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AVIACIÓN **C**IVIL

Report
IN-014/2019

Incident involving a Boeing 737-800 aircraft, registration G-TAWA, at Lanzarote Airport on 25 March 2019

GOBIERNO
DE ESPAÑA

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DE TRANSPORTES, MOVILIDAD
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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) nº 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.

Contents

Abbreviations

° ′ ″	Sexagesimal degrees, minutes and seconds
%	Per cent
ºC	Degree(s) Celsius
AMSL	Above mean sea level
AOC	Air operator certificate
ATC	Air traffic control
ATPL(A)	Airline Transport Pilot License (aircraft)
CAA	Civil Aviation Authority
CAT	Category
CCI	Crew and Company Information
CPL(A)	Commercial aircraft Pilot License
DME	Distance Measuring Equipment
EGKK	ICAO code for London Gatwick Airport
EGPWS	Enhanced Ground Proximity Warning System
FAF	Final Approach Fix
FCOM	Flight Crew Operating Manual
FL	Flight level
ft	Feet
ft/min	Feet/minute
FMC	Flight Management Computer
FO	First Officer
GCRR	ICAO code for Lanzarote Airport
GPWS	Ground Proximity Warning System
h	Hours
hPa	Hectopascal
IAC	Instrument Approach Chart
IF	Intermediate Fix
IFR	Instrumental Fight Rules
ILS	Instrument Landing System
IR(A)	Instrument Rating (Aircraft)
km	Kilometers
kt	Knot(s)
LIFUS	Line Flying Under Supervision
LNAV	Lateral Navigation
LTC	Line training captain
LTE	Identification of the DVOR/DME at Lanzarote Airport
m	Meters
MAPT	Missed-approach point
MCP	Mode Control Panel
MDA	Minimum Descent Altitude

METAR	Aviation routine weather report (in aeronautical meteorological code)
NDB	Non-directional radio beacon
NNE	North-northeast
NM	Nautical mile
ICAO	International Civil Aviation Organisation
OCA/H	Obstacle Clearance Altitude/Height
PAPI	Precision Approach Path Indicator
PBN	Performance-based navigation
PF	Pilot flying
PFD	Primary Flight Display
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RNP	Required Navigation Performance
RWY	Runway
STAR	Standard Terminal Arrival Route
TAF	Terminal Aerodrome Forecast
TAWS	Terrain Awareness And Warning System
UTC	Universal Time Coordinated
VMC	Flight Visual Meteorological Conditions
VOR	VHF Omnidirectional Range
V/S	Vertical Speed
VSS	Visual Segment Surface

Synopsis

Owner:	Yamasa Sangyo Co Ltd
Operator:	TUI Airways Ltd
Aircraft:	Boeing 737-800, registration G-TAWA
Date and time of incident:	25 March 2019, 13:47 h[1]
Site of incident:	Lanzarote Airport (GCRR)
Persons on board:	7 crew members and 181 passengers, unharmed
Type of flight:	Commercial air transport - Scheduled - International - With passengers
Phase of flight:	Approach - Final approach
Type of operation:	IFR
Date of approval:	28 October 2020

Summary of incident

The aircraft was flying from London Gatwick Airport (EGKK) to Lanzarote Airport (GCRR).

The flight crew was making the VOR A approach to land on runway 21 at Lanzarote Airport. When the aircraft was on the final approach segment, 4.75 NM DME LTE[2] and at 1280 ft of altitude, a "PULL UP" warning was emitted by the Enhanced Ground Proximity Warning System (EGPWS). The flight crew continued the descent in manual flight mode, and the aircraft landed without further incident.

The occupants of the aircraft were unharmed, and the aircraft did not sustain any damage.

The investigation has concluded that the incident was caused by an incorrectly executed approach to Lanzarote Airport.

[1] All times used in this report are local time, which coincides with UTC.

[2] Equivalent to 4.35 NM from the threshold of runway 21. The DME LTE is located approximately 0.4 NM from the threshold.

1. FACTUAL INFORMATION

1.1. History of the flight

On 25 March 2019, aircraft B-737-800, with registration G-TAWA, was flying from London Gatwick Airport (EGKK) to Lanzarote airport (GCRR), with 188 people on board (2 pilots, 5 cabin crew and 181 passengers).

The captain was the pilot at the controls.

At 13:36:54 h, the aircraft was cleared to make "the direct VOR A approach to runway 21" at Lanzarote airport.

After passing the TUXAM intermediate approach fix (IF), the aircraft continued flying the instrumental procedure towards the final approach fix (FAF).

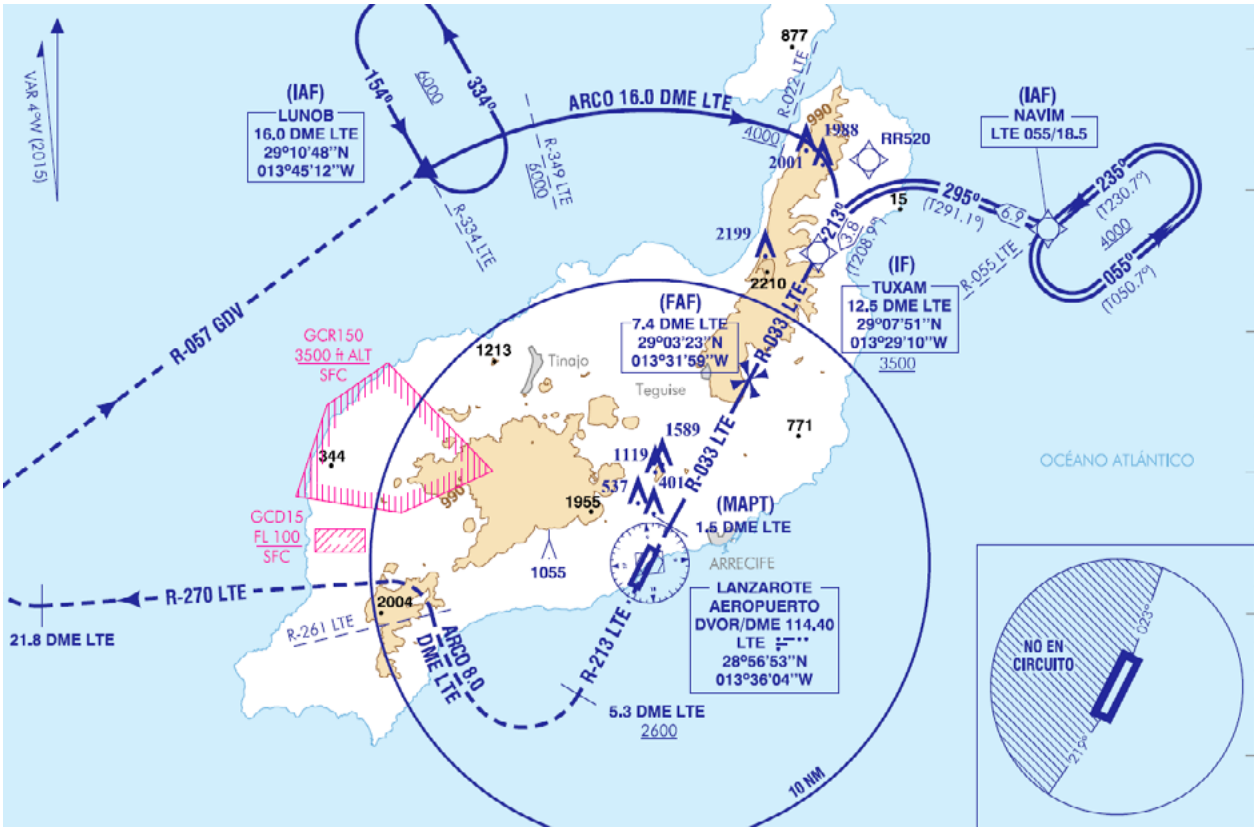


Illustration 1: Plan of the VOR A approach to Lanzarote Airport

At 13:45:00 h and 11.75 NM DME LTE, the aircraft was configured for landing with the landing gear deployed, flaps at 30°, and was descending through 3648 feet towards 2800 feet, which had been selected in the altitude window of the MCP[3].

[3] The pilot uses the MCP or mode control panel to programme the autopilot to perform selected actions. When an altitude value is entered in the MCP altitude window, the autopilot will maintain the aircraft at the selected value on reaching it.

According to the flight crew, when they reached mile 10 DME LTE (i.e. 10 NM from it), the terrain, obstacles and airport environment were in view.

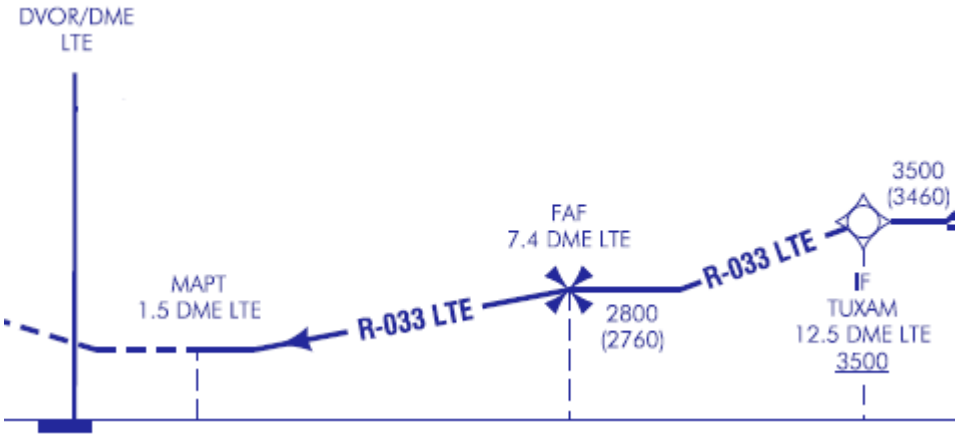


Illustration 2: Vertical profile of the VOR A approach to Lanzarote Airport

When the aircraft was at mile 9.5 DME LTE and descending through 3136 feet, the flight crew selected the MDA rounded up to the higher hundred of 2100 feet in the MCP altitude window.

They continued the approach, and at mile 8.75 DME LTE, the aircraft descended below the 2800 feet minimum altitude established for the approach section between the intermediate and final approach fix. They continued their descent.

When the aircraft reached an altitude of 2112 feet at mile 7.5 DME LTE, the flight crew selected 1400 feet in the MCP altitude window. As the aircraft continued its descent through 1920 feet at mile 6.75 DME LTE, the flight crew selected 1000 feet in the MCP altitude window.

At 13:47:27 h, when the aircraft was at 5.25 NM from the DME LTE, the enhanced ground proximity warning system (EGPWS) sounded the "CAUTION TERRAIN" alert. When the aircraft was 4.75 NM from the DME LTE, the "TERRAIN, TERRAIN, PULL UP" warning was also activated.

Having made positive visual verification that no obstacles or terrain hazards existed, and given that they were flying under daylight VMC conditions, the flight crew continued with the approach. They disconnected the autopilot and autothrottle, the aircraft halted its descent, levelled up, and later resumed the descent following the correct profile. The aircraft landed without further incident on runway 21 at 13:49:33 h.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Other
Fatal				
Serious				
Minor				N/A
None	7[4]	181	188	N/A
Total	7	181	188	

1.3. Damage to the aircraft

No damage sustained.

1.4. Other damage

No other damage sustained.

1.5. Personnel information

1.5.1 Information on the pilot

The 43-year-old British captain had an airline transport pilot license for aircraft, -ATPL(A)-, with B737 300-900/IR/PBN ratings, valid until 29 February 2020.

He had a Class 1 medical certificate valid until 10 August 2019.

1.5.2 Information on the co-pilot

The 34-year-old British co-pilot had a commercial pilot license for aircraft, -CPL(A)-, first issued on 22 November 2011. He had B737 300-900/IR ratings, among others, valid until 29 February 2020.

He had a Class 1 medical certificate valid until 01 April 2020.

1.5.3 Regarding the composition of the crew

The co-pilot was carrying out the required hours of line flying under supervision (LIFUS). During this phase, which is a normal part of the pilot training process when accessing an operator, the co-pilot under supervision performs all of their co-pilot duties under the tutelage of a Line Training Captain (LTC).

The captain was appointed as an LTC in October 2008 and was supervising the co-pilot in the line flying stage of his training.

[4] Two flight crew and five cabin crew.

1.5.4 Crew's previous experience of performing the VOR A instrumental procedure at Lanzarote Airport

The captain stated he had performed the approach once previously but that it was "years ago".

1.6. Aircraft information

The Boeing 737-8K5 aircraft, with registration G-TAWA and serial number 37264 was registered with the UK Aircraft Register on 27 April 2018.

It had an airworthiness certificate issued on 1 May 2018 and valid until 30 April 2019.

1.6.1 Description of the GPWS system installed in the aircraft

The G-TAWA aircraft was equipped with an Enhanced Ground Proximity Warning System manufactured by Honeywell; specifically, it was a Honeywell MK V, with part number 965-1690-055. Among other things, the system is designed to prevent collisions by issuing warnings that alert the crew to terrain proximity.

Annexes V and IX provide more detail on the system's operating modes and the audible and visual alerts it emits.

During the approach, the following warnings were activated: "CAUTION TERRAIN" and "TERRAIN, TERRAIN, PULL UP".

- The system issues the "CAUTION TERRAIN" warning when the aircraft is between forty and sixty seconds before the projected impact with the ground.

- The system issues the "TERRAIN, TERRAIN, PULL UP" warning when the aircraft is between twenty and thirty seconds before the projected impact with the ground.

1.7. Meteorological information

1.7.1 General meteorological conditions

At medium and high levels, there was an isolated depression located in the west of the Canary Islands, with temperatures below -20 °C and 500 hPa in its interior. The associated frontal jet stream was traversing the islands. There was a deformation line over the Peninsula. To the north of the line there was a north-east circulation bordered by a ridge situated between France and the Cantabrian Sea. To the south, there was a sub-tropical-originating system located in front of the depression's frontal ridge. At low levels, there was an Atlantic anticyclone centred to the south-west of Ireland that extended over much of the Iberian Peninsula, the western Mediterranean and North

Africa. Low pressures over the Canary Islands, with several secondary systems between the islands and Africa, and a weakened front passing over the archipelago. Stable atmosphere over the Peninsula and the Balearic Islands. The front was producing precipitation and isolated storms as it passed over the western Canary Islands. Easterly winds in the Strait of Gibraltar.

1.7.2 Meteorological conditions in the area of the incident (13:47 UTC)

According to the METAR data, at the time of the incident, the conditions at Lanzarote Airport were as follows:

METAR GCRR 251230Z 20011KT 9999 FEW030 22/16 Q1008=
METAR GCRR 251300Z 21012KT 9999 FEW026 SCT035 21/15 Q1008=
METAR GCRR 251330Z 21012G25KT 170V270 9999 FEW026 SCT035 22/15 Q1008=
METAR GCRR 251400Z 21012KT 190V260 9999 FEW026 SCT035 21/15 Q1007=
METAR GCRR 251430Z 22011KT 200V260 9999 FEW030 SCT041 22/13 Q1007=

And the forecast applicable to the aerodrome at the time was:

TAF GCRR 250800Z 2509/2609 25012KT 9999 TX22/2514Z TN14/2606Z PROB40 TEMPO 2600/2609 SHRA BKN025TCU=

The remote sensing images (radar and satellite), forecasts included in the low-level maps and expected winds confirm that Lanzarote was ahead of the active front which, at the time of the incident, was nearing the island of Gran Canaria. There was a south-westerly wind ahead of the front, with some oscillation in direction within the third quadrant. Its intensity exceeded 10 knots, and the 13:30 h METAR details occasional gusts of up to 25 knots. The orographic configuration of the land also contributes to the local conditions. Visibility was good. There was scattered cloud cover with a less abundant first layer based at 2600 feet, and a second layer that was increasing but not yet forming a ceiling, rising from 3500 to 4100 feet. The clouds were not convective, a possibility foreseen for the following night.

Having considered all the data, with the exception of the occasional gust of wind, AEMET concluded that the meteorological situation was unlikely to have contributed to the incident.

1.8. Aids to navigation

1.8.1 VOR A approach at Lanzarote Airport

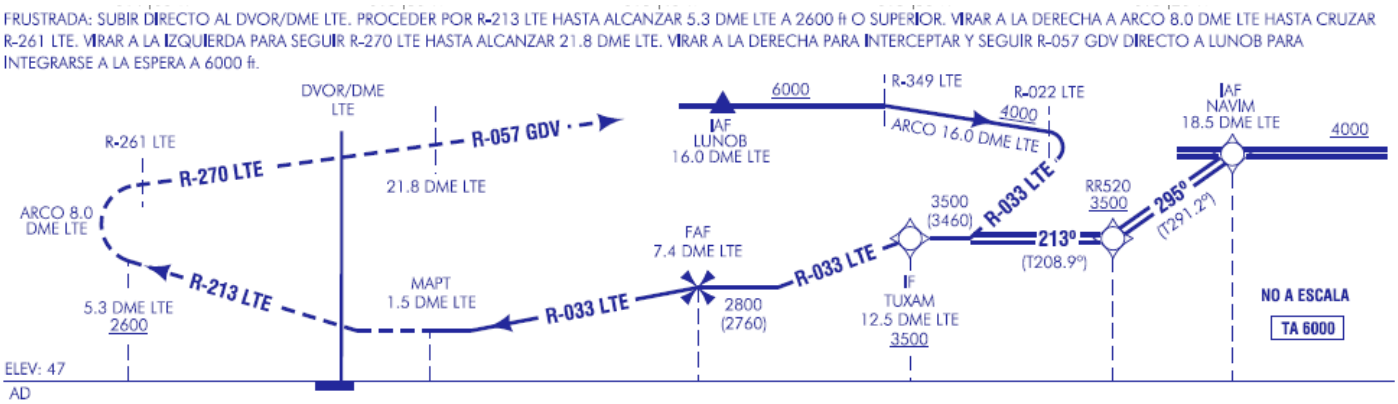
The orography that is flown over during the approach to runway 21 at Lanzarote airport (See Annexe II) is characterised by:

a. the rising terrain level and
b. the height of volcanic formations.

Illustration 3: Image of the terrain that is flown over during the VOR A approach (indicated by a green line)

Because of these obstacles, ENAIRE developed two non-precision procedures for the approach to runway 21: IAC VOR A and IAC VOR B. The IAC VOR A approach (see Annexe I), which the aircraft involved in the incident was following, is subject to a circling OCA/H due to infringement of the VSS (visual segment surface).[5]

Once the circling OCA/H is reached, and the terrain and runway 21 environment are visible, the pilot visually manoeuvres the aircraft to land either by performing a visual circuit or, if the landing can be completed satisfactorily from that position, continuing with a direct visual approach. It is common for both pilots and controllers to opt for the second option. In this case, the orography dictates a demanding descent profile (3.7 degrees).
The vertical profile of the VOR A approach sheet published in the AIP-Spain is shown below.



HGT REF ELEV AD

OCA/H		A	B	C	D
STA	2.5%	RESTRINGIDA A OCA/H DE CIRCUITO POR VULNERACIÓN VSS			
En circuito (H) sobre		1780 (1740)		2020 (1980)	

GS	kt	80	100	120	140	160	180
FAF-THR:	min:s						
FAF-MAPT: 5.9 NM	min:s	4:26	3:32	2:57	2:32	2:13	1:58
ROD:	ft/min						

ALT/HGT DME ( ) FNA												
13 DME	12 DME	11 DME	10 DME	9 DME	8 DME	7 DME	6 DME	5 DME	4 DME	3 DME	2 DME	1 DME

Illustration 4: Vertical profile of the VOR A approach

[5] In those cases where terrain or other constraints cause the final approach track alignment or descent gradient to fall outside the criteria for a straight-in approach, or there is an infringement of the visual segment surface, a visual manoeuvre (circling) approach will be specified. A straight-in OCA/H is not published where final approach alignment or descent gradient criteria are not met, or where there is an infringement of the VSS. In this case, only circling OCA/H are published. When only circling minima are provided on a chart, the approach procedure shall be identified by the last navaid providing final approach guidance followed by a single letter, starting with the letter A. (Reference ICAO doc 8168 and ENAIRE).

The pilot is assisted by the visual PAPI gradient indicator system to facilitate the final descent to runway 21. The uneven terrain necessitates a 3.7-degree[6] gradient, which means the approach to landing on runway 21 is steeper than standard approach angles.

During the investigation, ENAIRE explained that a new instrumental approach procedure, based on performance navigation (PBN), is being designed for landings on runway 21. It is scheduled to be operational in 2021.

1.8.2 Lanzarote Airport briefing issued by the operator

In its airport briefing, the operator provides its pilots with instructions on flying the VOR A instrument approach procedure and landing on runway 21 at Lanzarote. The operator classifies Lanzarote Airport as category B[7]. On the day of the incident, the briefing, published on 7 March 2019, was in force.

In the briefing, the operator states that the descent should be maintained according to the VOR A procedure until reaching 2100 feet at mile D5.6 DME LTE[8]. It also reminds pilots that, after mile D7.4 DME LTE, an approximate descent angle of 3.7 degrees is required.

On reaching the MDA at mile D5.6 DME LTE, pilots can continue with a direct visual approach manoeuvre as long as the runway environment remains in sight. During the visual manoeuvre, visual contact with the ground must be maintained at all times, and the descent path must be kept in line with the guidance provided by the PAPI (3.7 degrees, which is equivalent to a descent gradient of 6.5%).

If it is not possible to finish the approach with a direct visual manoeuvre, the operator's instructions are to maintain the circling MDA to the missed approach point (MAPt), and from there, to join a left-hand visual circuit to complete the landing on runway 21. Should this not be possible, pilots should initiate the missed approach manoeuvre.

The briefing contained a directory of crossing altitudes in correlation with distance from the VORDME LTE to assist pilots during the direct visual manoeuvre following the 3.7-degree descent path.

1.8.3 Approach made by the flight crew

Annexe IV shows the aircraft's descent from the TUXAM intermediate approach fix (12.5 NM from the DME LTE) until its eventual landing on runway 21.

[6] The standard descent angle of a PAPI is three degrees.

[7] The airport category indicates its level of complexity. Airports are classified from 'A' to 'C', with 'C' being the most complex (Regulation (EU) 965/2012 AMC1. ORO.FC.105 b(2);(c)).

[8] Mile 5.6 DME LTE is the point where the MDA would be reached when flying at an approximate 3.7-degree descent angle between the FAF and runway 21.

The illustration shows how the aircraft descended below 2800 feet at mile 8.75 DME LTE (1.35 NM before the FAF), reaching the circling MDA of 2020 feet around mile 7.4 DME LTE (approximately 1.8 NM before mile 5.6 DME LTE). It then stays below the descent profile until, after levelling and halting the descent, it then joins it.

The values selected by the flight crew in the MCP altitude window during the descent from TUXAM to runway 21 are also illustrated.

1.9. Communications

For the purposes of subsequent analysis, the communications between the crew and the air traffic control units are summarised below:

The aircraft had been cleared to descend to flight level FL130 following STAR TERTO4Q.

At 13:33:30 UTC, it was transferred to the Canary Islands Approach frequency, which subsequently cleared the aircraft to fly the direct VOR A approach to runway 21. The aircraft acknowledged the instruction.

At 13:44:59 UTC, the Canary Islands Approach controller instructed the aircraft's crew to contact the control tower at Lanzarote Airport.

At 13:45:33 the flight crew communicated with the control tower at Lanzarote Airport and they were cleared to land on runway 21.

1.10. Aerodrome information

The aircraft was making its approach to land on runway 21 at Lanzarote Airport (ICAO code GCRR). The airport is located 5 km to the south-west of the city. Its elevation is 14 meters, and it has a single runway 03/21. The runway is 2400 m long and 45 m wide.

Runway 03 has VOR, NDB, RNP and ILS approaches, while runway 21 has VOR approaches. The prevailing winds are from the NNE[9], and threshold 03 is used for take-off and landing most of the year. According to data provided by AENA, the Lanzarote aerodrome operator, in 2019, runway 21 was used for 3.2% of arrivals and 9.5% of departures.

1.11. Flight recorders

The recorded flight parameters were obtained from the aircraft's QAR (raw data). However, the CIAIAC laboratory did not have the file needed to decode it (parameter data frame). CIAIAC, therefore, asked the company that makes the software used by the laboratory (Plane Sciences) to create the necessary file.

[9] According to the master plan of Lanzarote Airport.

The data was converted, and the parameters were validated without errors.

The following information has been obtained from their analysis:

- The aircraft passed mile 12.5 DME LTE (IF TUXAM) at 3744 ft (barometric altitude) with a vertical descent speed of 784 ft/ min.
- At mile 11.75 DME LTE, the aircraft was configured with flaps at 30º and landing gear down.
- At mile 9.5 DME LTE and descending through 3136 feet, an altitude of 2100 feet was selected in the MCP altitude window.
- The aircraft descended through 2800 ft of altitude at mile 8.75 DME LTE with a vertical speed of 1328 ft/min.
- At mile 7.5 DME LTE and 2112 feet of altitude, an altitude of 1400 feet was selected in the MCP altitude window.
- The aircraft passed mile 7.4 DME LTE (FAF) at 2080 ft (720 ft below the theoretical profile), with a vertical descent speed of 704 ft/min.
- The aircraft's highest vertical descent speed values were reached between miles 9.0 to 7.5 DME LTE. In that section, values of between 1200 and 1300 ft/min were maintained.
- Mile 6.75 DME LTE was passed at 1920 ft of altitude (964 ft radio altimeter) with a vertical descent speed of 704 ft/min. 1000 ft was subsequently selected in the altitude window of the MCP. At that moment, the following parameters were registered by the flight recorder: GPWS – Glide slope (1 second) and GPWS - Alert. The latter was maintained until mile 4.75.
- At mile 5.75 DME LTE and 1632 feet of altitude, an altitude of 6000 feet was selected in the MCP altitude window.
- Mile 5.25 DME LTE was passed at 1440 ft of altitude (983 ft radio altimeter) with a vertical descent speed of 976 ft/min. At that moment, the GPWS - Terrain Caution parameter was registered by the flight recorder together with the GPW - CAUTION TERRAIN parameter. The former remained active until mile 4.75 DME LTE, while the latter remained active until mile 5 DME LTE, for four seconds.
- As the aircraft crossed mile 4.75 DME LTE at 1312 ft of altitude (901 ft RA) with a vertical descent speed of 944 ft/min, the following parameters were registered by the flight recorder: GPWS – Terrain warning and GPWS – Warning at the same time as the GPWS – TERRAIN and GPWS – PULL UP parameters. The PULL UP warning was triggered when the aircraft was at 1280 ft (892 ft radio altimeter) and had a vertical descent speed of 816 ft/min.
- Mile 4.25 DME LTE was passed at 1120 ft of altitude (613 ft radio altimeter) with a vertical descent speed of 656 ft/min. At that point, the flight recorder again registered the GPWS - Alert, and it was maintained until mile 3.5 DME LTE.
- At mile 3.75 DME LTE and an altitude of 1024 feet, the autopilot and autothrottle were disconnected and the aircraft levelled-off for fifteen seconds. The descent was then resumed.

A graphical representation of these events is provided in both the following image and Annexe X.

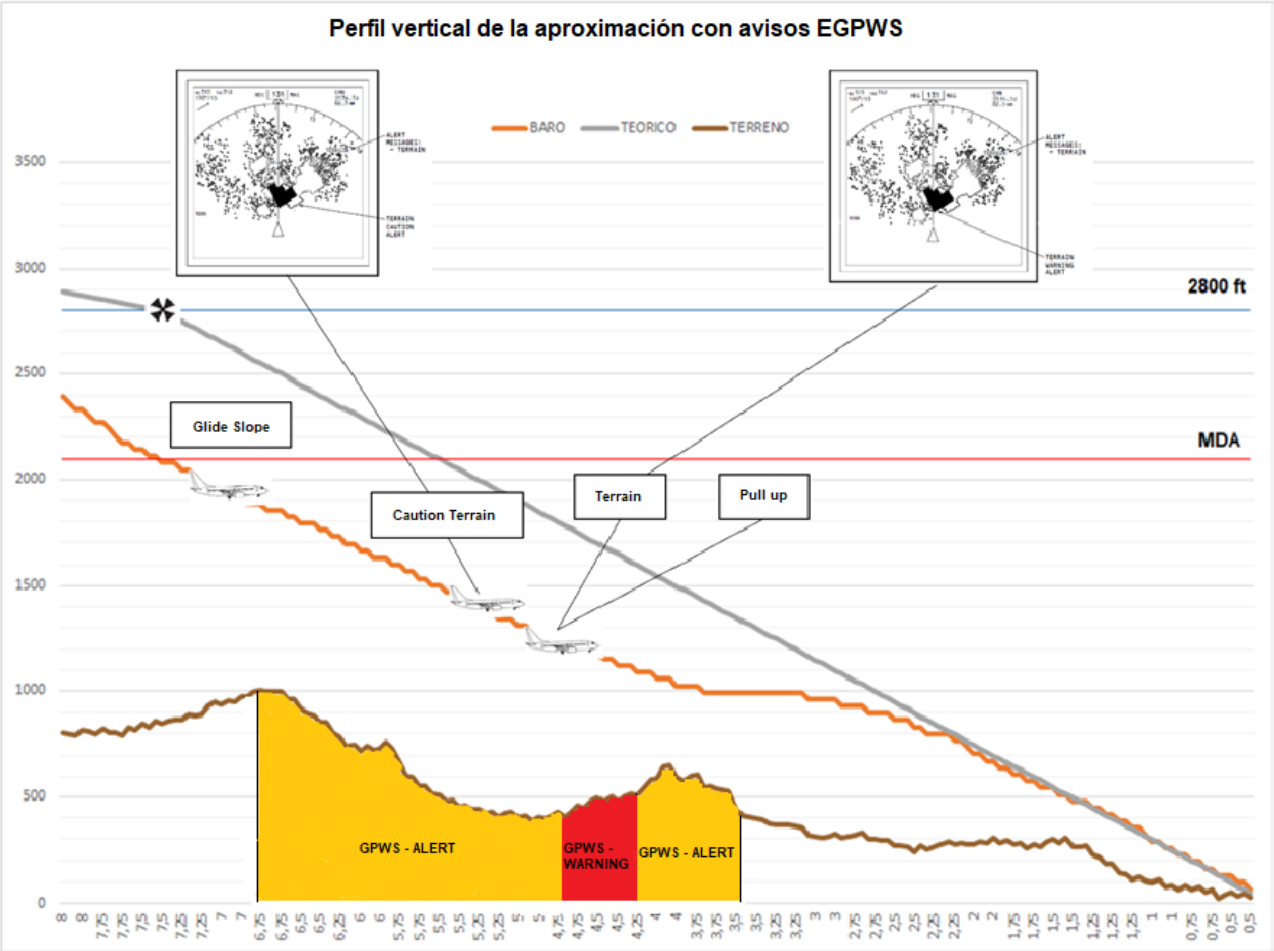


Illustration 7: Vertical profile of the approach with the EGPWS warnings

1.12. Aircraft wreckage and impact information

N/A.

1.13. Medical and pathological information

There is no evidence of any physiological factors or disabilities that may have affected the crew's performance.

1.14. Fire

There was no fire.

1.15. Survival aspects

N/A.

1.16. Tests and research

1.16.1 Captain's testimony

The content of the report written by the aircraft's captain is summarised below.

The incident occurred during a supervised line training flight (LIFUS) with a relatively inexperienced co-pilot. They had been in contact before the flight and followed the pre-flight procedures.

If runway 21 was in service, allowing the co-pilot to be the PF (pilot flying) was not an option. Therefore, it was agreed that the captain would be the PF if RWY 21 were to be used for arrival, and the co-pilot would make the approach if RWY 03 were to be used.

A fairly extensive briefing was held for RWY 21. The Captain considered requesting the ILS approach to RWY 03 with a tailwind but finally decided that RWY 21 was an acceptable risk. He consulted the CCI. Lanzarote Airport has an unenviable reputation among the company's pilots for its challenging RWY 21 approach. It requires good manual flight coordination and the difficulties encountered on this particular approach path have been documented. He had flown the RWY 21 approach once before, several years ago.

The CCI instructions were unclear. As a result, he decided they would use the LNAV and V/S modes for the approach. Altitudes from mile 15 were extrapolated from CCI table. The CCI indicates that the approach is challenging. The captain, therefore, intended to conserve "energy" to allow for a more effective monitoring of the approach and the co-pilot. The aircraft is CAT C. The approach glideslope table appears in the 757/767 section of the CCI.

During the briefing, a cutback in the flight procedure, skipping the NAVIM waypoint, was anticipated. They also discussed where the runway would appear due to the approach offset, and the fact that they would be closest to terrain after mile 7.4 DME LTE.

During the approach, the DME LTE was selected on both VOR devices. During the briefing, it was not apparent that the distance was going to appear on the PFD. Two distance arcs were inserted in the fixes page —one at mile 7.4 DME LTE and another at 15 NM from TUXAM.

After passing TUXAM, they entered visual flight conditions, making visual contact with the runway environment at 10 NM. They could see the volcanic pitons but not the PAPI or the approach lights, and the visibility was hazy and grey.

They completed the "landing" checklist promptly as they were more concerned about what was happening outside the aircraft than inside.

The distance information on the PFD differed by about 1.5 NM from the DME LTE distance. After TUXAM, an altitude of 2800 ft was selected on the MCP. 2200 ft was selected when visual contact was made. At mile 7.4 DME LTE, the distance appeared to be wrong; it seemed high to him at the time.

Possibly because he was expecting to follow a 3° visual path. The ground proximity warning did not come as a surprise (as at other airports with terrain issues). After the warning, as everything seemed to be in order, he continued with the approach. Shortly afterwards, he made visual contact with the PAPI, which was displaying four red lights. He was aware that the ground was close. The offset appeared to be greater than expected. The note on the EGPWS (in the CCI) may have predisposed him to expect the warning.

When the terrain warning was received, he was confident he had prepared for and anticipated the threat of terrain proximity.

There have been a lot of procedural changes. There are a lot of modes but less training and fewer guidelines for using them.

1.17. Organisational and management information

The aircraft was operated by TUI Airways Limited which holds an Air Operator Certificate (AOC) issued by the United Kingdom Civil Aviation Authority (CAA) on 19 December 2018, to carry out commercial air transport operations for passengers and cargo.

1.18. Additional information

1.18.1 Operator's internal report

The operator carried out an internal investigation into the incident. It determined the root cause as a failure, on behalf of the crew, to monitor the approach and to perform the instrument procedure as published. This resulted in the aircraft flying below the vertical profile and triggered the EGPWS warnings.

1.18.2 Response to the EGPWS warnings

During the approach, the following ground-proximity warnings were activated:

- "CAUTION TERRAIN" at mile 5.25 DME LTE.
- "TERRAIN, TERRAIN, PULL UP" at mile 4.75 DME LTE.

The B737-800 QRH and part A of the *Aircraft operator's operating manuals* (see Annexes VI and VII) state that in the event of a "CAUTION TERRAIN" warning, pilots must adjust the aircraft's path to separate it from the ground. If a "TERRAIN, TERRAIN, PULL UP" warning is received, they must disconnect the autopilot and autothrottle, apply maximum power, and climb as steeply as possible to avoid the ground.

The documents specify that, in both cases, if the alarms are produced when flying under daylight VMC conditions and a positive visual verification that no obstacle or terrain hazard exists can be made, the alert may be regarded as cautionary, and the approach may be continued.

1.18.3 Previous incidents at Lanzarote Airport

We consulted the Spanish Occurrence Reporting System for all occurrences involving EGPWS alerts at Lanzarote Airport between 2017 and 2019. The primary source of these reports was the crews of the aircraft involved.

In the indicated period, there were 81 occurrences relating to EGPWS warnings at Lanzarote Airport, of which 59 applied to runway 21 approaches, and 22 to runway 03 approaches.

This indicates that 72.8% of the events reported occurred during runway 21 approaches, despite the fact that GCRR runway 21 is only used for 3.2% of the traffic (according to the data for 2019).

Taking into account the types of EGPWS warnings reported in the occurrences, two main groups can be distinguished. One involves EGPWS warnings for excessive terrain proximity (Terrain, Terrain ahead, Pull Up), and the other involves EGPWS warnings for excessive sink rate and deviation below the descent path.

The occurrences reported for runway 03 mainly involved EGPWS warnings for sink rate and deviation below the descent path. By contrast, in 61.1% of the occurrences reported for runway 21, EGPWS terrain proximity warnings were reported (Terrain, Terrain ahead, Pull Up). The remaining 38.9% were EGPWS warnings for sink rate and deviation below the descent path.

Furthermore, 69.5% of the flights that experienced terrain-proximity EGPWS warnings (Terrain, Terrain ahead, Pull Up) on approach to runway 21 had visual references of the terrain and were, therefore, able to continue with the approach and land without incident. The remaining 30.5% had to abort the approach.

The aerodrome operator, AENA, also provided data from its Safety Management System relating to missed approaches following ground proximity warnings:

- In 2017, there were five incidents
- In 2018, there were two incidents
- In 2019, there was one incident

For its part, Saerco, Lanzarote Air Traffic Control (ATC) Tower provider, has registered the following missed approaches following ground-proximity warnings:

- In 2017, there were five incidents
- In 2018, there were three incidents, one of which ended up diverting to an alternative airport
- In 2019, there was one incident

1.19. Useful or effective investigation techniques

N/A.

2. ANALYSIS

Various aspects of the incident were analysed, including the approach made by the crew, the flight manuals, and other material provided by the operator in relation to the runway 21 approach at Lanzarote Airport.

2.1. Analysis of the approach executed by the crew

The flight crew was cleared by ATC to make the "direct VOR A approach to runway 21" and acknowledged the authorisation.

They configured the plane for landing at an early stage and carried out the pre-landing checklist so as to be able to focus on the final leg of the approach.

With the autopilot and autothrottle engaged, the flight crew used LNAV mode for horizontal navigation and V/S mode to fly the vertical profile of the approach. When using the V/S mode, the pilot calculates the vertical speed required to fly the vertical profile of the approach path and makes the necessary adjustments to stay on it by modifying the vertical speed value. When the aircraft reaches the altitude selected by the flight crew in the MCP altitude window, the autopilot maintains that altitude.

According to the captain's statement, at mile 10 DME LTE, they had the terrain, obstacles and the airport environment in sight. They passed the TUXAM point and continued the descent to 2800 feet according to the VOR A instrument procedure, which was selected in the altitude window of the MCP.

In his testimony, the captain said that once he had made visual contact, he selected 2200 feet on the MCP[10]. The QAR recorded that when the aircraft was at mile 9.5 DME LTE and descending through 3136 feet, an MDA rounded to the higher hundred of 2100 feet was selected in the MCP altitude window. This altitude is lower than the previously selected, 2800 feet, which they should have maintained until the FAF. Thus, at mile 8.75 DME LTE, in other words, 1.35 miles before the FAF, the aircraft descended below the minimum altitude of 2800 feet. They continued the descent, and when the aircraft reached 2100 feet, the flight crew selected 1400 feet in the MCP altitude window. The aircraft continued to descend, passing mile 7.4 DME LTE a few moments later at 2080 feet (720 feet below minimum altitude). The descent continued with the subsequently selected altitudes of 1000 feet in the MCP altitude window and, lastly, the missed approach altitude (6000 feet) until the ground proximity warnings were received.

Based on the preceding information, we can conclude that the flight crew deviated from the flight profile for the manoeuvre, and on making visual contact, descended prematurely below the minimum altitude published for between the IF and FAF (2800 feet). They then proceeded to fly over the FAF at approximately 720 feet below the

[10] The QAR recorded that this selection was actually 2100 feet.

minimum altitude and continued to descend below the vertical profile, which generated the EGPWS warnings.

In his statement, the captain also said that he was possibly expecting to follow a 3-degree visual path, instead of the required 3.7 degrees.

The co-pilot, who was undergoing line training under supervision (LIFUS), performed the functions of PM (pilot monitoring). According to the captain, his workload was high, and he performed his job in accordance with his level of experience. We believe that this aspect of the flight could have influenced the effectiveness of the flight crew's approach monitoring.

On receiving the two ground-proximity warnings, the captain declared that he had the obstacles in sight and, given that he was unsurprised by the warnings, decided to continue the approach instead of performing the terrain escape manoeuvre. He disconnected the autopilot and autothrottle, levelled the plane, and subsequently continued the descent following the correct profile.

As a result of the incident, the operator drew up an individualised training plan for the captain, which covered the flight procedures for non-precision approaches and the response to EGPWS warnings, among other things. Following a favourable report from the training department, he resumed his regular flight activity. The co-pilot, who was carrying out line flying under supervision (LIFUS), continued with his training which was expanded to include aspects related to the incident.

2.2. Analysis of the flight manuals and other material provided by the operator

The briefing on Lanzarote Airport is found in part C of the *Operator's operating manuals*. Because the airport is classified as category B, the pilots would have needed to read it in order to be able to carry out the flight to Lanzarote Airport.

The airport briefing explained the options for flying the VOR A approach. Should pilots opt to carry out a direct visual manoeuvre to land on runway 21 after reaching the MDA, the briefing provided guidance to assist them with the said manoeuvre. It also provided pilots with a second option that involved maintaining the MDA until the MAPT and then joining a left-hand visual circuit.

It should be noted that the Lanzarote Airport briefing included a table with guide altitude values in relation to DME LTE distance for the approach section between the FAF and landing on runway 21. However, the table was found under the B757/767 section, which dealt with the operator's type B757/767 aircraft.

After the incident, the operator amended the Lanzarote Airport briefing, expanding and clarifying the information contained in it, including the FMC programming and a detailed guide to flying the approach (including altitude tables and distances in the section applicable to the B737).

The structure of the CCI and its location within part C of the operating manuals formed part of the individualised training plan that the operator provided for the captain.

3. CONCLUSIONS

3.1. Findings

- The crew had valid licenses and medical certificates.
- The aircraft's documentation was in order.
- The meteorological conditions were suitable for the type of flight.
- The captain was supervising the co-pilot as part of his line flying under supervision (LIFUS).
- The operator had classified Lanzarote Airport as category B.
- The airport briefing prepared by the operator provided the flight crew with information on making the VOR A approach to land on runway 21 at Lanzarote Airport.
- The aircraft was cleared to make a "direct VOR A approach to runway 21" at Lanzarote airport.
- The crew descended below the minimum altitudes on the approach chart prematurely and continued the descent.
- As a result of staying below the minimum altitudes, the enhanced ground proximity system (EGPWS) warnings were activated.
- As they were flying in daylight and had the ground and obstacles in view, the crew corrected the trajectory and continued the approach instead of performing the terrain escape manoeuvre.

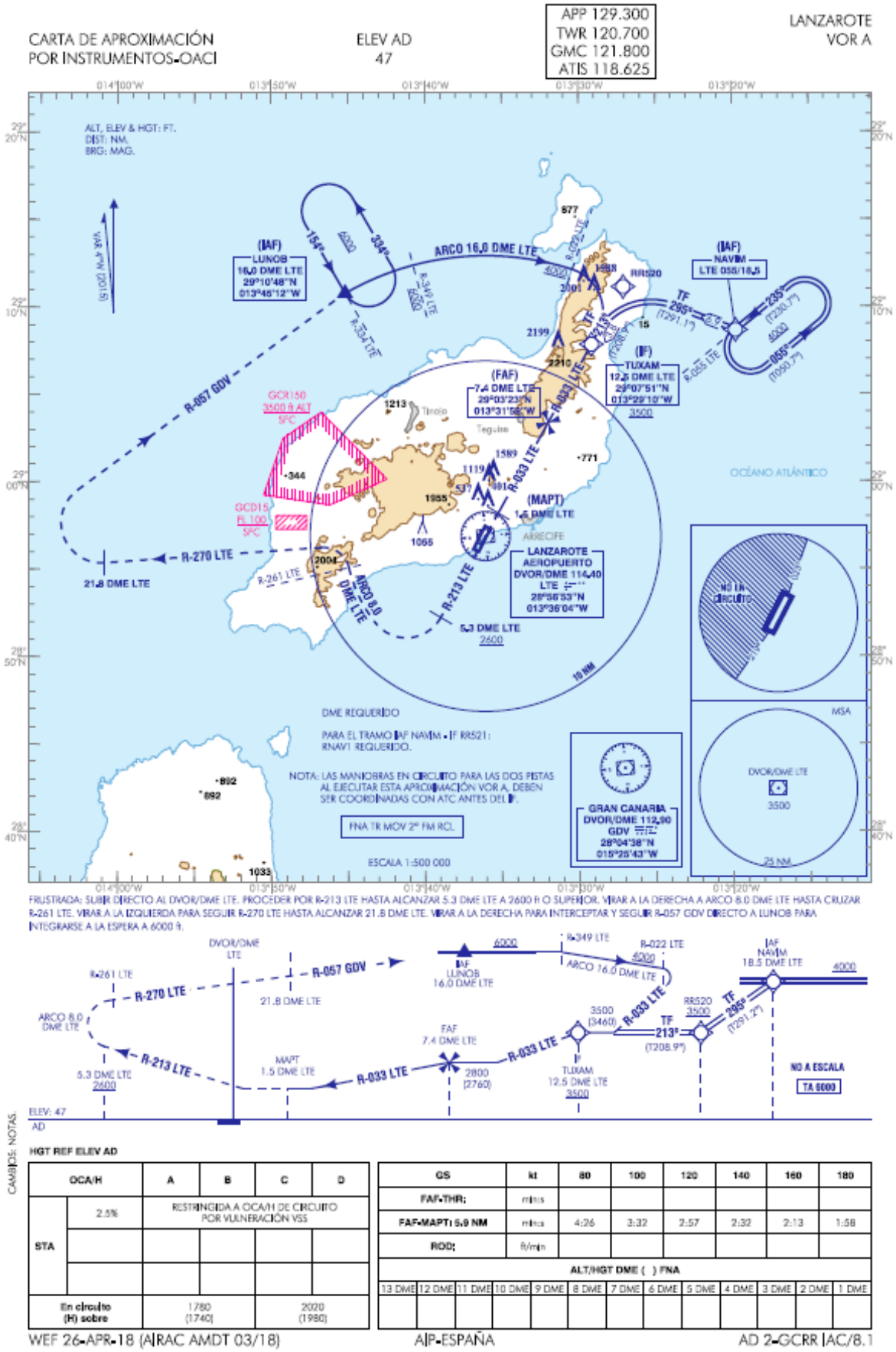
3.2. Causes/contributing factors

The investigation has concluded that the incident was caused by an incorrectly executed approach to Lanzarote Airport.

4. OPERATIONAL SAFETY RECOMMENDATIONS

Given that the aircraft's operator has already taken the appropriate measures, there are no further safety recommendations.

ANNEXE I: VOR A APPROACH CHART



ANNEXE II: OROGRAPHY OF THE APPROACH TO RUNWAY 21 AT LANZAROTE

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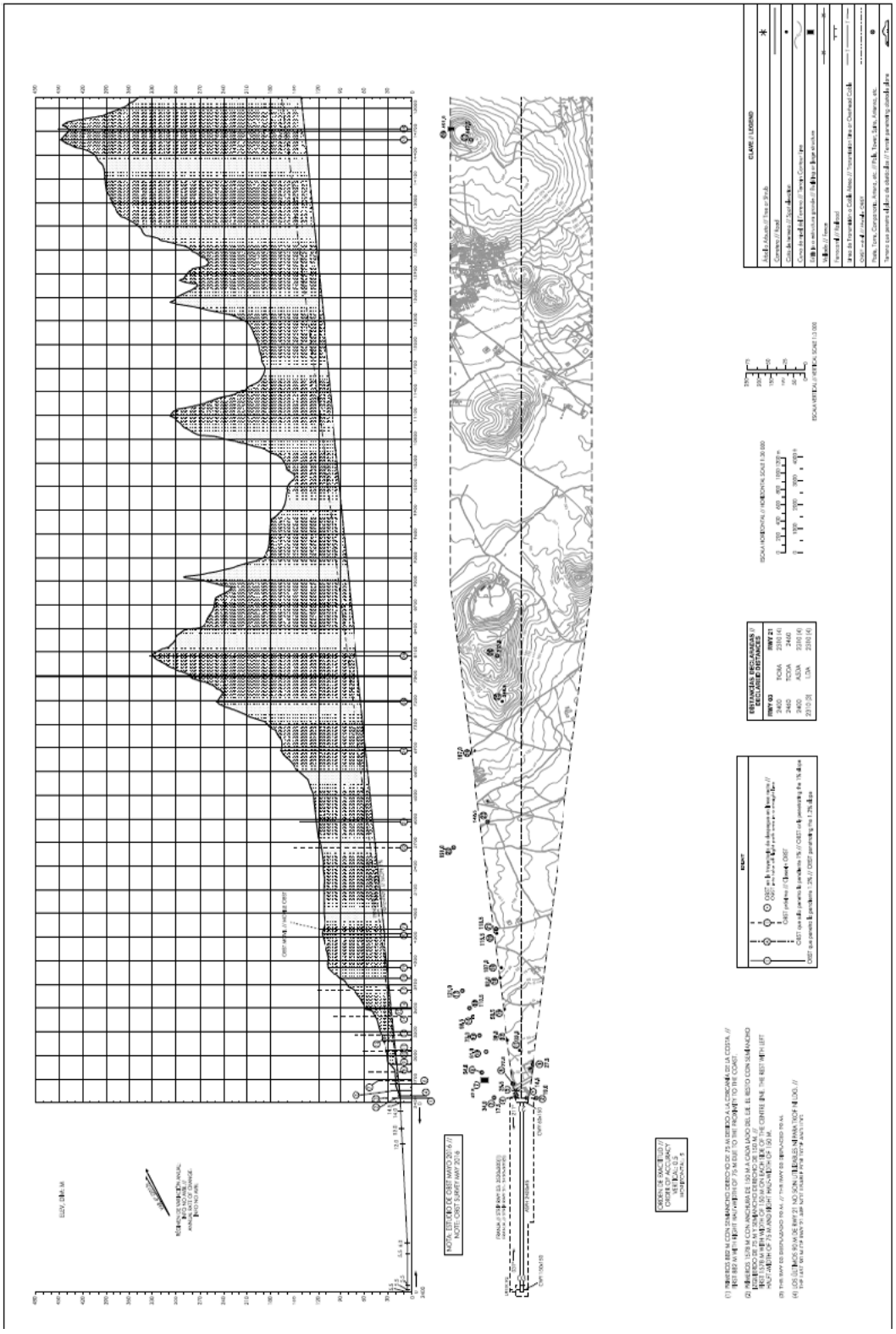

ANNEXE III: TRAJECTORY OF THE AIRCRAFT WITH THE EGPWS WARNINGS

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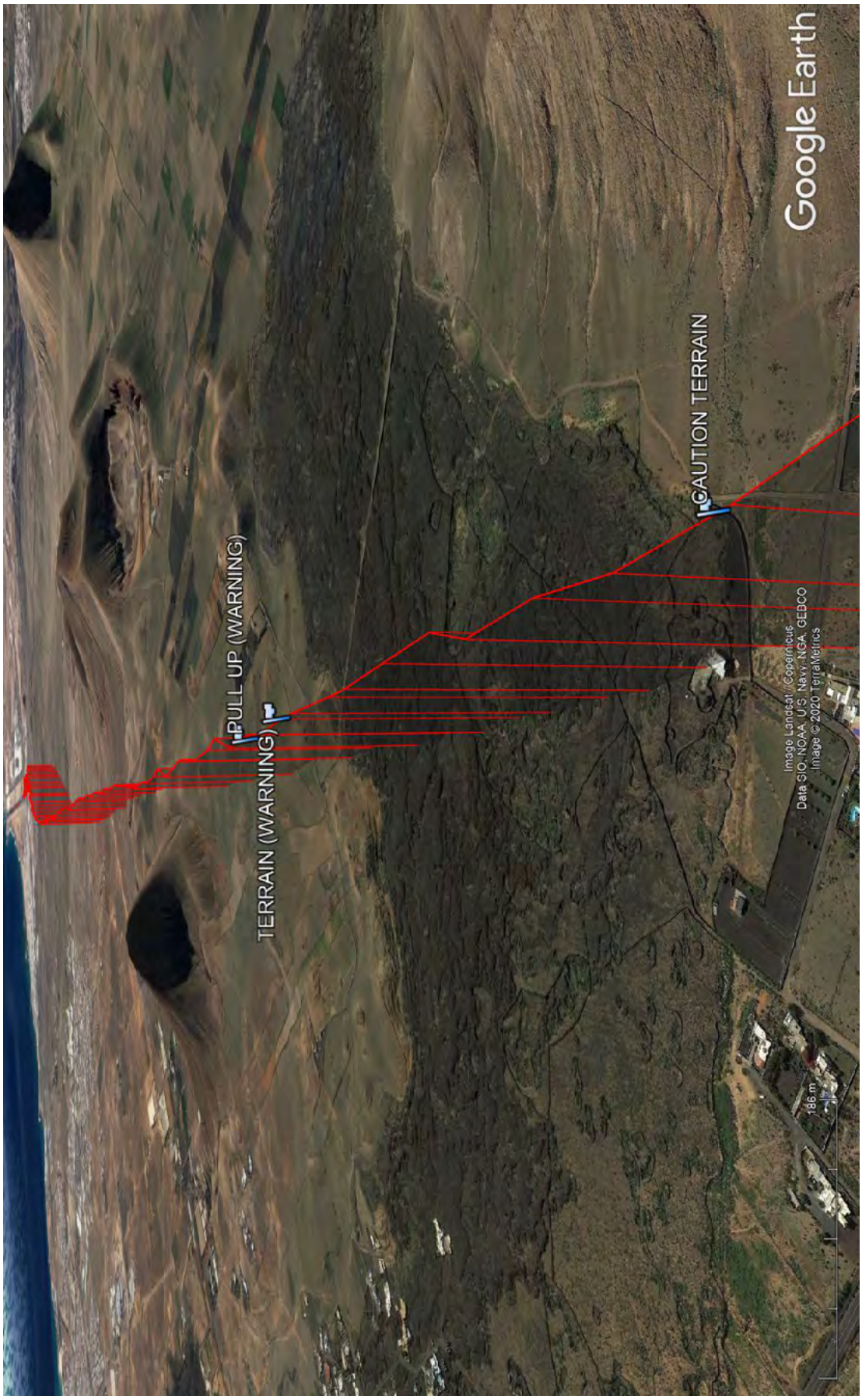
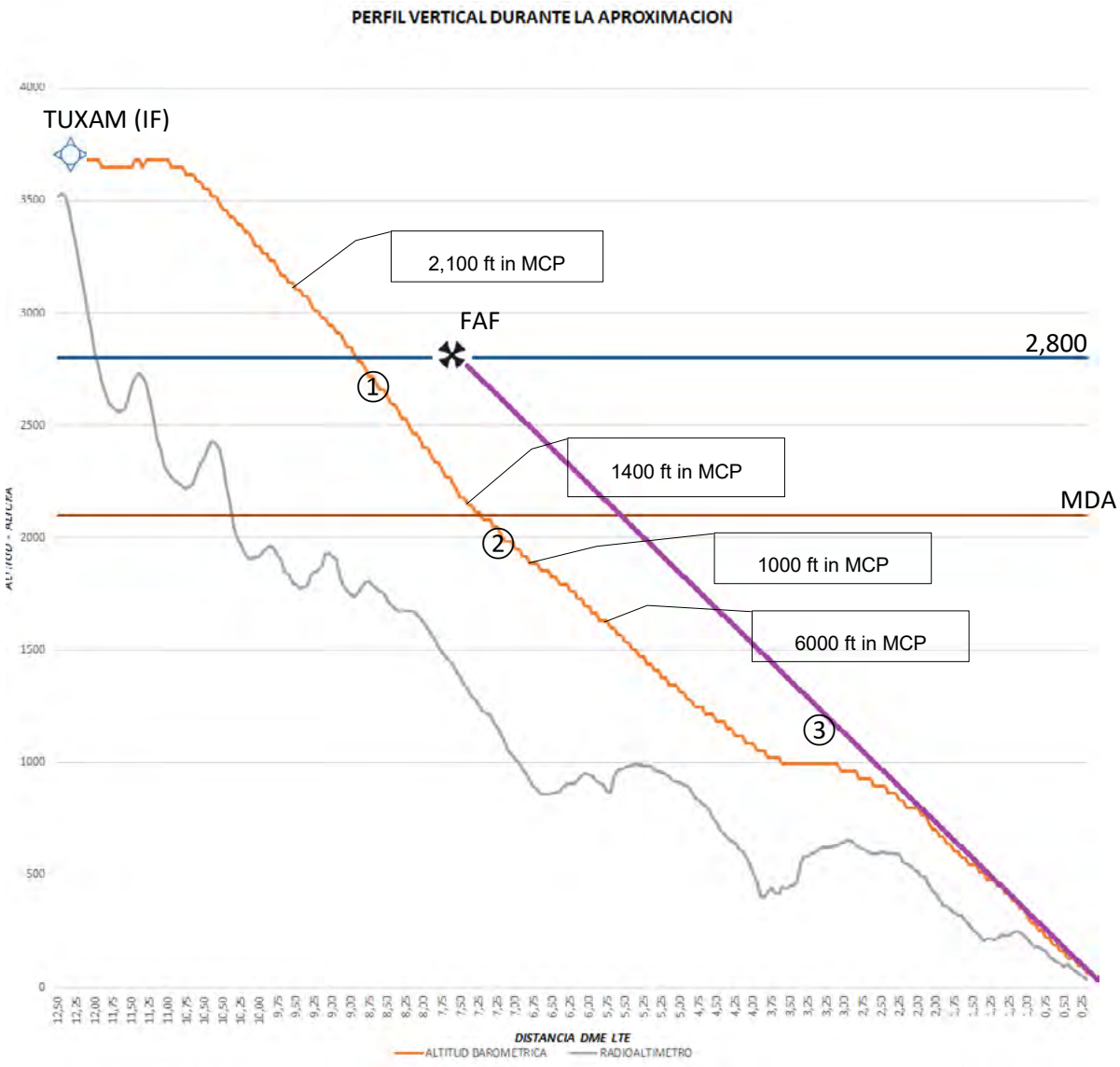


ANNEXE IV: ALTITUDES GRAPH



① The aircraft descends below 2,800 ft at mile 8.75 DME LTE.
② The aircraft reaches the circling MDA around mile 7.4 DME LTE.
③ The aircraft halts its descent, levels up and corrects to the 3.7-degree profile.

ANNEXE V: DESCRIPTION OF THE EGPWS ALERTS

The following is an extract from the FCOM of the B737-800 with a description of the different audio and visual alerts emitted by the EGPWS.

Look Ahead Terrain

AURAL ALERT	VISUAL ALERT	DESCRIPTION
TERRAIN **TERRAIN,** **PULL UP**	PULL UP on both attitude indicators Red TERRAIN message on Navigation display (all modes) Solid red terrain on navigation display	20 to 30 seconds from projected impact with terrain shown solid red on the navigation display (in expanded MAP, center MAP, expanded VOR, or expanded APP modes only). Moving the ground proximity terrain inhibit switch to TERRAIN INHIBIT inhibits the alert.
CAUTION **TERRAIN**	Amber TERRAIN message on navigation display (all modes) Solid amber terrain on navigation displays	40 to 60 seconds from projected impact with terrain shown solid amber on the navigation display (in expanded MAP, center MAP, expanded VOR, or expanded APP modes only). Moving the ground proximity terrain inhibit switch to TERRAIN INHIBIT inhibits the alert.
TOO LOW, **TERRAIN**	PULL UP on both attitude indicators	Descent below unsafe radio altitude while too far from any airport in the terrain database. Moving the ground proximity terrain inhibit switch to TERRAIN INHIBIT inhibits the alert

Radio Altitude Based Alerts

AURAL ALERT	VISUAL ALERT	DESCRIPTION
PULL UP	PULL UP on both attitude indicators	Follows SINK RATE alert if excessive descent rate continues or increases. Follows radio altitude based TERRAIN alert if excessive terrain closure rate continues and landing gear and/or flaps are not in landing configuration.
TERRAIN	PULL UP on both attitude indicators	Excessive terrain closure rate.
DON'T SINK	PULL UP on both attitude indicators	Excessive altitude loss after takeoff or go–around
GLIDESLOPE	BELOW G/S P–INHIBIT Lights	**G-FDZA - G-FDZS** Deviation below glideslope. Volume and repetition rate increase as deviation increases. **G-FDZT - G-TAWW** Deviation below glideslope or glide path. Volume and repetition rate increase as deviation increases. Pushing the ground proximity BELOW G/S P-INHIBIT light cancels or inhibits the alert below 1,000 feet RA.
SINK RATE	PULL UP on both attitude indicators	Excessive descent rate.
TOO LOW, FLAPS	PULL UP on both attitude indicators	Unsafe terrain clearance at low airspeed with flaps not in a normal landing position. Pushing the ground proximity flap inhibit switch to FLAP INHIBIT inhibits the alert.

TOO LOW, GEAR	PULL UP on both attitude indicators	Unsafe terrain clearance at low airspeed with landing gear not down. Pushing the ground proximity gear inhibit switch to GEAR INHIBIT inhibits the alert.
TOO LOW, TERRAIN	PULL UP on both attitude indicators	Unsafe terrain clearance at high airspeed with either landing gear not down or flaps not in landing position. Follows DON'T SINK if another descent is initiated after initial alert, before climbing to the altitude where the initial descent began.

Obstacle Alerts

Aural Alert	Visual Alert	Description
OBSTACLE OBSTACLE, PULL UP	PULL UP on both attitude indicators Red OBSTACLE message on ND (all modes) Solid red terrain on ND	20 to 30 seconds from projected impact with obstacle shown solid red on the ND (in MAP, MAP CTR, VOR, or APP modes only). Moving the ground proximity terrain inhibit switch to TERRAIN INHIBIT inhibits the alert
CAUTION OBSTACLE	Amber OBSTACLE message on ND (all modes) Solid amber terrain on ND	40 to 60 seconds from projected impact with obstacle shown solid amber on the ND (in MAP, MAP CTR, VOR, or APP modes only). Moving the ground proximity terrain inhibit switch to TERRAIN INHIBIT inhibits the alert.

ANNEXE VI: QRH - RESPONSE TO GPWS WARNINGS

RESPONSE TO GPWS CAUTION

The following is an extract from the QRH which instructs the crew on how to respond to a GPWS caution.

Ground Proximity Warning System (GPWS) Response

GPWS Caution

Accomplish the following manoeuvre for any of these aural alerts:

- *SINK RATE*
- *TERRAIN*
- *DON'T SINK*
- *TOO LOW FLAPS*
- *TOO LOW GEAR*
- *TOO LOW TERRAIN*
- *GLIDESLOPE*
- *BANK ANGLE*
- *AIRSPEED LOW (airplanes with AIRSPEED LOW aural)*
- *CAUTION TERRAIN*
- *CAUTION OBSTACLE*

Pilot Flying	***Pilot Monitoring***
Correct the flight path, airplane configuration, or airspeed.	

The below glideslope deviation alert can be cancelled or inhibited for:

- *localizer or backcourse approach*
- *circling approach from an ILS*
- *when conditions require a deliberate approach below glideslope*
- *unreliable glideslope signal*

Note: If a terrain caution occurs when flying under daylight VMC, and positive visual verification is made that no obstacle or terrain hazard exists, the alert may be regarded as cautionary and the approach may be continued.

Note: Some aural alerts repeat.

RESPONSE TO A GPWS WARNING

The following is an extract from the QRH which details the actions the crew must take in response to a GPWS warning.

GPWS Warning

Accomplish the following maneuver for any of these conditions:

- *Activation of "PULL UP" or "TERRAIN TERRAIN PULL UP" warning.*
- *Activation of the "PULL UP" or "OBSTACLE OBSTACLE PULL UP" warning.*
- *Other situations resulting in unacceptable flight toward terrain.*

If a Ground Proximity Warning maneuver is executed, either FCM calls "TERRAIN, GO"

Pilot Flying	***Pilot Monitoring***
Disengage autopilot. *Disengage autothrottle.* *Aggressively apply maximum* thrust.* *Simultaneously roll wings level and rotate to an initial pitch attitude of 20°.* *Retract speedbrakes.* *If terrain remains a threat, continue rotation up to the pitch limit indicator (if available) or stick shaker or initial buffet.*	*Assure maximum* thrust.* *Verify all needed actions have been completed and call out any omissions*
Do not change gear or flap configuration until terrain separation is assured. *Monitor radio altimeter for sustained or increasing terrain separation.* *When clear of terrain, slowly decrease pitch attitude and accelerate.*	*Monitor vertical speed and altitude (radio altitude for terrain clearance and barometric altitude for a minimum safe altitude.)* *Call out any trend toward terrain contact.*

Note: *Aft control column force increases as the airspeed decreases. In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit. Flight at intermittent stick shaker may be needed to obtain a positive terrain separation. Use smooth, steady controls to avoid a pitch attitude overshoot and stall.*

Note: *Do not use flight director commands.*

Note: **Maximum thrust can be obtained by advancing the thrust levers full forward if the EECs are in the normal mode. If terrain contact is imminent, advance thrust levers full forward.*

Note: *If positive visual verification is made that no obstacle or terrain hazard exists when flying under daylight VMC conditions before a terrain or obstacle warning, the alert may be regarded as cautionary and the approach may be continued.*

ANNEXE VII: OPERATING MANUALS - RESPONSE TO GPWS WARNINGS

The following is an extract from part A of the *Operator's operating manuals*, which provides instructions on how the flight crew should respond to EGPWS warnings.

8.3.5 GPWS / TAWS procedures and instructions

The rate of descent should be limited to a maximum of 2000 fpm below 2000 ft AGL until the stabilised approach criteria apply.

GPWS / TAWS Caution

The FCM shall without delay initiate the response as described in OM-B, QRH Maneuvers required to correct the condition which has caused the caution and be prepared to respond to a warning.

If a caution is not followed by a warning and if applicable, the commander shall ensure that ATS is notified of the new position, heading and/or altitude/flight level of the airplane and state intentions.

GPWS / TAWS Warning

The FCM shall without delay:

- *perform the terrain avoidance maneuver as described in OM-B, QRH Maneuvers;*
- *maintain the climb until visual verification can be made that the airplane will clear the terrain or obstacle ahead or until above the appropriate sector safe altitude.*

Note: If positive visual verification is made that no obstacle or terrain hazard exists when flying under daylight VMC conditions prior to a terrain or obstacle warning, the alert may be regarded as cautionary and the approach may be continued.

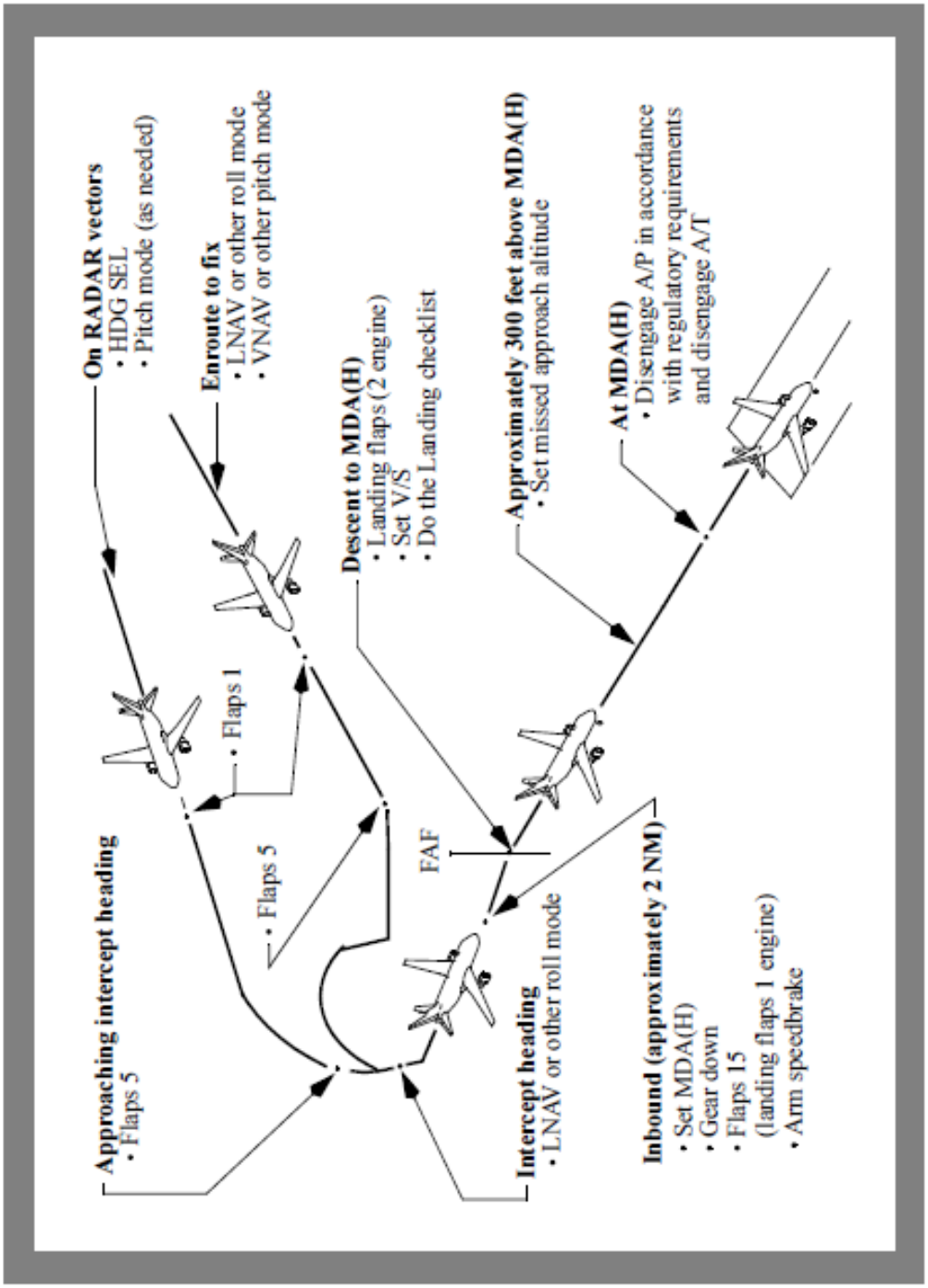
If, subsequently, the aeroplane climbs up through the sector safe altitude, but the visibility does not allow the flight crew to confirm that the terrain hazard has ended, checks shall be made to verify the location of the aeroplane and to confirm that the altimeter subscale settings are correct.

When the workload permits, the flight crew shall notify ATS of the new position and altitude/flight level, and state intentions.

ANNEXE VIII: FCTM – APPROACH USING V/S MODE

ANNEXE VIII: FCTM – APPROACH USING V/S MODE

Instrument Approach Using V/S



ANNEXE IX: DESCRIPTION OF THE EGPWS MODES

MODES	CONDITION			AURAL MESSAGE	PFD-RED MESSAGE	ND MESSAGE	GND PROX-G/S INHIBIT LIGHT
1	INITIAL ANNUNCIATION			SINK RATE...	PULL UP		
	WARNING			PULL UP...	PULL UP		
2A	FLAPS <30 AND G/S AND LOC DEV >2 DOTS	INITIAL ANNUNCIATION		TERRAIN TERRAIN	PULL UP		
		WARNING		PULL UP...	PULL UP		
		ALTITUDE GAIN FUNCTION: - STARTS WHEN MODE 2 CONDITION STOPS - STOPS WHEN 300 FT OF INERTIAL ALT IS GAINED OR 45 SECS ELAPSED		TERRAIN..	PULL UP		
2B	FLAPS >30 AND G/S OR LOC DEV <2 DOTS	FLAPS AND GEAR DOWN		TERRAIN..	PULL UP		
		FLAPS OR GEAR UP	INITIAL ANNUNCIATION	TERRAIN TERRAIN..	PULL UP		
			WARNING	PULL UP...	PULL UP		
3A	FLAPS <30 OR GEAR UP (FOR ALTITUDE LOSS OF 10% TO 20%)			DON'T SINK...	PULL UP		
3B	FLAPS <30 OR GEAR UP, RA LESS THAN THRESHOLD VALUE.			TOO LOW TERRAIN..	PULL UP		
4A	GEAR UP AND FLAPS <30	AIRSPEED <190 KNOTS AND RA <500 FT		TOO LOW GEAR..	PULL UP		
		AIRSPEED >190 KNOTS AND RA <1000FT		TOO LOW TERRAIN..	PULL UP		
4B	GEAR DOWN AND FLAPS <30	AIRSPEED <159 KNOTS AND RA <245 FT		TOO LOW FLAPS..	PULL UP		
		AIRSPEED >159 KNOTS AND RA <1000FT		TOO LOW TERRAIN..	PULL UP		
5	APPROACH AND GEAR DOWN	RA <1000 FT AND G/S DEVIATION >1.3 DOTS		GLIDE SLOPE... AT 1/2 VOLUME, FREQ PROPORTIONAL TO DEVIATION AND GROUND PROXIMITY.			X
		RA <300 FT AND G/S DEVIATION >2.0 DOTS		GLIDE SLOPE... AT FULL VOLUME, FREQ PROPORTIONAL TO G/S DEVIATION AND GROUND PROXIMITY.			X
6	PROGRAM PIN SELECTABLE			RADIO ALTITUDE CALLOUTS AS SELECTED BY PROGRAM PINS			
7	WINDSHEAR CONDITION			SIREN, THEN WINDSHEAR, WINDSHEAR, WINDSHEAR...	WINDSHEAR		
TA	60 SEC TO THREAT TERRAIN			CAUTION, TERRAIN..		TERRAIN	
	30 SEC TO THREAT TERRAIN			TERRAIN, TERRAIN, PULL UP..	PULL UP	TERRAIN	
TCF & RFCF	INITIAL PENETRATION OF TCF AND AFTER EACH 20% FURTHER RA LOSS			TOO LOW TERRAIN..		TERRAIN	
	WARNING			PULL UP...	PULL UP	TERRAIN	

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ANNEXE X: GRAPHICS FROM THE QAR