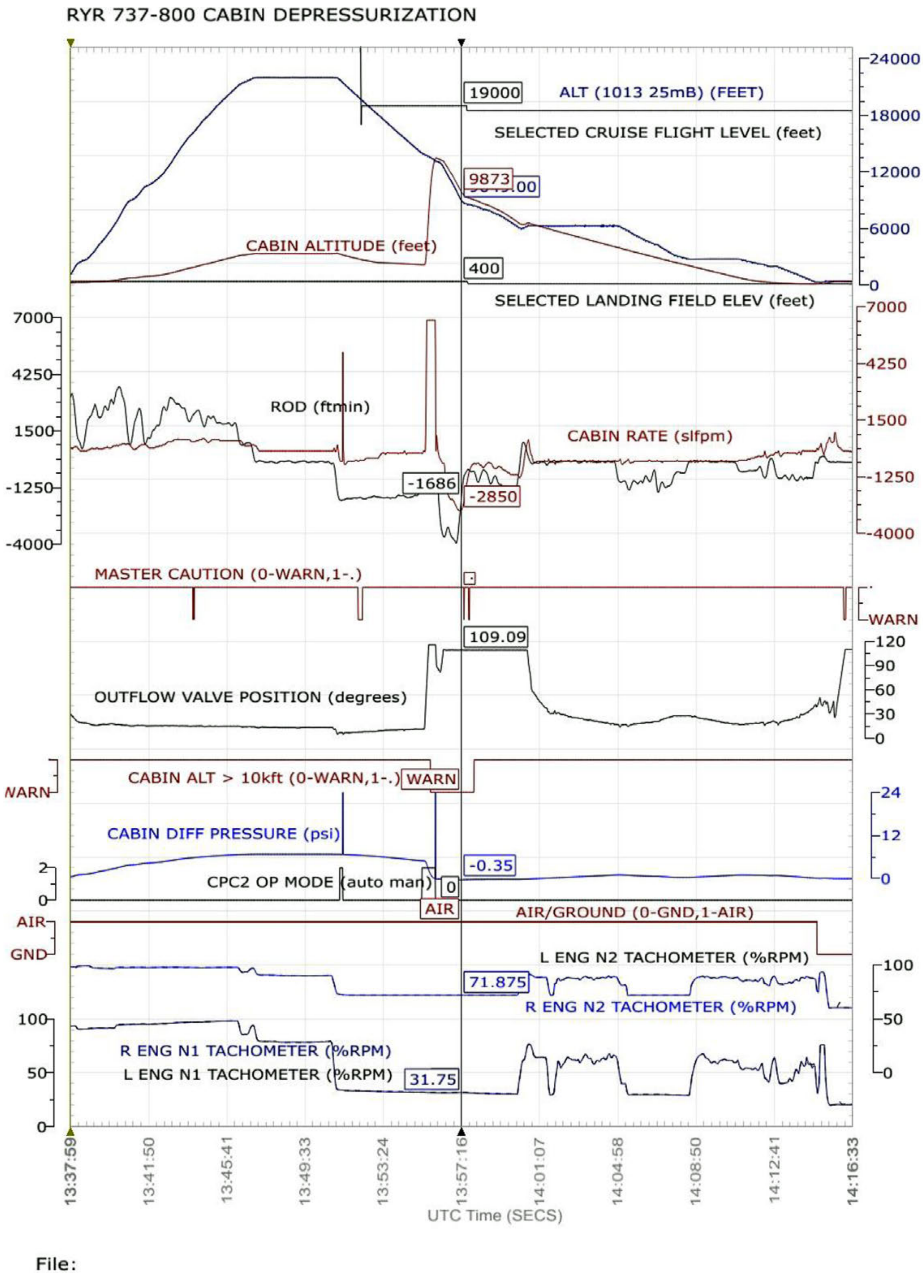

Figure 5. Relevant pressurization parameters

1.6.1. *Parameters during rotation*

According to the FDR data, the airplane was configured with flaps 5 and a horizontal trim tab position of 5.6, which was not moved until the airplane became airborne. The value of N1 reached a maximum of 93% during take-off, associated with a reduced thrust. The FDR recorded a value for the take-off weight of 146,200 lb (66.3 MT).

The wind calculated by the airplane's systems immediately after take-off (ground data are not reliable) indicated a certain left crosswind component, which is consistent with the data provided by ATC and weather services.

The rotation was started at the same time that the airspeed stagnated some 10 kt with regard to the speed trends (for both airspeed and ground speed) present immediately prior during the take-off run. The average rotation rate during the first part of the rotation remained below 3°/s, which later increased to over 5°/s in response to a second input to the elevator control.

The first officer's control inputs were consistent with a left crosswind. During the run the bank control was kept slightly deflected to the left. This deflection increased during the final rotation phase to 48°, which resulted in the left-side spoilers deploying considerably (with the ensuing reduction in lift).

The ground-air transition signal from the main gear legs was activated first on the left side, when the pitch angle was approximately 10°, and then on the right side, with a pitch angle of 11.7°, and therefore in excess of the 11° needed for the tail to strike the ground with the struts extended. The vertical acceleration also reached a local maximum at that time, confirming the tailstrike.

The trends in the parameters once airborne indicate that the airplane continued climbing normally.

1.6.2. *Cabin pressure control system parameters*

The data recorded indicate that the pneumatic and air conditioning systems were configured normally before take-off and remained that way throughout the flight. Both bleed valves were open, the two air conditioning packs were working normally and the pressure in the air ducts was within the normal operating range.

The altitude profile indicates that after take-off, the airplane climbed continuously to 22,000 ft over about 10 minutes. After remaining at that altitude just 4 minutes, it began to descend, leveling off at 6,000 ft. The descent rate was approximately constant (1700 ft/min average) until shortly after the cabin altitude alert was activated, at which time the rate was increased to above –3,000 ft/min, before moderating again once below 9,000 ft.

The rate used during the remaining descent phase below 6,000 ft was normal for an approach (typically between 500 ft/min and 1,000 ft/min).

During the flight, before reaching 14,000 ft descending, the outflow valve operated in automatic mode except for a few seconds just before the start of the descent, when it was placed in manual only to immediately revert to automatic mode. The trend in cabin pressure, its gradient and the position of the valve are consistent with operation in automatic mode. The discontinuity seen in the cabin pressure gradient and differential pressure at the start of the descent is a spurious reading resulting from the transition from manual to automatic mode, and the corresponding momentary loss of information by the controller.

When descending through 20,000 ft, a Master Caution alarm was received. This indication was consistent with the "Off-Schedule Descent" light turning on in the pressurization panel, which happens when a descent is started before the cruising level selected on the panel itself (FL340 on this flight) is reached. The Master Caution alarm was deactivated when the crew selected a different cruise flight level (FL190) that was below their altitude at that time.

At 13,600 ft and descending, the cabin pressure control system was put in manual mode and 8 s later the outflow valve was opened manually to its manual full open position (approximately 115º). This resulted in the cabin pressure altitude going from 2,160 ft to 13,320 ft in barely 30 s. The maximum gradient is unknown, since its value exceeded the cabin pressure controller's maximum recordable cabin rate. The cabin altitude alarm was received when passing through 10,105 ft and remained active until the cabin altitude was reduced to 9060 ft.

Forty seconds after manual mode was selected, the crew reverted to automatic mode. By then the cabin pressure had already equalized with the outside (zero differential pressure). The system initially commanded the valve to close to reduce the cabin altitude (from 13,000 ft at the time). The negative differential pressure was increasing as a consequence of the descent rate (about –3,000 ft/min and rising), which caused the protective measure to activate; namely, the valve returned to its automatic full open position, which allowed the pressures inside and outside the cabin to equalize. The activation of this protective measure overrode the measures that normally limit the cabin pressure gradient, such that this gradient reached a value of –2,900 slfpm. The delay in equalizing the pressures translated into a slight negative differential pressure whose maximum value was limited to –0.37 psi.

When the airplane leveled at 6000 ft, the outside pressure stabilized, allowing the pressure controller to pressurize the cabin by closing the valve and resuming the pressurization regime for a descent to the altitude of the airfield (150 ft) that had been re-selected (from the initial 400 ft) during the previous descent stage. The differential pressure remained positive and less than 1 psi for the rest of the flight.

No new changes were identified in the mode of operation (automatic or manual) during the approach or landing. During the rest of the flight the system's behaviour was consistent with automatic operation. By the time contact was made with the runway, the cabin altitude had decreased gradually to a value slightly below the altitude of the landing airfield. The recorded data indicate a normal transition to the expected pressurization regime on the ground. The system went into take-off mode as a result of the increase in N1 and N2 when the crew activated the reversers. Once in ground mode, the valve opened to equalize the pressure difference.

1.6.3. *Voice recorders*

The downloaded CVR allowed investigators to listen to the conversations held on the flight deck during the event. The times are approximate, the result of synchronizing with the UTC data downloaded from the FDR. The conversations in the cockpit took place in English and Dutch. The English without italics was transcribed literally, and the English in italics is a translation from Dutch with the aid of the Dutch Safety Board (DSB).

The ATIS was tuned in at 13:11.

At 13:31, after starting the engines, the crew executed the Before-taxi checklist, which includes the position of the stab trim (5.6) and the flaps (flaps 5). These same values were repeated for the Before Take-off list a few minutes later.

At 13:37, once lined with the runway, the captain was heard transferring control to the first officer. The increasing engine noise confirmed the application of take-off thrust ("take-off thrust set"). At t = 20 s the 80 kt callout was issued by the captain, followed 10s later by the rotation callout ("V1, rotate"). The speed calculated and recorded at that instant in the FDR was 142 kt.

Twenty seconds after the rotation, the first officer noted the strange way in which they had become airborne *("The way we left the ground was strange, wasn't it?"),* an observation shared by the captain *("Yes, that didn't sound right")*. The captain explicitly mentioned the possibility of a tailstrike *("Do you think we had a tailstrike?"),* to which the first officer replied *"I hope not"*. Then, after cleaning the aircraft, the first officer suggested the possibility of asking the FAs for information, which the captain agreed to before reporting their position to ATC, which cleared them to continue climbing to FL120.

At 13:39, two minutes after take-off and passing through 4500 ft, the interphone rang indicating a call from the passenger cabin. After verifying that the cabin pressure was normal – the differential pressure at that time was 2.4 psi ("2.4 climbing normally"... *"Yes, it looks normal"*), the captain transferred communications to the first officer to answer the call from the purser.

The purser reported that another FA (n.º 3) seated at the rear of the airplane had heard a thud, as if they had touched the runway with the tail. The captain spoke for a few minutes with the FA, who specified that the noise sounded like they had gone over a pothole but with the airplane already in the air. The captain asked her explicitly if she thought they had touched the runway. She could not confirm this, repeating that she had heard the noise very late, possibly with the wheels already in the air. She and her colleague at the rear of the airplane were all right and everything seemed to be working normally.

After the conversation the captain informed the first officer of what the FA had told him, and both agreed that something strange had happened. They agreed to monitor the pressure and that it would be advisable to check the airplane upon arriving at the destination, though the captain underscored that according to the FA, there were no abnormal noises.

At 13:44 the first officer confirmed they were at FL147 climbing to FL220. At the same time the captain expressed his concern over their assigned cruise altitude *("I hope we're not flying high today"),* to which the first officer replied by stating the altitude shown on their flight plan (FL340). When they reached 18,000 ft, the captain read out loud the procedure for a suspected tailstrike. On reaching the item in the procedure that instructed the crew to land at the nearest airport, and after ordering the first officer to hold at their last assigned level (FL220), he decided to talk to the FAs once more.

This time it was FA no. 2 who stated that she had never before heard such a noise and that, though she could not be sure, it in fact had felt as if they had brushed the ground with the tail, "but it was loud to be... It felt like we touch a little bit, I don't know, with the tail, I was our first impression and that's why we call you straight away".

Immediately afterwards the captain informed the FA and the first officer of his decision to return to Alicante. The first officer agreed *("It might not be a bad idea")*.

Again the captain read the checklist out loud, noting that they had to wait to descend below 10,000 ft before depressurizing the cabin (they were already level at FL220). Once again the first officer concurred *("Yes, exactly")*.

After verifying they did not exceed the maximum authorized landing weight[10] (at that moment the aircraft's weight was 65.3 tons, and they estimated they would burn an additional 500 kg of fuel), they contacted ATC to report their suspicions and their intention to return, and to suggest that the runway from which they had taken off be checked for debris (see Communications section).

At 13:51, having just commenced their descent to the flight level cleared by ATC (FL130), the captain suggested they start the items on the checklist *("We should do this*

[10] According to the load sheet, the maximum authorized landing weight was 65.3 tons.

first"). Initially the first officer agreed *("OK, good idea")*, so the captain started reading them out loud ("Pressurization mode selector to manual... Outflow valve... hold in OPEN until..."), but the first officer then asked, *"Do you want to do it now?"* The captain stopped the checklist before opening the valve *("Let's see, there seems to be a trick to it... Let's go back to automatic for now... It's under control")*. Shortly thereafter the captain noted that the "OFF-SCHED-DESCENT" had turned on, which he deemed logical.

During this first descent phase, ATC once more contacted the aircraft to request additional information about the type of impact (see Communications section). The captain also informed the passengers and told the purser that it would be a normal descent with no special requirements.

At 13:55 the first officer informed the captain that they had reached 14,000 ft, and he asked if he wanted to continue with the checklist. The captain replied they would do it right away and not to descend faster than 1,000 ft/min.

He then started reading the full checklist once more. Some seconds after he finished reading it, the first officer noted that they would have to use the oxygen, which was confirmed by the captain, who added that the alarm would sound soon *("It should start sounding any minute now")*. Immediately after the captain confirmed the valve was fully open, the alarm started to sound, lasting for a little over two minutes. As soon as the alarm was activated and after a few comments by both crewmembers, the sound of the oxygen masks was heard, a sound that lasted until the captain confirmed out loud that they were below 10,000 ft. A few seconds later the alarm sound cleared as well.

When they removed their masks, both crewmembers made comments about a possible mistake they had made (Captain: *"[expletive] We shouldn't have done that"*. First Officer: *"No, I have no idea what's going on with this"*).

At 13:58 and 8,500 ft, once they had re-established a moderate descent rate, the purser called the flight deck to see if the pilots were all right and to inform the captain that some passengers had complained of ear aches.

They were cleared to hold to lose altitude, using this opportunity to prepare for the approach by holding the corresponding briefing, checking the weather, the landing weight, the altimeter settings and the FMS data. They also verified that the passengers' masks had not dropped and completed the descent and approach checklists. While waiting they once more questioned what had happened (Captain at 14:01: *"We shouldn't have done that… everything was under control*. First Officer at 14:03: *"[expletive] I wasn't thinking about what I was doing"*. Captain: *"Neither was I, we shouldn't have done it"*). During the wait ATC informed them that the runway had been checked and that nothing was found.

At 14:05, after receiving the ATC clearance, they started the approach from 6,000 ft. The captain then addressed the passengers to inform them they would be landing in five minutes and to apologize for any discomfort that the sudden change in pressure might have caused.

At 14:11:45 they were cleared to land. Shortly afterwards they were heard completing the landing checklist. The various altitude callouts issued by the airplane were also heard, along with the reversers and the transfer of control to the captain at 80 kt when on the ground.

1.7. Eyewitness statements

1.7.1. *Statements from the flight crew*

The captain and first officer stated that the flight preparation was normal. Weather conditions were good, with some wind in Alicante. They both agreed that the first officer would be the pilot flying on the away leg and would thus handle the cockpit preparations, while the captain conducted the walk-around inspection and supervised the refueling.

In keeping with the procedure, the captain was charged with checking the weight and balance calculations provided by the ramp agent and calculating the horizontal stabilizer trim position that was physically set by the first officer. Although the first officer did not check the weight and balance values in detail, he assured that the values are always very similar and that he relied on his experience to detect whether the trim setting calculated by the captain was expected or not. The first officer calculated the operating speeds for take-off using the performance data for the airport in question (see Section 1.9.1). They checked the validity of the values obtained from the performance tables against the data provided by the flight computer (FMS).Both agreed that during the take-off run, the airplane accelerated normally and, once the required speed was reached, made a standard rotation to achieve a 7° pitch angle. At that point they noticed an unusual increase in the rate of rotation until they reached a pitch angle of 15°, at which time they heard a noise. They looked quizzically at each other but did not say anything until after they completed the after-take-off checks. Neither one recalled specifically mentioning the possibility of a tailstrike at that point.

According to the pilot the over-rotation was not commanded by him but rather happened spontaneously. He attempted to compensate by pushing the control stick slightly. He also confirmed that the left crosswind forced him to apply some bank correction during the rotation to maintain the wings level.

They agreed in noting that the reason for the airplane’s abnormal behavior during the rotation could have been due to a gust of wind.

After take-off they continued to climb, retracting the gear and flaps normally. The captain then left the first officer in charge of communications so that the former could gather the flight attendants' impressions on what had happened, in particular those of the FAs who were seated at the rear of the airplane. After an initial enquiry, he contacted them a second time to gather additional information.

During the conversations between the captain and the flight attendants, the first officer continued to climb to the flight level cleared by ATC (FL220).

After speaking to the flight attendants the second time and confirming his suspicions about a possible tailstrike with the first officer, the captain decided they should return. They consulted the tailstrike checklist and decided to delay its execution due to their current altitude and because the procedure required them to depressurize the cabin. They periodically checked the cabin pressure, which was trending normally.

They reported to ATC their intention to return. They were cleared to descend first to FL130 and then to 6,000 ft.

On reaching 13,000 ft, the captain decided to continue with the checklist and proceeded to open the outflow valve manually. During the interview he admitted that his decision had been based on the faulty expectation that the depressurization would be gradual such that the cabin pressure would slowly transition to the outside pressure, a process that, given their descent rate, would not finish until they dropped below 10,000 ft. Both he and the first officer expressed their surprise at how suddenly the depressurization took place.

They reacted immediately to the cabin altitude alarm by donning the oxygen masks. The captain did not feel the need to initiate an emergency descent considering their current altitude (some 12,000 ft according to him). He realized it had been his action with the outflow valve that had triggered the alarm, and that the depressurization system had worked properly so far. Once they dropped below 10,000 ft, he again selected automatic mode. When asked why, he could not give a categorical response and suggested that since it had been his own action that had led to the "problem", he perhaps, somewhat confused, attempted to undo his mistake. The first officer said that the captain had informed him of it and that they were in agreement.

After landing they confirmed the presence of contact marks on the tail cone, which they qualified more as "scratches" than a dent.

Asked explicitly about the checklist, they agreed that it would probably had been optimal if the checklist somehow specified the flight altitude at the time of its execution, making reference to 10,000 ft, and cautioned the crew about aspects such as immediately halting the climb if a tailstrike was suspected and the likely intensity of the change in pressure associated with suddenly and fully opening the outflow valve.

After the incident both the captain and first officer underwent extra simulator sessions aimed mainly at training them on rotation techniques and the factors that can increase the likelihood of a tailstrike, as well as on the operation of the pressurization systems and the manual control of the outflow valve. They also simulated the procedure to be executed if a tailstrike was suspected, though at altitudes below 10,000 ft.

As part of the training received, they stated having been trained specifically on tailstrikes, though as they recalled, in the corresponding simulator scenario the aircraft also stayed below 10,000 ft.

1.7.2. *Statements from the flight attendants*

The flight attendants seated at the front of the airplane (n.os 1 and 4) did not notice anything unusual on take-off.

The two flight attendants seated at the rear (n.os 2 and 3) did hear an unusual sound just as the airplane went airborne and after talking to each other, they decided to inform the purser. When asked about their assessment of the unusual noise at the time, they stated that they were quite sure it had been a tailstrike, although they could not recall if they used that expression when they reported it.

The purser informed the captain, who questioned the flight attendants who were at the rear of the aircraft (n.º 3 first and then n.º 2) over the interphone about what they had felt. It was during the second conversation that the captain informed them of his decision to return without making any specific reference or allusion to an emergency descent. They proceeded to secure the cabin normally and prepared for landing.

Both the FAs and the passengers remarked on the suddenness of the depressurization. The purser, who had a lingering sinusitis due to a cold, stated experiencing severe and persistent pain in her ears and sinuses.

During the disembarkation two passengers who were seated at the rear of the aircraft told the flight attendants who were helping them that they too had heard an abnormal noise during the take-off.

After the incident all of the FAs were replaced by a stand-by crew. The purser was placed on temporary leave.

All of the FAs confirmed that they had been trained on tailstrikes and knew that as part of the procedure they could expect the cabin to be depressurized.

The FAs who reported the problem stated feeling relieved when, once on the ground, it was confirmed that there had in fact been contact with the ground, thus confirming their suspicions. They were worried that they may have been responsible for forcing the airplane to return with no justification.

1.7.3. *Statement from the controllers*

The tower controller said that even though he was aware of the tailstrike phenomenon and its possible effects in terms of the appearance of foreign objects on the runway, at no time was he aware that the airplane might have experienced an event of this type. The runway inspection was in response to a suspected birdstrike. This type of event is relatively frequent, and even though the animal's remains are often deposited outside the runway, it is a frequent cause of unscheduled runway inspections.

When asked about the clearances issued to the two aircraft to use the runway once he was informed of RYR9054's suggestion to inspect the runway, he stated that he felt there were no hazards on the runway because since the take-off of RYR9054, none of the aircraft that had taxied on the runway had reported anything. He also suggested that there may have been a problem with the slot of the aircraft he cleared to take off that demanded that he not delay its departure any further.

During the investigation it was noted that only one aircraft landed in the interval between the take-off of RYR9054 and the call from its crew requesting to return.

The route controller was the first to receive the information on the problem detected by the crew. As a former transport pilot, he was familiar with tailstrikes. Although he had no clear recollection of the event in question, he suspected that he had understood that it had been a birdstrike, which according to him and as stated by the tower controller, is relatively frequent and entails a runway inspection. In keeping with the usual procedure, he relayed the information to his colleague at the approach post so that he could in turn pass it on to the tower.

The approach controller who spoke with the tower was nearing the end of his shift and was turning over to a coworker. He was surprised that the airplane was so far away when it asked to return, given the nature of the problem (supposedly a birdstrike). He was unfamiliar with the term tailstrike per se, though he did know that certain aircraft can strike the runway with their tail on take-off. He recalled having received training on foreign objects on the runway during his initial training as a controller.

The coworker who relieved him was equally surprised at the airplane's delay in returning. He also corroborated the accounts provided by the other controllers as to the frequent nature of birdstrikes on take-off.

1.8. Organizational and management information

1.8.1. *Operating procedures at the airline*

The airline's standard operating procedures (SOP) include a guide for preventing tailstrikes that lists the typical factors, already mentioned, that can cause a tailstrike (improper horizontal stabilizer trim position, rotating at improper speed, excessive pitch angle, rotating during a gust or excessive use of the ailerons). It notes that the probability of a tailstrike is significantly increased with a crosswind in excess of 20 kt. If the first officer lacks experience, in crosswinds 2/3 above the limit (30 kt with a dry runway), the take-off is to be performed by the captain.

The manual notes the faulty perception that many pilots have that the greatest threat in crosswind conditions is to the airplane's directional control, which causes them to overcorrect with the control wheel, increasing the likelihood of a tailstrike.

The procedures manual makes reference to the FCTM as the reference document to be used to understand the phenomenon and learn the techniques to avoid it.

The actions to be carried out by the flight attendants are described in the Safety and Emergencies Manual (SEP).

- The n.º 2 FA (seated at the rear) will contact the n.º 1 FA on the interphone to report the situation.
- The n.º 1 FA, in turn, will inform the captain (via the interphone), providing details such as: the type of sound, any visible damage to the airplane, any abnormal sound (like the sound of air leaking out, indicative of a depressurization).
- The crew will remain seated and await the captain's instructions.

1.8.2. *Airline training*

The airline's training program includes sessions on the tailstrike phenomenon in different scenarios.

As part of the refresher training, which has a three-year periodicity, the flight crews have to take a line-oriented flight training (LOFT) session in which they review the aforementioned take-off techniques contained in the operating procedures, with a special emphasis on taking off in a strong crosswind. During this session crews also review the procedure involved with a suspected tailstrike. The study material for preparing the session discusses the importance of proper information processing and the situational awareness required to properly execute the procedure. It highlights the importance of the aircraft's altitude and the crew's knowledge of the operation of the air system. It also makes special mention of the care that must be taken when operating the pressurization system, and in particular when manually operating the outflow valve and the limits to observe to minimize passenger discomfort. The text explicitly mentions that a single flick in the open direction translates into cabin pressure gradients of 500 ft/min. It also recommends that the subsequent descent, once the airplane is depressurized, use a rate that does not affect passenger comfort.

In the simulator, crews practice taking off in a strong, gusty crosswind where once flight level 070 is reached, the captain is called and informed of a suspected tailstrike by one of the flight attendants. The crew must then carry out the suspected tailstrike procedure and return to the airport of origin.

During the CRM training module on hazard and error management, a real case is studied involving one of the airline's flights in which the crew depressurized the airplane at FL120 after a suspected tailstrike, resulting in a cabin altitude alarm[11].

The airline trains its pilots to handle abnormal situations by using a logical decision process known as PIOSEE[12], which consists of identifying the problem, sharing the relevant information using all available means, identifying the relevant options and risks, selecting the action to be taken, executing it and evaluating the results at regular intervals. As part of the information step, instructors emphasize the importance of ATC communications, noting the importance of using simple messages, speaking slowly and keeping in mind that the controller may not be familiar with the airplane.

The type training given to newly hired pilots also includes simulator sessions that deal with the factors that can lead to tailstrikes and pilots train on the techniques for avoiding them.

The integrated SEP/CRM course given annually to both flight crews and flight attendants also covers the tailstrike phenomenon. The procedure to be followed by the cabin crew is explained in detail in this course, as described in the Safety and Emergencies Manual (SEP) discussed in the previous section. They are also told that the flight crew will proceed to depressurize the airplane (when below 10,000 ft), and that the associated pressure change can cause the ears to pop more than normal.

1.8.3. *ATC procedures*

The Alicante tower, like other ATS stations in the AENA[13] network, has guidelines for ATS personnel to use in an emergency[14]. This document includes the appropriate

[11] The incident occurred in 2008 and was investigated by the Irish investigative authority (AAIU) (see Section 1.7.2).
[12] PIOSEE stands for Problem-Information-Options-Select-Execute-Evaluate.
[13] AENA was the tower control service provider at the Alicante tower on the day of the incident. FerroNATS is now the DGAC-designated provider of this service. As of the writing of this report, a transition process is underway to have the new provider render this service.
[14] PROCEDIMIENTO DE ACTUACION EN EMERGENCIAS Y SITUACIONES ESPECIALES DE LAS AERONAVES [PROCEDURE FOR HANDLING EMERGENCIES AND SPECIAL SITUATIONS ONBOARD AIRCRAFT](S41-02-GUI-001-3.1 de 25 MARZO 2011).

phraseology (in English) as well as the actions that crews expect of ATC and vice versa in these types of situations.

In the section on rejected take-offs, it mentions that this is typically caused by the appearance of foreign objects on the runway or a birdstrike, as well as structural damage, including damage to the tail cone.

Beyond this mention of damage to the tail as a reason for rejecting a take-off, the manual makes no reference to the English term "tailstrike", nor does it consider a situation in which an airplane would have to return for this reason after taking off.

A birdstrike is specifically identified as an emergency and/or special situation. In this case, an emergency or urgency call would be expected, along with a request from the aircraft to return to the aerodrome immediately. The actions to take once an event of this type is reported by an aircraft include checking the runway if the impact took place during take-off.

The training supervisors at the Alicante tower indicated that the term "tailstrike" per se is not used within the training program.

1.9. Additional information

1.9.1. *Airplane dispatch and performance*

Ground personnel calculated the take-off weight (66 MT) and the horizontal stabilizer trim setting (5.1) using the weight and balance sheet provided by the airline for this purpose[15]. No mistakes were detected in the calculations made by ground personnel. They were consistent with the values recorded for the number of passengers, the arrangement of the baggage in the cargo hold and the amount of fuel onboard.

This weight allowed the crew to use a reduced value for take-off thrust (22k), as shown on the associated performance table[16]. This table is also used to obtain the take-off speeds, including the rotation speed, which in this case was 141 kt, a value that matched that annotated by the crew on the load sheet.

[15] The sheet provides the weight and index corresponding to the payload (no. of adult or child passengers, no. of bags and position inside each of the airplane's holds) and fuel onboard. The sum of the resulting values yields the weight and the trim setting that should be used for take-off. These are annotated on the sheet itself, which is signed and given to the crew. The trim setting then has to be corrected by the crew on the same sheet based on the thrust/flap configuration selected. The value obtained in this case was within the allowable limits for the calculated TOW (4.6-6.3).

[16] These are the so-called RTOW charts, which crews use to determine the maximum allowable take-off weight for a specific runway at a given airport that local wind and temperature conditions allow based on the thrust level selected. The tables also give the operating take-off speeds, which include the rotation speed (Vr).

The final value for the trim setting written down by the crew was 5.6, which agreed with the initial value calculated by the loading agent once it was corrected for the applicable combination of thrust and flaps selected (+0.5 for 22 K/flaps 5).

The data downloaded from the recorders confirmed that the calculated values for the flap position, take-off weight, rotation speed and trim setting were properly entered by the crew into the corresponding systems (into the FMC via the CDU and on the flap and trim levers).

1.9.2. *Previous events*

In September 2008 another B737 airplane operated by the airline suffered a tailstrike while taking off from the Dublin Airport. The crew delayed a few minutes in concluding that the airplane had in fact made contact with the runway, during which the airplane continued with its climb. At FL120 the crew depressurized the cabin and manually activated the passengers' oxygen masks, some of which did not drop.

The incident was investigated by the AAIU, the report for which concluded as the probable cause that:

> "The aircraft was depressurized manually at FL120 by the flight crew while carrying out a Non-Normal Checklist (NNC) subsequent to a low-severity tailstrike event."

The same report noted the following contributing factors:

> "1) Allowing the aircraft to climb and pressurize while the nature of the problem was not clearly established."
> 2) Actioning a Non-Normal Checklist without fully appreciating the consequences of such action."

The report included the following safety recommendation, directed at the company:

> "SR14 2009. The Operator should ensure that a module specific to tailstrike events is included at the earliest opportunity in its Ground Training schedule for Flight Crew and Cabin Crew."

In response to this recommendation, in March 2010 the company informed the AAIU that since May 2008, the appropriate techniques for avoiding tailstrikes, including take-off simulations with Flaps 1 (the most unfavorable configuration) had been covered in recurring simulator training, in type training, in the course for promotion to captain and in the line training.

According to the company, the refresher ground training material for pilots was also being updated to include aspects involving the causes, symptoms and consequences of a tailstrike. Cabin crew training was also being revised to include aspects such as recognizing tailstrikes, its consequences, the information needed by the captain and the time available.

All of this new material was added to crew training in May 2010.

As part of the measures adopted in April 2009, the company modified the tailstrike non-normal procedure to explicitly indicate that the suspicion of a tailstrike was sufficient for its execution.

After reviewing the information supplied, the AAIU closed out the recommendation.

2. ANALYSIS

2.1. The take-off and rotation

The crew, using the weight and balance data provided by the loading agent, correctly calculated the rotation speed and the position of the stabilizer trim setting. They opted to perform a reduced thrust (22 K) take-off after verifying that the atmospheric conditions, the runway in use and the aircraft's weight allowed for this kind of take-off. The prevailing wind conditions were far from the 20 kt crosswind threshold that the company's manual regarded as posing an elevated risk of a tailstrike. The manual also did not restrict a first officer with limited experience from being the pilot flying during a take-off under these conditions.

The airplane started the take-off run properly trimmed. Once the calculated rotation was reached (141 kt), the first officer started to rotate with a slight correction to offset the effect of the crosswind. This correction became more evident as the rotation progressed, probably as a result of the first officer's efforts to compensate for the effect of a gust of wind, which caused the left-side flight spoilers to deploy, with the ensuing loss of lift. This bank angle correction was accompanied by a second pull back on the control stick that increased the rotation speed above the maximum values recommended to ensure separation between the tail and the runway.

The FDR data were used to identify the moment of contact with the runway, which took place at the end of the rotation when the pitch angle was in excess of 11° with the right gear still on the ground.

Both the operating manuals and the company's training guidelines give an in-depth analysis of the problems associated with tailstrikes and the factors that can lead to such an event, specifically crosswind and gusts. Both crewmembers had been specifically trained on the take-off technique to use to minimize the risk of a tailstrike.

The actions commanded by the first officer, however, deviated from these recommendations, primarily insofar as the bank correction is concerned. The additional simulator sessions he has received, and where special emphasis was placed on the proper rotation technique, should help him improve his handling of a similar situation in the future.

2.2. Operation of the pressurization system

The limited severity of the impact made it hard to notice at the front of the airplane, and thus for the flight crew to take immediate action. Both the captain and the first officer, who was the pilot flying, noticed something unusual and though they considered the possibility of a tailstrike, apparently both had doubts as to the true nature of what had happened.

The flight attendants seated at the rear of the airplane (and even some of the passengers) closest to the point of contact felt the impact more clearly and, in keeping with the relevant procedure, informed the purser so that she could relay it to the captain. The captain asked them specifically if they thought the airplane might have touched the runway, though they were unable to give a clear and definitive answer. It could be that their concern over interrupting the operation with undue cause might have influenced the way in which they conveyed the information during the flight, since the confidence they showed during statements made after the fact was not evident during their conversation with the captain.

This all served to delay the captain's decision, who needed a second conversation with the flight attendants before finally concluding that the safest course of action was to return to Alicante. This process of analyzing and exchanging information lasted ten minutes, during which the airplane continued to climb, as per the successive clearances from ATC received by the first officer. The crew verified the proper operation of the cabin pressurization system during the climb, but it was not until they were at 20,000 ft that the captain expressed his hope that their assigned flight level was not too high, indicative of his growing concern over the risk that flying any higher would pose. Shortly after they were level at FL220, the captain ordered the pilot to maintain that altitude and not to climb any further.

With the airplane pressurized, the differential pressure, and thus the stresses that the structure has to withstand, increase with altitude (in this case a differential pressure of 6.8 psi was reached at 22,000 ft). This is why the procedure used if a tailstrike is suspected requires the crew act to prevent pressurization of the aircraft, so as to prevent any pressure difference between the inside and outside of the airplane.

Completing of the QRH Tail Strike procedure as intended immediately after takeoff will prevent the airplane from pressurizing. If the completion of this procedure is delayed, the airplane will pressurize normally, if able, during climb, and a depressurization will be required to reduce the differential pressure. While a controlled depressurization below 10,000 ft should not pose any problems, the same cannot be said for higher altitudes where the possible harmful effects caused by the lack of oxygen would force the crew to make use of their oxygen masks, thus increasing their work load. The situation is further complicated above 14,000 ft, where the automatic deployment of the passenger oxygen masks could lead to stress and nervousness, as happened in another event of this type that was the subject of an investigation.

The aircraft must thus be kept from climbing in these situations if at all possible, both to minimize the structural stress and to speed up and simplify the prevention of pressurization required by the procedure.

Even though the importance of monitoring the altitude is highlighted in the guidelines written by the company to aid in training on these situations, there is no explicit mention of interrupting the climb if a tailstrike is suspected. As the captain recalled, and as indicated in the material in the guidelines, during training the tailstrike is reported at FL070, what does not guarantee an altitude above 10,000 ft before the return to the airport of origin is initiated. This is the most likely scenario when the contact with the runway is hard enough to remove any doubts as to what actually happened. This also seems to be the philosophy behind the design of the checklist, which specifically instructs "do not pressurize the airplane" and not to depressurize it, which implies that this list is carried out at the start of the climb.

It is reasonable to wonder whether placing a greater emphasis on this aspect during the training given to the crew would have reduced the crew's delay in interrupting the climb. An explicit reference in the checklist to halting the climb would also be useful when the checklist is consulted at the start of the climb (which was not the case in this instance).

According to data provided by the manufacturer, a non-trivial percentage of tailstrikes is only detected once the aircraft has gained some altitude. In this case the procedure was first checked at an altitude of about 18,000 ft. This probably disconcerted the crew and affected its ability to assess the situation, as happened in the case involving the same airline that was investigated by the AAIU.

Although initially, and after checking the QRH a second time, they agreed to start the descent after executing the items on the list *("we have to do this below 10,000 ft"),* a few minutes later, just as they were starting to descend and in response to a suggestion from the first officer *("we should do this now"),* the captain selected manual control of the outflow valve, apparently intending to depressurize the cabin. He must not have been too sure about the timeliness of the action since when asked by the first officer *("do you want to do it now?"),* he opted to postpone it without giving a clear reason for it *("there's a trick to this... let's go back to automatic for now")* and probably on noticing that the pressurization system was working properly *("it's under control").*

On reaching 14,000 ft (altitude below which the passengers no longer need to use the oxygen masks), the first officer once more mentioned the possibility of starting the non-normal checklist, again in apparent contradiction to what they had agreed upon earlier when they decided they would wait until 10,000 ft. The captain agreed and instructed the first officer to maintain the descent rate below 1000 ft/min, in keeping with the airline's recommendation, which is intended to minimize passenger discomfort during a depressurized descent.

Finally at 13,600 ft (and a differential pressure of 4.9 psi), the captain manually opened the valve, in the mistaken belief, as he himself admitted, that the depressurization would be gradual and that enough time would elapse to overcome the altitude difference before the cabin pressure equalized with the outside at 10,000 ft.

The crew was very aware of the need to depressurize the airplane, but they doubted as to the right time to do it. The checklist as it was written did not help them, since it made no reference at all to the flight altitude or to whether to descend below a certain altitude or not before starting the depressurization. The text in the list is confusing insofar as it speaks of "not pressurizing" an airplane that is already pressurized. The specific training module also does not have crews confront the depressurization requirement above 10,000 ft since in the simulator session the instructor reports the tailstrike at a relatively low flight level.

There seems to be room for improvement then in the way in which a depressurization due to a tailstrike is handled at altitudes above 10,000 ft, both in the procedure itself (the QRH Tail Strike procedure is under review by the manufacturer) and in the training the company gives to its crews.

Although the crew anticipated the altitude alarm *("It should start sounding any minute now")* – they were probably monitoring the gradual increase in cabin pressure – the sudden change in pressure surprised them (both were heard uttering expletives on the CVR) and made them doubt the appropriateness of their actions (Captain: *"We shouldn't have done that"*), creating a climate of uncertainty (First officer: *"I have no idea what's wrong with this now"*).

The checklist requests a full opening of the valve to equalize pressures as soon as possible. The captain completed the opening in 12 seconds without interruption. The cabin needed barely 12 additional seconds to equalize with the outside pressure, causing a change in the cabin pressure that surprised the crew and caused discomfort in the passengers. The purser was particularly affected due to a pre-existing condition.

The simulator does not reproduce cabin pressure conditions, meaning that crews do not experience the feeling of an actual depressurization during training, which complicates their awareness of this parameter and makes it difficult for them anticipate this aspect in an actual emergency.

Following the depressurization (40 s after manual mode was selected and only a few seconds after the cabin and outside pressures equalized), the captain returned the valve to automatic on the pressurization panel. As per the captain's own statement, there was no technical explanation for his decision; rather it was the result of his confusion and his desire to undo the situation that his mistake had caused. This confusion extended to the first officer (both said things such as, *"We shouldn't have done that... Everything was under control"* or *"I wasn't thinking about what I was doing"*).

Concurrent with the return to automatic mode, the crew accelerated the descent rate (to above –3,000 ft/min) in an effort to reach a safe altitude as soon as possible. Under these circumstances, the cabin pressure controller, instead of closing the valve to pressurize the cabin, kept it open so as to avoid the negative differential pressure that the rapid descent was starting to generate. It was not until they leveled off at 6,000 ft that the system commanded the valve closed and the airplane started to pressurize once more.

Although from an aircraft structural integrity standpoint this action is of little consequence (the differential pressure barely reached –0.4 psi during the fastest descent and +1 psi during the remaining of the flight), it still serves to underscore the crew's disorientation, as they seemed to have forgotten the logic behind the depressurization contained in the checklist (avoid structural damage) and instead prioritized a secondary objective like minimizing the cabin pressure gradient, and thus the potential additional discomfort of the passengers during the rest of the descent.

In light of this, the measure taken by the company to complement the two crewmembers' usual training by having them both undergo specific simulator sessions to reinforce their knowledge of the operation and handling of the pressurization system seems appropriate.

Regarded as positive is the captain's concern for the airport's operational safety despite this not being specifically mentioned in the company's manuals. He warned controllers of the potential danger from debris on the runway, in keeping with the importance that the company's training program gives to relaying information between the crew and ATC in abnormal situations.

2.3. Exchange with ATC and the check of the runway

By the time ATC was informed of the problem on the route sector frequency, the aircraft was some 50 NM away from the airport. Thus the captain's suggestion to check the runway was not made directly to the tower. It was first received by the route controller, who passed it on to his colleagues at the approach post, who in turn relayed it to the tower controller.

The route controller did not understand the first message given by the crew ("we have touch the tail") and asked for confirmation that they had been hit by a bird ("birdstrike"). The crew did not answer this query in the negative, instead explicitly using the term tailstrike, though this was not understood by the controller either. In none of the exchanges between the route and approach controllers, or between the latter and the control tower, was this word used. The similar sound of the two words in English (tailstrike versus birdstrike) could have caused the route controller to confuse them.

Of all the controllers involved, only the route controller was familiar with the term tailstrike, though this was apparently due to his previous training as a pilot and not to his training as a controller. The airport tower's training department confirmed that controllers are not taught its meaning. It is also not mentioned in the supporting documentation given to all AENA controllers to help them handle abnormal or emergency situations. There is no mention of the problems involved in tailstrikes either on take-offs or landings, nor of the link between these events and the appearance of foreign objects on the runway. These materials do mention, however, the need to inspect the runway after a reported birdstrike.

In the absence of a more specific exchange between the crew and ATC, this scenario involving the general unfamiliarity with this type of event probably predisposed the ATC personnel (and the route controller in particular) to accept the more probable and more routine birdstrike *("it may have been a bird"),* an event that is discussed in the documentation and that all of them were familiar with.

The tower personnel were thus ignorant of the true nature of the problem and of the possibility that there may have been debris on the runway from an aircraft, which is much more dangerous than the remains of a bird.

The tower controller, suspecting that a birdstrike may have occurred, given the frequency with which crews report such an event and which is of no great consequence to the safety of runway operations, and because no report was made by the aircraft that took off after the Ryanair flight, saw no need to delay the departure of the aircraft at the threshold, which was cleared to take off before the runway was checked. The landing of another aircraft, this one on approach, was also authorized before runway personnel could confirm that the runway was clear of debris (though it is reasonable to think that had anything been found, it would have been immediately reported to the tower).

Though no debris was found given the limited impact between the aircraft and runway, using a runway with debris detached from an aircraft is a potentially hazardous situation that must be avoided at all cost. While tailstrikes are not common, they are also not rare events. The analysis of this incident suggests the need to improve controller knowledge of this type of event and include it as part of the abnormal and emergency situations that ATC personnel might be required to manage.

3. CONCLUSIONS

- The crew properly trimmed and configured the aircraft for take-off based on the weight and balance information received from the loading agent, which was within the maximum limits.
- During the rotation, the pilot flying applied a corrective input to the bank controls of up to 48°, which caused the left-side spoilers to deploy.
- The input to the control column caused the rotation rate to peak at 5°/s, above the recommended value.
- The trend in airspeed over the course of the take-off run and the rotation was consistent with the appearance of a gust of wind.
- Before going airborne, the airplane attained a pitch angle of 11.7° and its tail struck the surface of the runway.
- After take-off the aircraft continued an uninterrupted climb to FL220.
- 20 seconds after takeoff, the flight crew mentioned the possibility of a tail strike but did not action the QRH Tail Strike procedure
- At FL220 the captain selected manual mode on the pressurization panel before immediately reverting to automatic.
- At 13,600 ft the captain opened the outflow valve manually. The ensuing depressurization resulted in a very sudden change in cabin pressure.
- Forty seconds after selecting manual mode, the captain again selected automatic mode on the pressurization panel. The system was kept in that mode until the end of the flight.
- The checklist used by the crew did not mention the effects of the flight level on its execution nor did it recommend halting the climb.
- Ten minutes after take-off the runway was inspected for foreign objects. The result was negative.
- An airplane took off after the airplane warned of the problem and before the runway was checked for debris.
- Another airplane was cleared to land before runway personnel informed the tower that the runway inspection had been negative.
- The limited scope of the contact with the runway allowed the airplane to be dispatched without the need for repair.

4. CAUSES

The tailstrike took place during take-off as a result of an excessive rate of rotation during the final phase of this maneuver, accompanied by a partial loss of lift caused by rotation during a wind gust that contributed to a change in the headwind component and the deployment of the spoilers on the left wing, which deployed due to the magnitude of the control wheel by the pilot flying in an effort to offset the effects of the gust of wind.

The manual opening of the outflow valve by the crew as per the applicable procedure but not promptly following the tailstrike led to the sudden depressurization of the cabin at an altitude of 13,600 ft.

Contributing factors in this event were:

- The flight crew delay in performing the QRH procedure for Tail Strike which per the Boeing Flight Crew Training Manual should be performed when a tail strike is suspected or known.
- The uninterrupted climb during the time it took the crew to conclude that the airplane had in fact struck the runway.
- The failure of the relevant non-normal checklist in the QRH to mention the importance of the flight altitude.

Even though the crew reported the tailstrike to ATC, the tower controller did not recognize the nature of the event and authorized two movements on the runway before it was checked and verified to be free from foreign objects. Two factors contributed to this:

- Deficient communications between ATC and the aircraft.
- The lack of knowledge of the tailstrike phenomenon by the ATC personnel involved.

5. SAFETY RECOMMENDATIONS

REC 27/14. It is recommended that Boeing revise the "Tailstrike" checklist in the B737 QRH and evaluate the suitability of explicitly mentioning the implications of the flight level at which the procedure is carried out and the explicit recommendation to interrupt the climb.

REC 28/14. It is recommended that Ryanair, as part of its training program, emphasize and reinforce the importance of avoiding an increase in flight level insofar as possible whenever a tailstrike is suspected during take-off, as well as the implications that the flight level has on the execution of the associated procedure.

REC 29/14. It is recommended that AENA Air Navigation, as part of the procedure and training on emergency and abnormal situations, include known as "tailstrike events" and explicitly include the implications that this type of event can have on the presence of foreign objects on the runway.

REC 30/14. It is recommended that AENA Air Navigation, as part of the procedure and training on suspected birdstrikes during take-offs and landings, underscore the hazard associated with the presence of foreign objects on the runway and the need to immediately check the affected runway before authorizing new operations on it.

APPENDIX
Checklist contained in the QRH

Tail Strike <>

Condition: A tailstrike is suspected.

Caution! Do not pressurize the airplane due to possible structural damage.

1 Pressurization mode selector . . . . .MAN

2 Outflow VALVE switch . . . . Hold in OPEN until the outflow VALVE indication shows fully open to depressurize the airplane

3 Plan to land at the nearest suitable airport