Technical report
IN-010/2022

Incident on 06 March 2022 involving a BOEING B737-8AS aircraft operated by Ryanair, registration EI-EVR,19 NM to the northwest of Málaga-Costa del Sol Airport (Málaga)

Please note that this report is not presented in its final layout and therefore it could include minor errors or need type corrections, but not related to its content. The final layout with its NIPO included (Identification Number for Official Publications) will substitute the present report when available.

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES Y MOVILIDAD SOSTENIBLE
SUBSECRETARÍA
COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Notice

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

In accordance with the provisions in Article 5.4.1 of Annexe 13 of the International Civil Aviation Convention; and with Articles 5.5 of Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010; Article 15 of Law 21/2003 on Air Safety; and Articles 1, 4 and 21.2 of RD 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent their recurrence. The investigation is not intended to attribute any blame or liability, nor to prejudge any decisions that may be taken by the judicial authorities. Therefore, and according to the laws specified above, the investigation was carried out using procedures not necessarily subject to the guarantees and rights by which evidence should be governed in a judicial process.

Consequently, the use of this report for any purpose other than the prevention of 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
°C	Degrees Celsius
AESA	Spain’s National Aviation Safety Agency
AFDS	Autopilot Flight Director System
AIP	Aeronautical information publication
MA	Minimums alert
AMAN	Arrival MANagement
AMIN	Adaptation of the MSAW alert in the control tower environment
AOC	Air Operator Certificate
APP	Approach control service
ARP	Aerodrome reference point
ASM (sector)	Approach sector of the Seville TMA (Area 3A)
ATC	Air traffic control
ATPL (A)	Airline transport pilot license
ATS	Air traffic service
CDU	Control display unit
CPL(A)	Commercial pilot license
CVR	Cockpit voice recorder
DME	Distance measuring equipment
EASA	European Aviation Safety Agency
EGPWS	Enhanced ground proximity warning system
FAP	Final approach point
FCOM	Flight Crew Operations Manual
FL	Flight level
FMA	Flight mode annunciator
FMC	Flight management computer
ft	Foot
GPWS	Ground proximity warning system
h	Time
HDG	Heading
hPa	Hectopascal
IAA	Irish Aviation Authority
IAC	Instrument approach chart
IAF	Initial approach fix
IATA	International Air Transport Association
IF	Intermediate fix
IFR	Instrument flight rules
ILS	Instrument landing system
IR	Instrument rating

kg	Kilogram
KIAS	Knots indicated airspeed
km	Kilometre
kt	Knot
LEMG	ICAO code for Málaga-Costa del Sol Airport
LNAV	Lateral navigation
m	Metre
MCP	Mode control panel
ME	Multi-engine
METAR	Aviation routine weather report (in aeronautical meteorological code)
MHz	Megahertz
MIDAS	Málaga Improved Design of Air Space
MPA	Multi-pilot aeroplane
MSAW	Minimum safe altitude warning
ND	Navigation display
NM	Nautical mile
MVA	Minimum vectoring altitude
NNW	North-northwest
ICAO	International Civil Aviation Organisation
OM	Operations Manual
PF	Pilot flying
PM	Pilot monitoring
P/N	Part number
QAR	Quick access recorder
QNH	Altimeter setting to obtain elevation above sea level when on the ground
QRH	Quick Reference Handbook
RNAV	Area navigation
RWY	Runway
SEL	Selected
SID	Standard instrument departure
S/N	Serial number
STAR	Standard terminal arrival route
SVQ	IATA callsign for Seville Airport
TMA	Terminal control area
TO/GA	Take-off / go-around
UTC	Coordinated universal time
VHF	Very high frequency (30 to 300 MHz)
VMC	Visual meteorological conditions
VNAV	Vertical navigation
VOR	VHF omnidirectional range

Synopsis

Aircraft operator:	Ryanair
Aircraft:	Boeing 737-8AS, registration EI-EVR
Date and time of the incident:	06 March 2022, 08:59[1] UTC
Site of incident:	19 NM to the northwest of Málaga-Costa del Sol Airport (Málaga)
Persons on board:	6 + 167, unharmed
Type of operation:	Commercial air transport – Scheduled – International – Passengers
Phase of flight:	Approach
Flight rules:	IFR
Date of approval:	19th December 2023

Summary of the incident:

At 08:59 UTC on Sunday, 06 March 2022, a Boeing 737-8AS aircraft with registration EI-EVR, operated by Ryanair and flying from Charleroi-Brussels South Airport (Belgium) to Málaga-Costa del Sol Airport (LEMG), experienced an incident involving a loss of terrain separation.

The EI-EVR aircraft made an initial approach to runway 12 LEMG but was instructed to go around by ATC due to a breach of the minimum separation with the preceding aircraft when both were on the final leg of the approach to the runway.

After completing the missed approach, when they were following ATC instructions to reposition on ILS runway 12, the captain of the EI-EVR aircraft requested priority to land on the grounds of low fuel without using the correct phraseology, and, as a result, the arrival sequence remained unchanged.

Subsequently, the EI-EVR aircraft was cleared to proceed to NEPUR, descend to 6000 ft and fly the ILS Z RWY 12 approach to LEMG. The aircraft then continued to descend below the cleared altitude, breaching the minimum vector altitudes of the sectors it was flying over without ATC alerting the pilots to their position.

The aircraft's GPWS warned the flight crew of the proximity to the ground, who, after initiating a climb manoeuvre, later managed to intercept the LEMG runway 12 localizer.

Following the incident, the aircraft continued its flight with no damage of any type.

The investigation has concluded that the incident occurred as the flight crew did not correctly perform the Malaga (LEMG) approach that they had been cleared to follow.

The following factors contributed to the incident:

[1]All times used in this report are UTC. To calculate the local time add 1 hour.

- ATC did not monitor actively and did not detect that the aircraft was flying below the cleared altitude in the first instance and subsequently below the minimum vectoring altitudes prescribed for the different areas through which the aircraft flew.

1. THE FACTS OF THE INCIDENT

1.1. Summary of the incident

On Sunday, 06 March 2022, at 06:16:05 h, a Boeing 737-8AS aircraft operated by Ryanair, registration EI-EVR, took off from Charleroi-Brussels South Airport (Belgium) bound for Málaga-Costa del Sol Airport (Spain) with a total of 173 people on board (of which 6 were crew). Its callsign was RYR93SM.

The flight crew consisted of two pilots and four cabin crew. It was the first flight of the two they had been assigned for that day. On this flight, the co-pilot was the pilot flying (PF).

The flight passed without incident until, at 08:35:47 h, during the ILS approach to runway 12 at LEMG, following the procedure from NEPUR, an infringement of the minimum separation distance (3 NM) from the preceding aircraft occurred when both were on the final leg of the approach to said runway. For this reason, at 08:37:31 h (see ① in figure 1), when the EI-EVR aircraft was on short final, the LEMG control tower instructed it to perform a go-around manoeuvre because the preceding aircraft had not yet left the runway.

During the approach briefing, the pilots had discussed[2] the course of action to be taken in the event of a missed approach. They had calculated that they had sufficient fuel to proceed to the alternate airport (Seville) but also that, in the event of a missed approach, the necessary conditions were in place to fly a second approach to LEMG, landing with sufficient margin over the final reserve fuel[3].

At 08:39:50 h (see ② in figure 1), while carrying out the standard missed approach manoeuvre, maintaining 2200 ft altitude, the aircraft's crew requested radar vectors to make a second approach to LEMG[4]. LEMGDSM cleared them to climb to FL090, maintaining the current heading and subsequently instructed them to proceed to the TOLSU waypoint (see ③ in figure 1).

At 08:46:26 h (see ④ in figure 1), while the aircraft proceeded to TOLSU at FL090, LEMGDSM cleared them to descend to FL080 and later to turn to a heading of 300º (see ⑤ in figure 1). Subsequently, after a frequency change, LEMGASM instructed them to continue on a heading of 270° (see ⑥ in figure 1).

Meanwhile, the aircraft's captain repeatedly tried to re-program the new approach route in the aircraft's FMC[5] without success. As he explained in his post-incident statement, the route to follow was displayed on the ND as a dashed line, but he was unable to execute it.

[2] According to their statement made after the incident.

[3] See section 1.18.1 Operator's in-flight fuel management procedure.

[4] The operational configuration/sectorisation of Málaga at the time of the incident was as follows: 4 tower positions and 2 SOUTH sectors (LEMGASM and LEMGDSM) in the Approach Office.

[5] Flight management computer

They finally decided to fly the approach with the autopilot engaged in HDG SEL[6] mode, following the dashed line. The AFDS[7] lateral mode used up until intercepting the runway 12 localizer was HDG SEL.

At 08:52:50 h (see ⑦ in figure 1), when the EI-EVR aircraft was maintaining FL080 and a heading of 268º 26.5 NM NNW of LEMG, the aircraft crew informed LEMGASM that it was running low on fuel using the following words: *"RYR93SM, we are running low on fuel now; we are committed to Málaga".* Six seconds later, LEMGASM informed him that he was number 6 in the approach sequence and that he would call him in 12 NM to turn. At 08:53:04 h, the crew of the EI-EVR aircraft requested priority approach using the following words: *"Requesting priority approach, RYR93SM".*

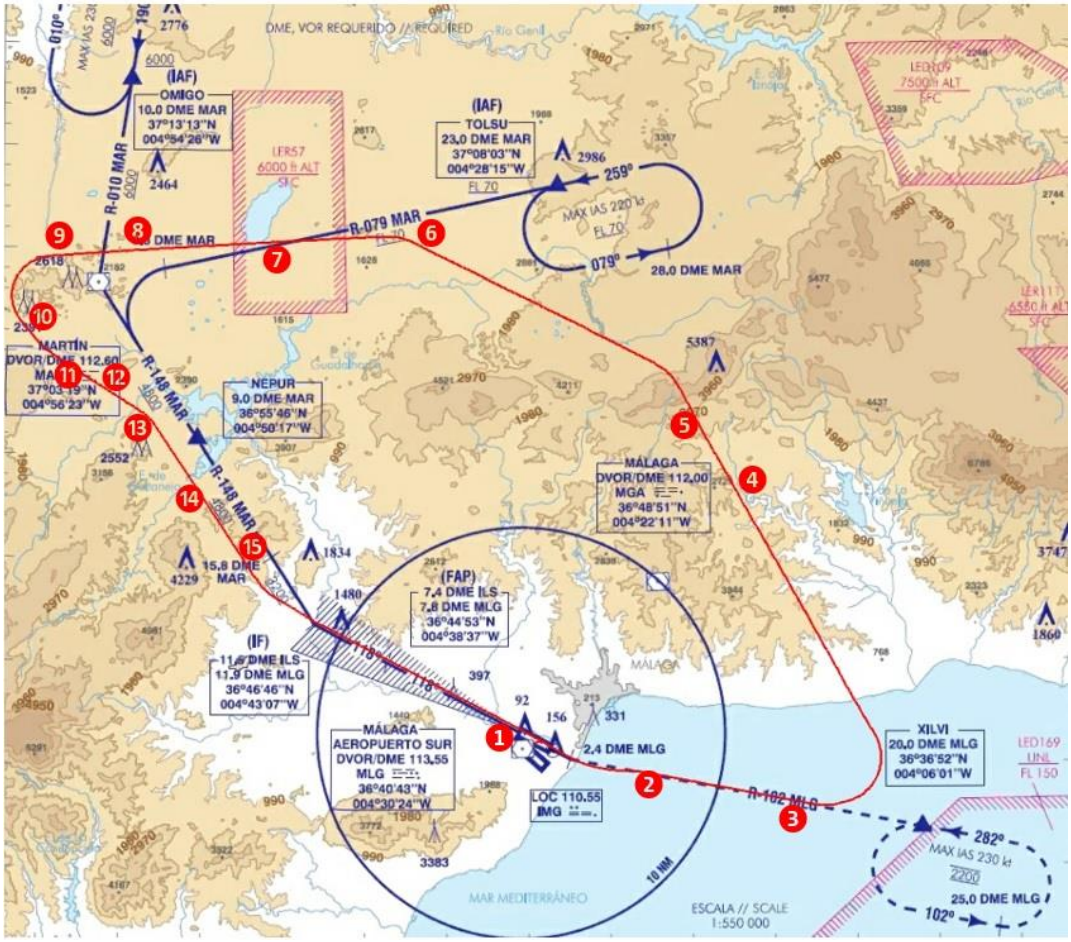


Fig. 1 Extract from the ILS Z RWY 12 approach chart showing the path followed by the aircraft, with the points of interest marked in red circles

At 08:54:25 h (see ⑧ in figure 1), LEMGASM cleared the EI-EVR aircraft to descend to 6000 ft, reporting the QNH and requesting it reduce its indicated speed to 210 kt. Shortly afterwards, they instructed it to turn left to the NEPUR waypoint and proceed from NEPUR to the ILS Z RWY 12 approach, with correct readback by the crew (see ⑨ in figure 1).

[6] With the HDG SEL lateral mode activated the autopilot maintains the heading selected by the flight crew on the mode control panel (MCP). The pilot uses the MCP to instruct the autopilot to perform selected actions.

[7] Autopilot Flight Director System.

At 08:56:14 h, on course to the NEPUR waypoint and descending through 6700 ft, the crew of the EI-EVR aircraft requested confirmation that they were clear to proceed to the ILS Z RWY 12 approach without initially receiving a response. After 15 seconds, when the frequency became clear, the EI-EVR crew again requested confirmation of the clearance, and LEMGASM confirmed that they were cleared. They selected 4800 ft in the altitude window of the MCP[8] (see ⑩ in figure 1).

At 08:57:05 h (see ⑪ in figure 1), proceeding to the NEPUR waypoint, the EI-EVR aircraft descended below the cleared altitude (which was 6000 ft).

At 08:57:53 h (see ⑫ in figure 1), descending through 5169 ft, they selected 3200 ft in the MCP altitude window.

At 08:58:35 h (see ⑬ in figure 1), when the EI-EVR aircraft was descending through 4554 ft, it turned to its right before reaching the NEPUR waypoint and flew parallel to radial 148 MAR, positioned 1.5 NM to the west of it.

The aircraft continued to descend, flying parallel to the aforementioned radial and at 08:59:48 h, the CAUTION TERRAIN alert was activated.

At 08:59:58 h (see ⑭ in figure 1), the TERRAIN, TERRAIN, PULL UP warnings were activated, the autopilot disengaged, and the aircraft began to climb. The lowest barometric altitude recorded was 3235 ft. The minimum radio altimeter altitude recorded was 1065 ft at 09:00:12 h whilst already climbing through 3343 ft at 18.5 NM from LEMG. The captain took over the controls and PF role until landing.

As stated by the pilots after the incident, the visual conditions during the approach were VMC, and they were in visual contact with the ground at all times.

Asked about the loss of separation from the terrain, the deviation from the nominal route and the lack of corrective actions on their part, the executive controller[9] and the LEMGASM sector planner replied respectively:

- *We saw that the traffic deviated from its nominal route, descended below nominal altitude, and then climbed again to follow the procedure. Given that the traffic did not report any problems with the approach and completed the approach and landing without further problems, we assumed that the deviation may have been caused by some minor confusion arising from the tense situation brought about by the earlier missed approach.*
- *After the NEPUR waypoint, we observed that the traffic deviated from the radial it was supposed to follow according to procedure without notifying us. Just as we were*

[8] When an altitude value is entered in the MCP altitude window, the autopilot will maintain the aircraft at the selected value on reaching it.

[9] The position providing air traffic control services in the LEMGASM sector was staffed by 2 persons: an executive controller and a planning controller.

about to advise it of the situation, we saw that it was correcting its altitude and position, completing the approach without problems.

At 09:01:04 h (see ⑮ in figure 1), after the climb manoeuvre, the EI-EVR aircraft reached 4300 ft, which it maintained until intercepting the ILS localizer for runway 12.

At 09:01:35 h, it intercepted the localizer and descended following the ILS for runway 12. Approximately one and a half minutes later, LEMGASM transferred the EI-EVR aircraft to the LEMG control tower frequency.

At 09:04:52 h, the LEMG control tower cleared the EI-EVR aircraft to land on runway 12, where it landed safely at 09:06:44 h.

At 09:07:07 h, i.e. 23 seconds after landing, the aircraft had[10] 1556 kg of fuel on board, i.e. 437 kg above the final reserve fuel.

1.2. Injuries to persons

Injuries	*Crew*	*Passengers*	*Total*	*Others*
Fatal				
Serious				
Minor				
None	6	167	173	
TOTAL	6	167	173	

1.3. Damage to the aircraft

The aircraft involved in the incident did not sustain any damage.

1.4. Other damages

There was no other damage.

[10] The fuel quantity data is recorded in the aircraft's QAR (Quick Access Recorder) every 64 seconds, thus providing the data immediately after landing. The immediately preceding measurement, which was recorded at 09:06:03: h (41 seconds before landing) was 1610 kg, i.e. 491 kg above final reserve fuel.

1.5. Information about the personnel

1.5.1. Information about the crew of aircraft EI-EVR

The 54-year-old captain of the aircraft had an airline transport pilot license for aircraft (ATPL(A)) issued on 03 May 2019 by the Irish Aviation Authority (IAA), with B737 300-900 / ME IR (MPA) ratings valid until 31 March 2023. He also had a Class 1 medical certificate valid until 17 December 2022 and an English proficiency level of 6.

He had 12800 h of flight experience, of which 6050 h were in the type of aircraft involved in the incident, and 1571 h as a captain in the company, having been employed by the operator since 4 February 2019. With regard to his recent activity, he had flown 5:20 h in the last 24 hours, 29:46 h in the last 7 days, and 165:18 h in the last 90 days. It was his fifth day of duty and as he had finished work at 11:45 UTC the day before, he had rested for 17:30 h prior to the incident flight. On the incident flight he was the pilot monitoring (PM) and it was the first time he had flown with this co-pilot. He had flown to LEMG on several occasions.

The 37-year-old co-pilot had a commercial pilot license for aircraft (CPL(A)) issued on 18 October 2021 by the Irish Aviation Authority (IAA), with B737 300-900 / ME IR (MPA) ratings valid until 30 November 2022. He also had a class 1 medical certificate, valid until 18 October 2022.

He had 400 h of flight experience, of which 190 h were in the type of aircraft involved in the incident. He had been working for the operator since 23 August 2021. With regard to his recent activity, he had flown 5:19 h in the last 24 hours, 16:44 h in the last 7 days, and 182:09 h in the last 90 days. It was his fourth day of duty, and as he had finished work at 12:09 UTC the day before, he had rested for 17:06 h prior to the incident flight. On the incident flight, he was the pilot flying (PF), and it was the first time he had flown with this captain. He had flown to LEMG before, but never when RWY 12 was in service.

1.5.2. Information about the control tower personnel

The position providing air traffic control services in the LEMGASM sector was staffed by 2 people: an executive controller and a planning controller.

The executive controller was 63 years old and had an air traffic controller license issued by AESA on 22 December 1988. He also had a valid medical certificate in force until 02 August 2022. His experience at the unit was 3 years. He had the unit endorsements with an approach rating valid until 03 May 2023. For the executive controller, it was his third consecutive day of duty and previously he had had 3 days off. With regard to his shift on the day of the incident, he started on the morning shift at 06:30 UTC, covering the position of planning controller 3 times in the ANM/DNM approach sector, with the corresponding breaks. With regard to the time of the incident, he assumed the position of executive controller in the ASM sector at 08:00 UTC and remained there until 09:09 UTC. Subsequently, he served as executive controller and planner in different sectors, with the appropriate breaks, finishing his duties at 11:38 UTC.

The planning controller was 46 years old and had an air traffic controller license issued by AESA on 28 August 2006. He also had a valid medical certificate in force until 09 October 2022. His experience at the unit was 1 year. He had the unit endorsements with an approach rating valid until 02 March 2023. For the planning controller, it was his second consecutive day of duty and previously he had had 3 days off. With regard to his shift on the day of the incident, he started on the morning shift at 08:00 UTC, serving as planning controller for the ASM sector until just after the incident at 09:00 UTC. After a break, he returned to cover the position of planning controller for the same sector. For the remainder of the morning, he occupied, on several occasions, both the executive and planner positions in that sector, concluding his duties for the day as the executive controller of the unified ASM/DSM sector at 13:50 UTC.

1.6. Information about the aircraft

The BOEING B737-8AS aircraft with registration number EI-EVR and serial number 40295, was built in 2012 and registered with the IAA's registry on 14 September 2012.

This aircraft has a maximum take-off weight of 77,900 kg, a maximum landing weight of 65,317 kg and was equipped with two CFM56-7B26 turbofan engines, whose serial numbers were 962199 (engine 1) and 962205 (engine 2). Both engines had 28,049:00 flight hours and 13,744 cycles at the time of the incident.

The aircraft had three fuel tanks that could hold a total of 20896 kg of fuel.

It had an Airworthiness Certificate issued by the IAA, the latest revision of which was valid until 09 March 2023.

The aircraft was operated by Ryanair Designated Activity Company, whose Air Operator Certificate (AOC) was last renewed on 04 March 2022. The AOC allowed for the operation of B737-8AS aircraft, such as the EI-EVR.

At the time of the incident, the aircraft had 28,049:00 h of flight time and 13,744 cycles.

The last scheduled maintenance overhaul was performed on 1 March 2022, when the aircraft had 28,004:03 h of flight time and 13,726 cycles. It consisted of a 50FC CHECK (performed every 50 cycles, 15 days or 100 flight hours, whichever comes first). The previous 50FC CHECK was performed on 20 February 2022.

There were no items on the aircraft's deferred list prior to the start of the incident flight.

1.6.1. Description of the GPWS system installed in the aircraft

The EI-EVR aircraft was equipped with an Enhanced Ground Proximity Warning System (EGPWS) manufactured by Honeywell; specifically, it was a Honeywell MK V, with P/N 965-1690-071 and S/N EMK5-32081. Among other things, the system is designed to prevent collisions by emitting warnings and alerts that aware the crew to terrain proximity.

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

- The system emits the “CAUTION TERRAIN” alert when the aircraft is between 40 and 60 seconds before the projected impact with the ground.
- The system emits the “TERRAIN, TERRAIN, PULL UP” warning when the aircraft is between 20 and 30 seconds before the projected impact with the ground.

The operator's procedures for responding to GPWS warnings and alerts are included in section 1.18.2.

1.6.2. Flight Management Computer (FMC)

The EI-EVR aircraft was equipped with two GE Aviation manufactured flight management computers (FMC), model 2907C, with P/N 176200-01-01 and S/Ns 007218 and 007201. They used software version U14 with P/N 650630-002.

The FMCs use information entered by the flight crew, data from the aircraft's systems and data from the FMC's own navigation database to calculate the aircraft's current position and fly the flight profile programmed by the flight crew.

Pilots insert and modify the route in the flight plan via the CDU[11]. The navigation display (ND) shows the active route as a solid magenta line between waypoints. Dashed lines between waypoints represent modifications to an active route and inactive routes.

Pilots select the AFDS LNAV lateral mode to follow the active FMC route.

If, after making modifications to the route in the flight plan, the FMC detects a conflict related to the programmed altitude constraints at a point in the route, it issues the message ALT CONSTRAINT XXXXX (where XXXXX is the point where the conflict exists in the route).

ENTRY ERROR MESSAGE	CAUSE	CORRECTIVE ACTION
ALT CONSTRAINT XXXXX (waypoint identifier)	A flight plan modification has caused an altitude conflict with a waypoint that has an altitude constraint.	Clear the message and revise the entry.

Fig. 2 Extract of the list of error messages from the operator’s FCOM

[11] Control Display Unit

To amend this situation, the crew must review and correct the data entered into the FMC via the CDU.

Both pilots indicated in their post-incident statement that when re-programming the FMC after the first missed approach, the ILS Z RW12 approach was selected via TOLSU, but an "ALTITUDE CONSTRAINT at TOLSU" message was displayed. The altitude constraint at TOLSU was FL070 or higher, and the current maintained altitude was FL090. They made several further attempts, but these were also unsuccessful. According to their statement the FMC allowed them to select the approach but not to activate it. However, the route was shown as a dashed line on the ND, so the co-pilot (PF) suggested to the captain that they could fly it following the dashed line with the autopilot engaged in HDG SEL mode until they intercepted the localizer.

1.7. Meteorological information

The weather at Málaga-Costa del Sol Airport (19 NM southeast of the incident site) was favourable. As reported by the pilots in their statements, they were in visual contact with the terrain throughout the approach. The closest METAR to the time of the event (09:00 UTC) was:

LEMG 060900Z 29008KT 9999 FEW026 11/05 Q1012 NOSIG

It indicated a wind speed of 8 kt coming from 290º. Visibility 10 km or more with few clouds at 2600 ft. Temperature 11ºC, dew point 5ºC, QNH 1012 hPa and no significant changes.

1.8. Aids to navigation

All the navigation systems were functioning correctly.

1.8.1 The ILS Z RWY 12 approach manoeuvre at Málaga Airport

The ground overflown during the approach to runway 12 at Málaga Airport is characterised by the rising levels of terrain forming part of the Penibaetic System mountain range that runs parallel to the coastline, creating a barrier between the coast and the interior; in this mountainous area, some of the elevations around the flight path reach up to 4229 ft.

The AIP Spain ATC-ICAO minimum surveillance altitude chart in force on the date of the incident (see relevant excerpt in Figure 3) shows minimum vectoring altitudes (MVA) of 5500 ft, 5700 ft, 5800 ft and 6500 ft in the vicinity of the NEPUR waypoint. To facilitate understanding, the names MAR and NEPUR have been encircled with a red ellipse, and colours have been added to the relevant altitudes and their areas of influence.

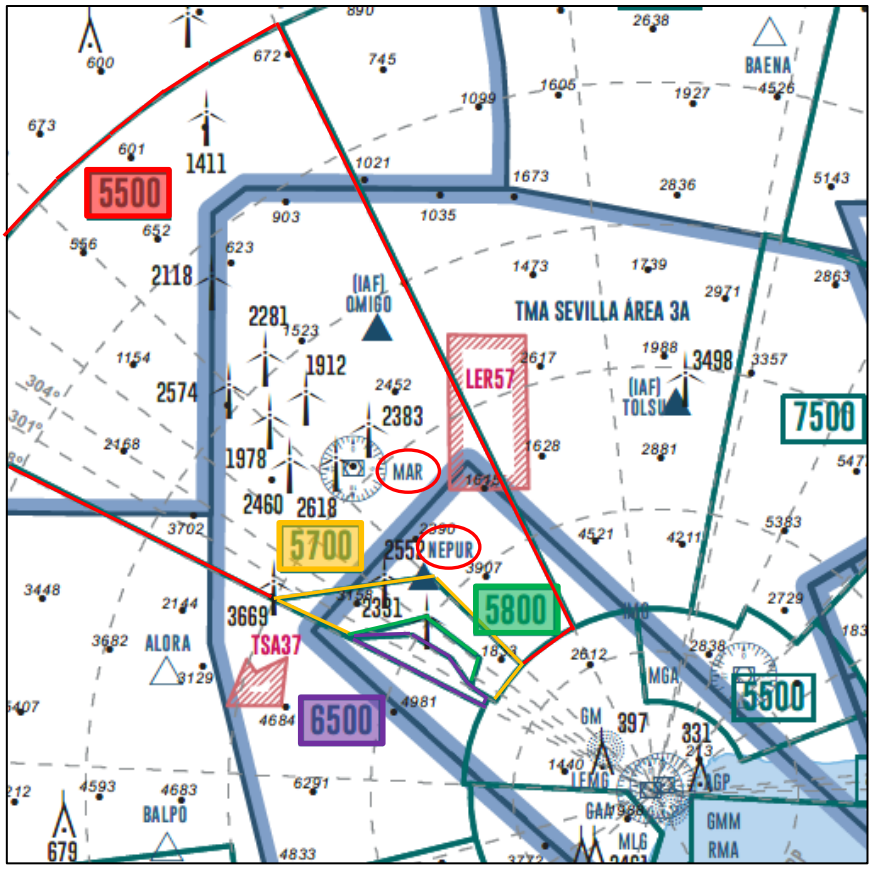


Fig. 3 Extract from the ATC-ICAO minimum altitude surveillance chart published in the AIP

Figure 4 below contains an extract from the ILS Z RWY 12 approach chart published for LEMG[12] in the AIP Spain showing the section where radial 148 of the MARTIN (MAR) VOR/DME has to be intercepted and followed in order to eventually intercept the runway 12 localizer. The NEPUR waypoint on this radial must be overflown at 4800 ft or above. Aircraft then descend to 3200 ft from mile 15.8 DME MAR to intercept the runway 12 localizer.

[12] The full approach chart in force on the date of the incident can be found in Section 5.2.

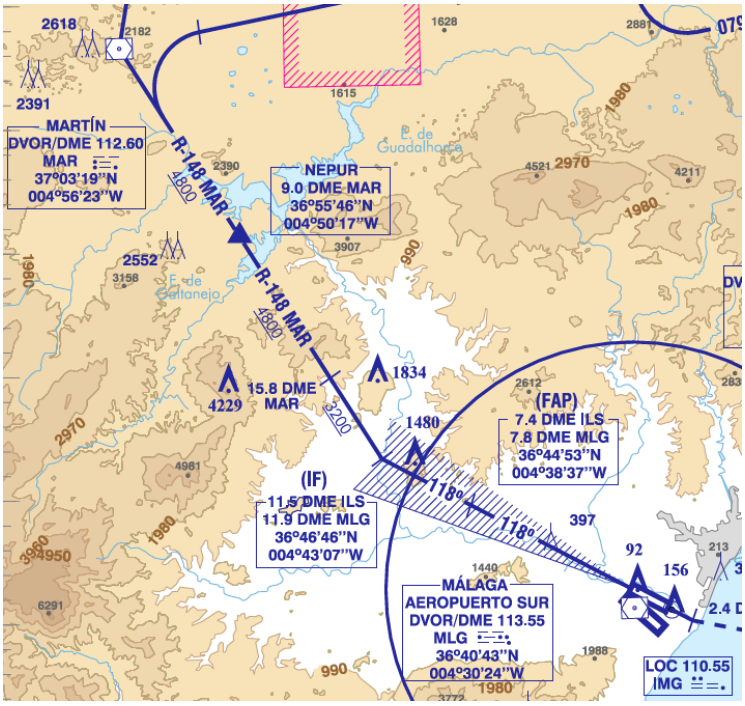


Fig. 4 Extract from the ILS Z RWY 12 approach chart

In the event of a missed approach, aircraft must, according to the published manoeuvre: *"Climb on runway heading to reach 2.4 DME MLG. Turn left to intercept and follow R-102 MLG to XILVI to integrate the holding to 2200 ft. Maximum altitude 2200 ft during the missed approach manoeuvre. Await ATC instructions"*

1.9. Communications

We were provided with the records of the verbal communications between the ATC personnel (LEMGDSM and LEMGASM sectors) and the crew of the aircraft. To facilitate understanding of the sequence of events, this section also includes relevant information extracted from the QAR.

Missed approach manoeuvre

At 08:37:13 h, moments before commencing the missed approach manoeuvre, the amount of fuel recorded was 2703 kg.

At 08:37:31 h (see ① in figure 1), the local controller instructed the EI-EVR aircraft to perform a go-around. Three seconds later, at 08:37:34 h, the QAR recorded the activation of the AFDS TO/GA[13] vertical mode when the aircraft was at 295 ft, according to the radio altimeter.

[13] This mode is activated by pressing the TO/GA button on the thrust lever to initiate a missed approach.

Subsequently, at 08:37:42 h, the local controller informed the LEMGDSM sector of APP LEMG using a line specifically for this purpose.

The aircraft maintained a runway heading until mile 2.4 of VOR/DME MLG, where it began to turn to intercept VOR/DME MLG radial 102, reaching 2200 ft at 08:38:50 h, as indicated in the missed approach manoeuvre. While conducting the missed approach, the aircraft was transferred to the LEMGDSM departure sector of APP LEMG. The crew of the EI-EVR aircraft acknowledged the information correctly. During this leg, the aircraft's crew selected the LNAV lateral mode on the AFDS.

At 08:39:14 h, the EI-EVR aircraft crew informed the LEMGDSM sector that they were at 2200 ft following the go-around. Immediately, the controller cleared them to climb to FL090. The crew of the EI-EVR aircraft read back correctly, and 9000 ft was selected in the MCP altitude window.

At 08:39:50 h (see ② in figure 1), the aircraft was still at 2200 ft altitude. The AFDS lateral mode was LNAV, and the vertical mode was VNAV PTH[14]. The flight crew requested radar vectors for a second approach. The controller informed them to expect vectors after climbing to FL090 and maintaining that heading. The crew of the EI-EVR aircraft read back correctly.

At 08:40:17 h, the aircraft crew selected the LVL CHG[15] vertical mode on the MCP, and the aircraft started to climb.

Five seconds later, at 08:40:22 h, the controller asked them if they were maintaining 2200 ft. The crew replied that they were climbing. The controller acknowledged receipt. At 08:40:50 h, the aircraft climbed through 2859 ft to FL090.

Vectors and route for a new approach

At 08:41:41 h (see ③ in figure 1), while the aircraft was on VOR/DME MLG radial 102 and climbing to FL090 through 6200 ft, the controller instructed them to turn left to the TOLSU waypoint (IAF). The crew of the EI-EVR aircraft read back the information correctly.

At 08:41:55 h, the aircraft crew momentarily selected the HDG SEL lateral mode and the aircraft began its turn to the left before subsequently switching back to the AFDS LNAV lateral mode. During this turn, the aircraft reached FL090.

[14] VNAV mode is used to fly the vertical profile selected in the CDUs of the FMC. The VNAV PTH sub-mode complies with the altitude constraints contained in the profile loaded in the FMC (in this case 2200 ft).

[15] The LVL CHG mode of the AFDS allows the aircraft to climb or descend to a predetermined altitude at a specific speed. This mode is selected by pressing the LVL CHG button on the MCP. This vertical mode is shown on the FMA as MCP SPD. To initiate a climb or descent in LVL CHG mode, the new altitude must be selected, the LVL CHG button on the MCP has to be pressed, and the desired speed must be selected. The LVL CHG mode does not take into account the vertical profile and constraints loaded in the FMC.

At 08:44:49 h, the controller asked the crew of the EI-EVR aircraft if they were proceeding to TOLSU and FL090. The crew of the EI-EVR aircraft replied in the affirmative.

At 08:46:26 h (see ④ in figure 1), the controller instructed the crew of the EI-EVR aircraft to descend to FL080. The crew of the EI-EVR aircraft read back the information correctly. They selected 8000 ft in the altitude window of the MCP, but the aircraft continued maintaining FL090. The vertical mode of the AFDS was ALT HOLD[16].

At 08:47:26 h (see ⑤ in figure 1), while the aircraft maintained FL090, the controller instructed them to fly on a 300° heading, descend to FL080 and contact the final approach sector on 123.855 MHz (LEMGASM Sector). The crew of the EI-EVR aircraft did not acknowledge, so the controller asked them if they had received the message. The crew of the EI-EVR aircraft replied that they were turning left to a heading of 300°, descending to FL070 and requested confirmation of the frequency. At 08:47:52 h, the aircraft crew selected the HDG SEL horizontal mode to turn left to a heading of 300º. They selected 7000 ft in the MCP altitude window.

The controller re-instructed them to FL080 and reconfirmed the frequency. The crew of the EI-EVR aircraft read back the information correctly. The aircraft crew re-selected 8000 ft in the MCP altitude window and the LVL CHG vertical mode in the MCP. The aircraft commenced its descent to FL080.

At 08:48:44 h, the LEMGASM controller asked the crew of the EI-EVR aircraft if they were on his frequency. The crew of the aircraft replied in the affirmative and reported that they were reaching FL080 on a heading of 300°. The controller replied that they were to continue as cleared.

At 08:49:05 h, when the aircraft reached the selected flight level (FL080), the AFDS vertical mode changed to ALT HOLD.

At 08:51:09 h (see ⑥ in figure 1), the controller instructed the EI-EVR aircraft to fly on a heading of 270º. The crew of the EI-EVR aircraft read back the information correctly.

At 08:51:17 h, the aircraft crew selected a heading of 270º on the MCP heading window, and the aircraft started to turn to heading 270º.

At 08:52:50 h (see ⑦ in figure 1), the crew of the EI-EVR aircraft informed ATC that they were low on fuel and that their intention was to land at Málaga airport using the following words *"RYR93SM, we are running low on fuel now, we are committed to Málaga"*. The controller acknowledged receipt and informed them that they would be number 6 for the approach and that he would advise them in 12 miles to turn. The crew of the EI-EVR aircraft responded that they required priority for the approach using the following words:

[16] In ALT HOLD mode, the AFDS maintains the attitude selected in the altitude window of the MCP. To initiate a descent to a lower altitude, the new altitude must be selected in the MCP altitude window, and the appropriate descent mode must be selected.

"*Requesting priority approach, RYR93SM"*. The controller acknowledged receipt at 08:53:08 h.

At 08:53:14 h, the aircraft had 1973 kg of fuel on board.

At 08:54:25 h (see ⑧ in figure 1), the controller instructed the EI-EVR aircraft crew to descend to 6000 ft with QNH 1012 hPa and reduce speed to 210 KIAS. The flight crew read back correctly.

At 08:54:32 h, the aircraft crew selected 6000 ft in the MCP altitude window and the LVL CHG vertical mode on the MCP. The aircraft commenced a descent to 6000 ft while reducing speed.

ILS Z 12 approach from the NEPUR waypoint

At 08:55:13 h (see ⑨ in figure 1), the controller instructed the crew of the EI-EVR aircraft to turn to their left to the NEPUR waypoint and, from there, cleared them for the ILS Z approach to runway 12. The flight crew read back correctly, and the aircraft commenced a left turn to NEPUR using the HDG SEL lateral mode of the AFDS.

At 08:56:14 h, the crew of the aircraft asked the controller if they were cleared for the ILS Z approach to runway 12, at which time the aircraft was descending through 6800 ft. In the absence of a response from control, they repeated the question. This time, the controller, at 08:56:34 h, answered in the affirmative. Then, at 08:56:41 h (see ⑩ in figure 1), they selected 4800 ft in the MCP altitude window.

At 08:57:05 h (see ⑪ in figure 1), the aircraft descended below the cleared altitude (which was 6000 ft).

At 08:57:43 h, the aircraft continued descending through 5400 ft in an area where the minimum vectoring altitude (MVA) was 5500 ft.

At 08:57:53 h (see ⑫ in figure 1), while descending through 5169 ft the aircraft crew selected 3200 ft in the MCP altitude window. In this regard, the co-pilot subsequently stated that he recalled requesting confirmation from the captain to descend to 3200 ft, receiving an affirmative response from him.

At 08:58:35 h (see ⑬ in figure 1), while descending through 4554 ft, the aircraft crew initiated a turn to their right (with the HDG SEL lateral mode selected in the AFDS) when they were close to the NEPUR waypoint, ending up on a heading of 148°, parallel to VOR/DME MAR radial 148, approximately 1.5 NM to the west. The aircraft had 1796 kg of fuel on board.

At 08:59:06 h, the aircraft was descending through 4107 ft on a heading of 148º parallel to VOR/DME MAR radial 148.
At 08:59:23 h, the aircraft continues descending through 3900 ft in an area where the MVA was 5700 ft.

At 08:59:39 h, while continuing to descend through 3543 ft, the remaining fuel on board was 1778 kg, and the radio altimeter height was 2488 ft.

At 8:59:48 h, the CAUTION TERRAIN alert was activated.

At 08:59:58 h (see ⑭. in figure 1), the TERRAIN, TERRAIN, PULL UP warnings were activated, the autopilot disengaged, and the aircraft began to climb. The lowest barometric altitude recorded was 3235 ft. The minimum radio altimeter altitude recorded was 1065 ft at 09:00:12 h whilst already climbing through 3343 ft at 18.5 NM from LEMG in an area where the MVA was 5800 ft.

At 09:00:26 h, the aircraft crew selected 4800 ft in the altitude window of the MCP.

At 09:01:04 h (see ⑮ in figure 1), the aircraft reached 4260 ft on a heading of 148º. The aircraft remained at 4300 ft until 09:01:35 h when it intercepted the runway 12 localizer approximately 14.5 NM from its threshold. The autopilot remained disengaged.

At 09:03:02 h, the controller transferred the EI-EVR aircraft to the LEMG control tower frequency, and the aircraft crew read back correctly. This was the first communication from ATC to the aircraft since the previous one was made at 08:56:34 h when the aircraft was above the 6000 ft to which it was cleared to descend. In other words, 6 minutes and 28 seconds elapsed between these two consecutive communications, and for almost all that time (from 08:57:05 h), the aircraft was flying below the cleared altitude and (from 08:57:43 h) below the applicable MVAs.

The air traffic control unit did not communicate with the aircraft to warn its crew that they were flying below the cleared altitude, nor the applicable MVAs.

At 09:03:19 h, the crew of the EI-EVR aircraft contacted the LEMG control tower and reported that they were fully established on the ILS for runway 12. The controller advised them to continue with their approach. Subsequently, the EI-EVR aircraft was cleared to land on runway 12, and its crew immediately read back correctly.

At 09:06:44 h, the aircraft landed on runway 12, and a few seconds later, at 09:07:07 h, the remaining fuel on board was 1556 kg.

1.10. Information about the aerodrome

Málaga-Costa del Sol Airport (LEMG) is located 8 km to the southwest of the city of Málaga. It has 2 runways, one measuring 2750 m long, designated 12-30, and the other 3200 m long and designated 13-31, both of which are 45 m wide. It is located at an elevation of 52 ft (16 m).

At the time of the incident, the airport was operating with runway 13 for departures and runway 12 for arrivals.

1.11. Flight recorders

The aircraft's flight recorders were not made available to the investigation due to the fact that by the time the investigation was initiated, the flight recorders no longer contained data on the relevant flight because the flight crew did not preserve it after the incident.

Part A, Chapter 11, paragraph 11.7.5 of the Operator's Operations Manual "List of Mandatory Occurrence Reporting Requiring CVR Retention" explicitly states that after an incident involving a GPWS PULL UP warning, the CVR data must be retained. Yet, despite this warning being triggered during the incident, the CVR data was not retained.

Nevertheless, the investigation did have access to the flight parameter records recorded in the QAR and the audio recordings of the communications with the control centre. We were also given access to the radar traces. This information was analysed and any relevant content has been included in section 1.9.

1.12. Aircraft wreckage and impact information

N/A.

1.13. Medical and pathological information

N/A.

1.14. Fire

No fire broke out.

1.15. Survival aspects

N/A.

1.16. Special tests and investigations

1.16.1. Fuel planning and management

Calculation of the fuel required for the flight

In accordance with EASA CAT.OP.MPA.150[17], the operator made the following fuel calculation during the flight dispatch:

FUEL (BIAS P03.0)	ARPT	FUEL (KGS)	TIME (HHMM)
TRIP FUEL		5790	0225
CONT 5%		290	0007
ALTN	SVQ	1026	0022
FINRES		1119	0030
PLANNED T/OFF FUEL		8225	0324
ATC		36	0001
T/OFF FUEL		8261	0326
TAXI		195	0015
BLOCK		8456	0326
PIC EXTRA		184	
TOTAL FUEL		8640	

Fig. 5 Extract from the operational flight plan containing the calculation of the fuel required for the flight

An extra 184 kg was added to the amount proposed in the operational flight plan, resulting in a total fuel quantity of 8640 kg, which would allow them to land in Málaga with 2655 kg of fuel remaining if they kept the contingency fuel (290 kg) or 2365 kg if they used it.

The fuel required to proceed to the alternate destination airport (Seville, SVQ) and land with the final reserve fuel was 2145 kg.

In-flight fuel management

According to the documentation provided by the aircraft operator after the flight, the amount of fuel consumed en route was as expected, even though initially (for traffic reasons), the aircraft maintained FL360 instead of the planned FL370 before subsequently climbing to FL370.

In his post-incident statement, the captain indicated that the predicted fuel on landing was, in round numbers, 2400 kg, and the minimum fuel required to proceed to the alternate was 2200 kg, a difference of 200 kg. Therefore, in the event of a missed approach, they could use some of the fuel earmarked for proceeding to the alternate destination (Seville) to make another approach to Málaga, given the excellent weather conditions and the availability of several runways.

Moments before the aircraft initiated the missed approach, it had 2703 kg of fuel on board, which was 558 kg above the amount required to divert to the Seville alternate.

[17] Commission Regulation (EU) No 965/2012 of 5 October 2012.

When the crew of the EI-EVR aircraft received the radar vectors for a new approach, concerned about the amount of fuel onboard (1973 kg), they decided to declare minimum fuel but didn't use the standard phraseology for doing so.

The aircraft eventually landed with 1556 kg of fuel on board, i.e. 437 kg above the calculated final reserve fuel of 1119 kg.

Between the start of the missed approach and the moment the aircraft landed after the second approach, approximately 29 minutes elapsed, during which time the fuel consumption was 1100 kg.

1.16.2. Information in relation to the FMC error message

During the investigation, we consulted the operator about the issues encountered by the flight crew in activating a second ILS approach to Málaga runway 12 after the first missed approach. The operator considered it probable that:

- *On the missed approach, the FMC logic transitioned to the missed approach phase (Go Around), which was altitude limited to 2200 ft.*
- *The aircraft climbed to FL090. However, whether this was ever entered into the FMC cruise page could not be confirmed. If it wasn't, the FMC could have remained at 2200 ft.*
- *An updated approach via TOLSU required the aircraft to be at FL070 or above at this waypoint on the route.*
- *As the FMC believed it was at 2200 ft, it couldn't comply with the FL070 or higher restriction at TOLSU, resulting in the ALT CONSTRAINT TOLSU error message reported by the crew.*
- *An updated cruise level of FL090 could have prevented this message in the CDU.*

1.17. Organisational and management information

N/A.

1.18. Additional information

1.18.1. The operator's in-flight fuel management procedure

The Operator's Operations Manual Part A (OM-A), paragraph 8.3.7.1, details the in-flight checking and fuel management procedures from which a translated extract is shown:

> *Subject to assessing reasonable certainty of landing, the Commander is permitted to use the alternate fuel to continue to the destination aerodrome, (including possible holding), to land there with not less than final reserve fuel. It is typically used when the Commander decides a safe landing, with not less than final reserve fuel*

remaining, can be accomplished at the destination aerodrome. The commander makes this decision after taking into account the traffic and the operational conditions prevailing at the destination and destination alternate aerodromes. Practically speaking this in-flight analysis simply allows the Commander to convert fuel originally allocated for a diversion to an alternate into fuel to continue to or "divert to" the destination.

In addition, Part A, paragraph 8.3.7.6 of the same operator's manual refers to the minimum fuel declaration, a translated extract of which is shown below:

The pilot-in-command shall advise ATC of a minimum fuel state by declaring "ATC, MINIMUM FUEL, RYR 123" when, having committed to land at a specific aerodrome and the pilot calculates that any change to the existing clearance to that aerodrome may result in landing with less than planned final reserve fuel.

Note 1: The declaration of MINIMUM FUEL informs ATC that all planned aerodrome options have been reduced to a specific aerodrome of intended landing and any change to the existing clearance may result in landing with less than planned final reserve fuel. This is not an emergency situation but an indication that an emergency situation is possible should any additional delay occur.

Note 2: It should be noted that Pilots should not expect any form of priority handling as a result of a "MINIMUM FUEL" declaration. ATC will, however, advise the flight crew of any additional expected delays as well as coordinate when transferring control of the aeroplane to ensure other ATC units are aware of the flight's fuel state.

It is important to note that a common element in every scenario is that each time MINIMUM FUEL is declared, the Commander has already committed to land at a specific aerodrome and is concerned that a landing may occur with less than final reserve fuel in the tanks.

1.18.2. The operator's procedures for responding to GPWS warnings

The section on "Manoeuvres - Non-Normal Manoeuvres", GPWS, in the Operator's QRH (Quick Reference Handbook) explains that in the event of a "CAUTION TERRAIN" alert, pilots should correct the aircraft's flight path to clear the terrain and in the case of a "TERRAIN, TERRAIN, PULL UP" warning, they should disengage the autopilot and autothrottle, apply maximum thrust and commence as steep a climb as possible to avoid the terrain[18].

The procedure also notes that should a GPWS Caution alert (such as the "CAUTION TERRAIN" alert) occur 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. However, the operator states that the "terrain escape"

[18] The full procedure can be consulted in Annexe 5.1.

manoeuvre should be executed immediately and without discussion upon receipt of any GPWS PULL UP warning, irrespective of the flight conditions or aircraft configuration.

In his post-incident statement, the captain indicated that being aware of the procedures described above and the possible consequences, he decided to take the controls in manual and initiate a climb back to 4800 ft (although he eventually stopped at 4300 ft) rather than perform a "terrain escape" manoeuvre because, if the approach was aborted, the fuel quantity could have become a real threat and a safe landing could not have been guaranteed. In his statement, he added that he made his decision based on the amount of fuel remaining and the fact that he had visual contact with the ground.

1.18.3. Distribution of PF/PM tasks

Generally speaking, regarding normal operations, the Boeing 737-700/800 FCOM[19] states that the PF is responsible for flight path control, speed control, aircraft configuration and navigation. The PM, meanwhile, is responsible for reading checklists, making communications and performing tasks as requested by the PF.

During the descent and approach preparation phase, the FCOM[20] states that the PF must hand over control of the aircraft to the PM in order to prepare the approach in the FMC, which includes selecting the arrival and approach.

1.18.4. Minimum flight altitudes and Altitude Awareness

The Operator's Operations Manual Part A provides section 8.1.1 on Minimum flight altitudes, a translated extract of which is shown below:

> *Ryanair flight crew shall not fly below specified minimum altitudes except when necessary for take-off or landing or descending in accordance with procedures approved by the IAA.*

The same manual later addresses altitude awareness in section 8.3.0.2.4 below, from which a translated extract is also shown:

> *Altitude awareness is achieved by the active attention of the Flight Crew. This awareness with associated continuous monitoring is the primary means of ensuring that cleared altitudes are adhered to and clearances are not infringed.*

1.18.5. Measures taken by the air operator, Ryanair, after the incident

The operator conducted an internal investigation into the incident and proposed additional training for the flight crew as a mitigation measure.

[19] Normal procedures – Introduction.

[20] Normal procedures – Amplified Procedures- Cruise - Descent Procedure Pilot Flying and Pilot Monitoring.

1.18.6. Additional information from ATC

- The Aeronautical Information Publication (AIP) of Spain provides the ATC-ICAO Minimum Surveillance Altitude Chart that was in force on the date of the incident for Málaga-Costa del Sol Airport.

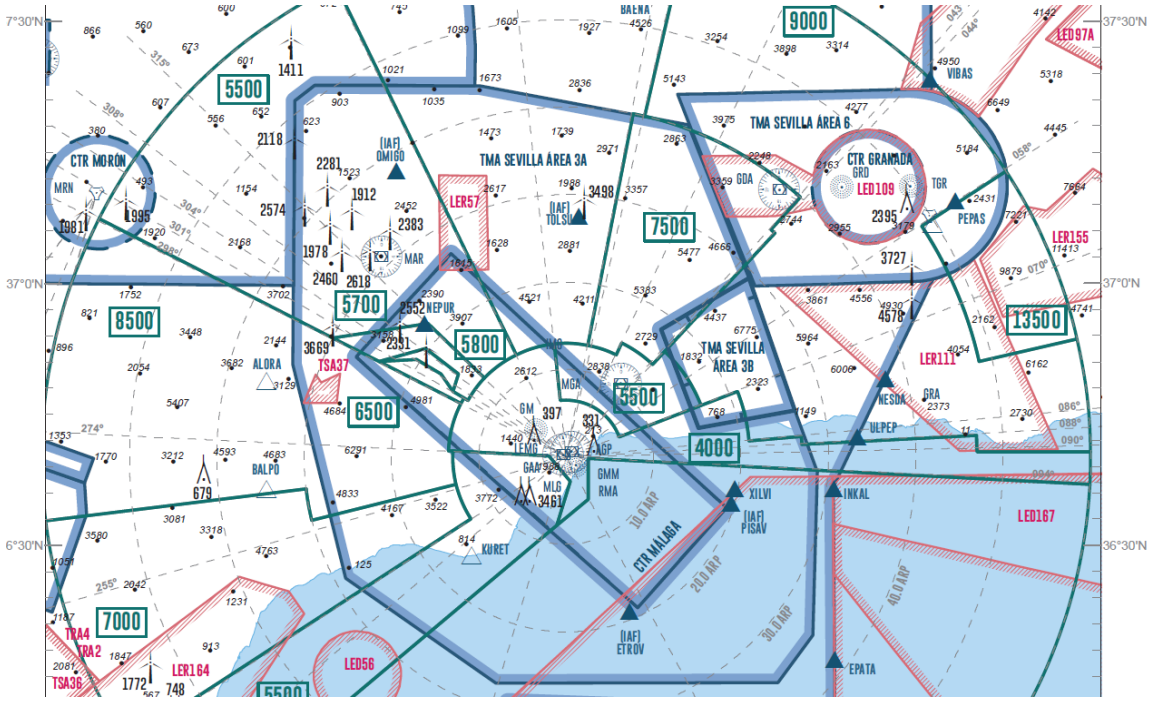


Fig.6: Relevant extract from the ATC-ICAO Minimum Surveillance Altitude Chart for Málaga-Costa del Sol Airport

- The *Air Traffic Regulation*[21] establishes the following:
  4.2.1.2 "The objectives of air traffic control, as prescribed in Book Three, do not include the prevention of collisions with terrain. Therefore, the procedures prescribed in this Book do not relieve the pilot of their responsibility to ensure that any clearances issued by air traffic control units are safe in this respect, except when an IFR flight is given radar vector guidance or a direct route that diverts the aircraft from an ATS route, for which the procedures in Chapter 6, paragraph 4.6.6.5.2 apply.

- The *Air Traffic Regulation* establishes the following:
  4.6.6.5.2. "When the controller is providing vector guidance to an IFR flight or giving a direct route that diverts the aircraft from an ATS route, they must ensure that the obstacle clearance margin is complied with at all times until the aircraft reaches a point where the pilot re-assumes responsibility for navigation. Whenever necessary, the minimum altitude for vector guidance must include a correction to allow for the effect of low temperatures. However, the regional supplementary procedures (ICAO Doc. 7030) provide for procedures applicable to the EUR region to which the exception provided for in this paragraph does not apply'.

- The *Air Traffic Regulation* uses the following wording:

[21] Royal Decree 1180/2018 of 21 September, which modifies RD 57/2002 of 18 January approving the implementation of the Air Traffic Regulation

1.1.3. Minimum fuel

…indicación de combustible mínimo	
*a) COMBUSTIBLE MÍNIMO;	*a) MINIMUM FUEL;
b) RECIBIDO [NO SE PREVÉ DEMORA o PREVEA (información sobre la demora)].	b) ROGER [NO DELAY EXPECTED or EXPECT (delay information)].
*Indica una transmisión del piloto.	* Denotes pilot transmission.

- At the end of June 2021, the Minimums Alert / Minimum Safety Altitude Warning (AM / MSAW) function was implemented in the unit. These alerts are inhibited in the vicinity of Málaga-Costa del Sol Airport, specifically within a cylinder centred on the airport's ARP, measuring 31 NM in radius and of variable altitude depending on the different zones defined, within which the aforementioned alerts are inhibited for traffic arriving or on take-off. The purpose of this inhibition is to prevent spurious MSAW alerts from being triggered by traffic on approach or take-off and below the established minima at that time, which explains why no such alerts were triggered at the control position during this incident.

1.18.7. Measures adopted by ENAIRE after the incident

The navigation service provider, ENAIRE, carried out an internal investigation into the incident, on the basis of which it proposed the following measures (in May 2022) in the interest of improving safety:

- Request that the AIS name waypoint 15.8 DME MAR to make it easier for crews to identify said point, from which the descent from 4800 ft to 3200 ft on ILS-Z RWY12 can be continued.
- Alert the LEMG air traffic controllers to the detected deviations and minimum breaches.
- Advise LEMG air traffic controllers to clear traffic to NEPUR at 6000 ft (so that it is above the minimums in that area) and to pay particular attention to traffic carrying out the manoeuvre after a missed approach.
- Contact LIDO-Jeppesen to try to highlight the 4299 peak that appears in AIP and not on their charts.
- Contact LIDO-Jeppesen to highlight information in regard to the detected problem on their charts.
- Implementation of AMIN[22] in airport facilities.

One year after the incident, ENAIRE reported that the first six actions had already been implemented and that for the seventh (the AMIN system), the estimated target date for implementation was June 2025.

[22] MSAW-AMIN is the adaptation of the MSAW (Minimum Safety Altitude Warning) alert in the control tower environment. In other words, it is a safety tool based on the ATS surveillance system designed to warn the controller about a predicted or actual violation of the defined minimum altitude by an IFR aircraft. It incorporates the safeguards of the SID and IAC procedures, including the missed approach section.

Furthermore, on 02 November 2023, a process of transition began as part of the implementation of a new project called MIDAS (Málaga Improved Design of Air Space), whose most significant lines of action are as follows:

- MIDAS uses RNAV1 precision navigation and the AMAN (Arrival Management) arrival manager to create new arrival routes that optimise the flight sequencing and are composed of reference points that improve the efficiency of air traffic management and make optimal use of the airspace.
- The new departure routes allow for an environmental improvement in emissions while maintaining the acoustic footprint.
- The separations between successive aircraft are more regular, and the number of pilot-controller communications is lower, which simplifies the workload of both actors.
- The approaches have also been modified, in particular the ILS Z approach chart for Málaga runway 12 (attached in appendix 5.3), the STAR to Málaga runways 12 and 13 (attached in appendix 5.4) and the ATC-IACO minimum surveillance altitude chart (attached in appendix 5.5).

1.19. Special investigation techniques

N/A.

2. ANALYSIS

2.1. General considerations

The crew of the aircraft had the required licenses and medical certificates for the flight. Their activity prior to the incident flight is considered to be compliant with the applicable rules.

The aircraft was airworthy, and its documentation was in order.

Both the executive controller and the sector planner had valid licenses, unit endorsements and medical certificates. Their activity prior to the incident flight is considered to be compliant with the applicable rules.

The meteorology during the flight was in no way limiting and did not have any adverse effect on it.

2.2. Generation and resolution of the conflict

The first approach ended in a missed approach, but it cannot be considered a conflict itself. It was a situation that had been foreseen in the approach briefing; it was nothing unusual for the pilots, and the aircraft had enough fuel to divert to the alternate airport (Seville) or to make a second approach. The flight crew opted for the second option, judging that they had the necessary safety margins (just before the missed approach, there was 2703 kg of fuel on board, 558 kg more than the fuel needed to divert to the Seville alternate, and considerably more than the fuel consumed to make the new approach and land at LEMG, which was 1100 kg).

2.2.1 The fuel issue

The first obstacle for the pilots was the fact that they were unable to reprogram the aircraft's FMC with the new route to follow for the second approach. This increased the workload on the flight deck.

The captain, who was acting as PM and therefore in charge of communications with ATC, focused on reprogramming the FMC and, not being able to activate the new approach and lateral navigation, decided to follow the dashed line route displayed on the ND using the different autopilot modes sequentially, which contributed to the deviation from the route and explains the premature turn before NEPUR and the flight parallel to MAR radial 148. Despite the issues with reprogramming the FMC, no radar vectors were requested by the crew from ATC on this segment of the approach.

At 08:52:50 h (see ⑦ in figure 1), the first conflict arose: when the EI-EVR aircraft was maintaining FL080 and heading 268º at 26.5 NM NNW of LEMG, the aircraft crew informed LEMGASM in the following terms: *"RYR93SM, we are running low on fuel now; we are committed to Málaga".* Six seconds later, LEMGASM informed him that he was number 6 in the approach sequence and that he would call him in 12 NM to turn. At 08:53:04 h, the

crew of the EI-EVR aircraft requested priority approach using the following words: *"Requesting priority approach, RYR93SM".*

This situation gave rise to a number of inconsistencies:

- Firstly, it was not true that the aircraft was running dangerously low on fuel. In fact, it was not given priority of any kind to land at LEMG; the sequence planned by the controllers was followed, and yet it landed with 1556 kg of fuel on board, i.e. 437 kg above the calculated final reserve fuel, which was 1119 kg.
- Secondly, the crew did not use standard phraseology to declare minimum fuel. Instead, they expressed an opinion or an intention: *"We are committed to Málaga"*, and in the second sentence, *"Requesting priority approach, RYR93SM"*, they did not verbalise the existence of an emergency that would require action to be taken by the controllers, which was why none was taken.

The crew were understandably more concerned about fuel management on the second approach, but this concern did not match the low fuel scenario described and verbalised as *"we are running low on fuel now"*. The amount of fuel remaining after landing confirmed that there was never a real danger of not having enough fuel to make the second approach.

2.2.2 The altitude issue

This conflict arose later when the aircraft began to fly below the prescribed safety altitudes for the route it was flying.

At 08:56:14 h, on course for NEPUR and descending through 6700 ft (it had been cleared to descend to 6000 ft at 08:54:25 h), the crew of the EI-EVR aircraft requested confirmation of clearance to the ILS Z RWY 12 approach without initially receiving a response. After 15 seconds, when the frequency became clear, the EI-EVR crew again requested confirmation of the clearance, and LEMGASM confirmed that they were cleared. They selected 4800 ft in the altitude window of the MCP (see ⑩ in figure 1). This is the first inconsistency related to flight altitude: the crew had been cleared to descend to 6000 ft, yet they decided to descend to 4800 ft. The request for confirmation of the clearance is considered relevant because although the workload in the communications was not high, the pilots perceived it as such (as they confirmed in their interviews).

We did not have access to the recordings of the conversations between the pilots on the flight deck (the CVR was not preserved after the flight), and therefore we were unable to ascertain why this decision was taken. Similarly, in the interviews conducted subsequently, no answer to this question emerged beyond the fact that the workload perceived by both pilots was high.

Under these circumstances, at 08:57:05 h (see ⑪ in figure 1), while proceeding to NEPUR, the EI-EVR aircraft descended below the cleared altitude (which was 6000 ft). From this point onwards, the aircraft remained below the altitude cleared by ATC.

Forty-eight seconds later, the problem, far from being corrected, worsened, as the pilots, at 08:57:53 h (see ⑫ in figure 1), while descending through 5169 ft, selected 3200 ft in the MCP altitude window.

At 08:58:35 h (see ⑬ in figure 1), when the EI-EVR aircraft was descending through 4554 ft, it turned to its right before reaching the NEPUR waypoint and flew parallel and 1.5 NM to the west of MAR radial 148.

According to the ILS Z RWY 12 approach chart published for LEMG in AIP Spain, aircraft must follow radial 148 of the MARTIN (MAR) VOR/DME to eventually intercept the runway 12 localizer. The NEPUR waypoint on this radial must be overflown at 4800 ft or above, and then descend to 3200 ft from mile 15.8 DME MAR to intercept the runway 12 localizer. Clearly, the EI-EVR aircraft did not conduct its approach as described above.

Meanwhile, the aircraft continued to descend, and at 08:59:48 h, the CAUTION TERRAIN alert was activated. The GPWS alerted the flight crew to the presence of the terrain.

Ten seconds later, at 08:59:58 h (see ⑭ in figure 1), the TERRAIN, TERRAIN, PULL UP warnings were activated, the autopilot disengaged, and the aircraft began to climb. The lowest barometric altitude recorded was 3235 ft. The minimum radio altimeter altitude recorded was 1065 ft at 09:00:12 h whilst already climbing through 3343 ft at 18.5 NM from LEMG.

The captain took over the controls and assumed the role of PF until landing, and according to the pilots' statement after the incident, the visual conditions during the approach were VMC, and they were in visual contact with the terrain at all times.

The GPWS warning was not corrected in accordance with Ryanair's procedure for terrain escape. The fact that the escape manoeuvre would have involved a new approach, with the consequent fuel consumption, contributed to this decision.

From the time the aircraft descended from the 6000 ft to which it was cleared (this happened at 08:57:05 h) until the GPWS alerted the crew of its altitude error (this occurred at 08:59:48 h), 2 minutes and 43 seconds elapsed. During this time, the crew was not aware of their error, nor were the controllers, as they did not alert them to the abnormal situation.

It should also be pointed out that the aircraft descended below the minimum vector guidance altitude (MVA) several times without ATC alerting the pilots. Specifically:

- At 08:57:43 h, the aircraft was descending through 5400 ft in an area where the MVA was 5500 ft.
- At 08:59:23 h, the aircraft continues descending through 3900 ft in an area where the MVA was 5700 ft.
- At 09:00:12 h, whilst already climbing through 3343 ft at 18.5 NM from LEMG in an area where the MVA was 5800 ft.

Following the communications between ATC and the aircraft at 08:56:34 h and 09:03:02 h, there were no further communications. In the first ATC reiterated the clearance for the aircraft to carry out the ILS Z approach to LEMG runway 12 (when it was above the cleared 6000 ft), and in the second, the controller transferred the EI-EVR aircraft to the LEMG control tower frequency.

6 minutes and 28 seconds elapsed between these two consecutive communications, and for almost all of that time (from 08:57:05 h), the aircraft was flying below the cleared altitude and (from 08:57:43 h) below the applicable MVAs.

The air traffic control unit did not communicate with the aircraft to warn its crew that they were flying below the cleared altitude, nor the applicable MVAs.

The aircraft eventually continued its approach and completed the flight with no further issues.

The actions taken by the aircraft operator and the air navigation service provider following the incident are deemed sufficient to prevent an event of this type from occurring again. For this reason, no safety recommendations are issued in this report.

3. CONCLUSIONS

3.1. Findings

- The EI-EVR aircraft was cleared to proceed to NEPUR on its second approach, descend to 6000 ft and from NEPUR fly the ILS Z RWY 12 approach to Málaga Airport (LEMG).
- The EI-EVR aircraft descended below 6000 ft without being cleared to do so.
- The aircraft turned to its right before reaching the NEPUR waypoint and flew parallel to MAR radial 148 at 1.5 NM west of it.
- The aircraft crew did not fly the cleared approach correctly, either in terms of the plotted route on the chart or the altitude.
- The aircraft flew below its cleared altitude for 2 minutes and 43 seconds (and for part of that time below the applicable MVAs as well) until the GPWS alerted the crew to their error. No communication was received from ATC during this time.
- The aircraft had enough fuel on board to make the flight to LEMG and to fly the second approach after being instructed to miss the first and go around.

3.2. Causes/contributing factors

The investigation has concluded that the incident was caused by the flight crew's failure to correctly perform the Málaga (LEMG) approach they had been cleared to follow.

The following factors contributed to the incident:

- ATC's failure to actively monitor and detect that the aircraft was flying below the cleared altitude in the first instance and subsequently below the minimum vectoring altitudes prescribed for the different areas through which the aircraft flew.

4. OPERATIONAL SAFETY RECOMMENDATIONS

None.

5. APPENDIX

5.1. The operator's procedures for responding to GPWS warnings

Ground Proximity Warning System (GPWS) Response (RYR)

GPWS Caution

Accomplish the following maneuver for any of these aural alerts:

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

Pilot Flying	Pilot Monitoring
Correct the flight path or the airplane configuration.	

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

- localizer approach, day or night
- circling approach from an ILS, day or night
- when conditions require a deliberate approach below glideslope, daylight VMC only
- unreliable glideslope signal, daylight VMC only.

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.

GPWS Warning

Accomplish the following maneuver for any of these conditions:

- Activation of "PULL UP", "OBSTACLE OBSTACLE PULL UP" warning.
- Other situations resulting in unacceptable flight toward terrain.

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.

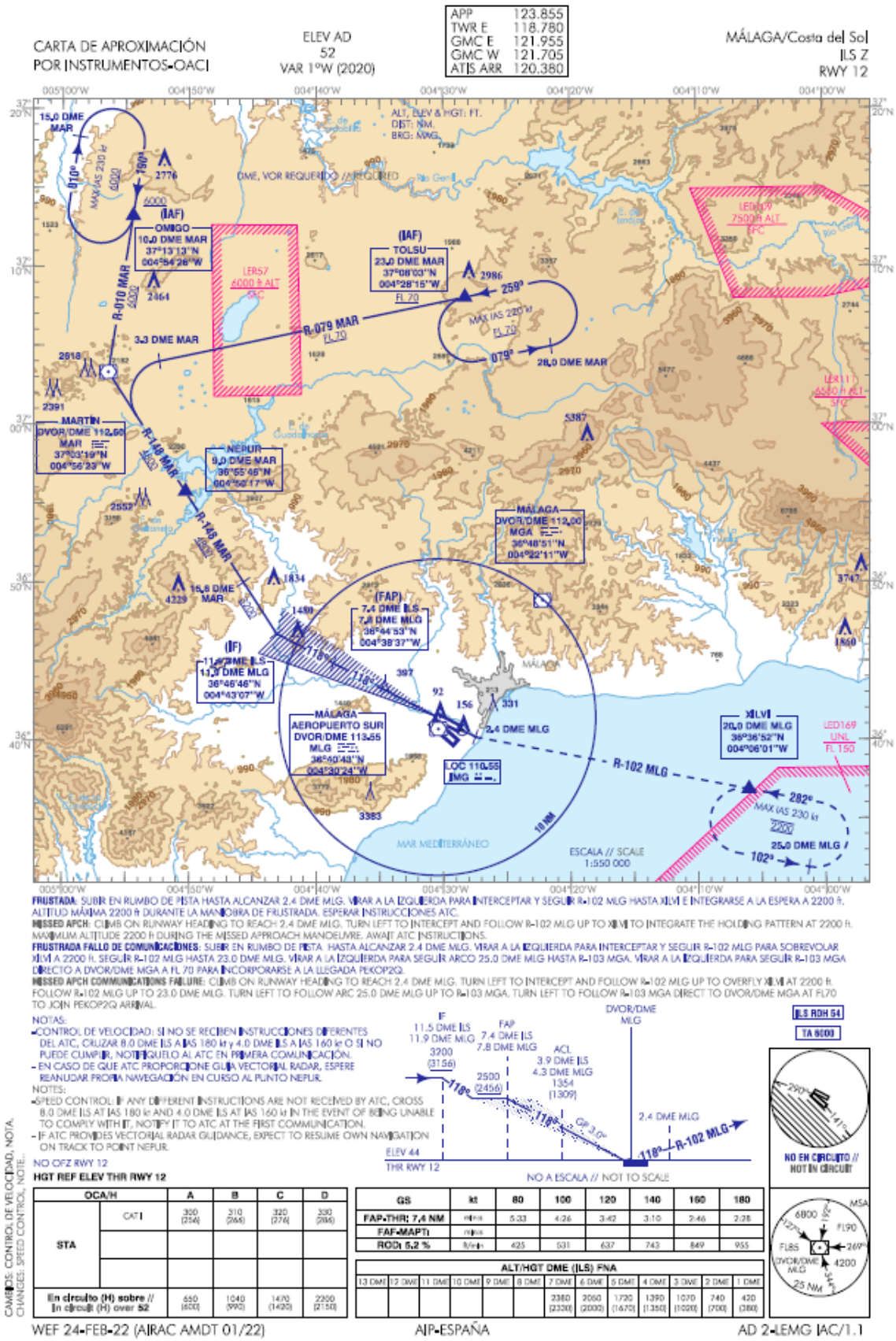
Note: Do not use flight director commands.

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.

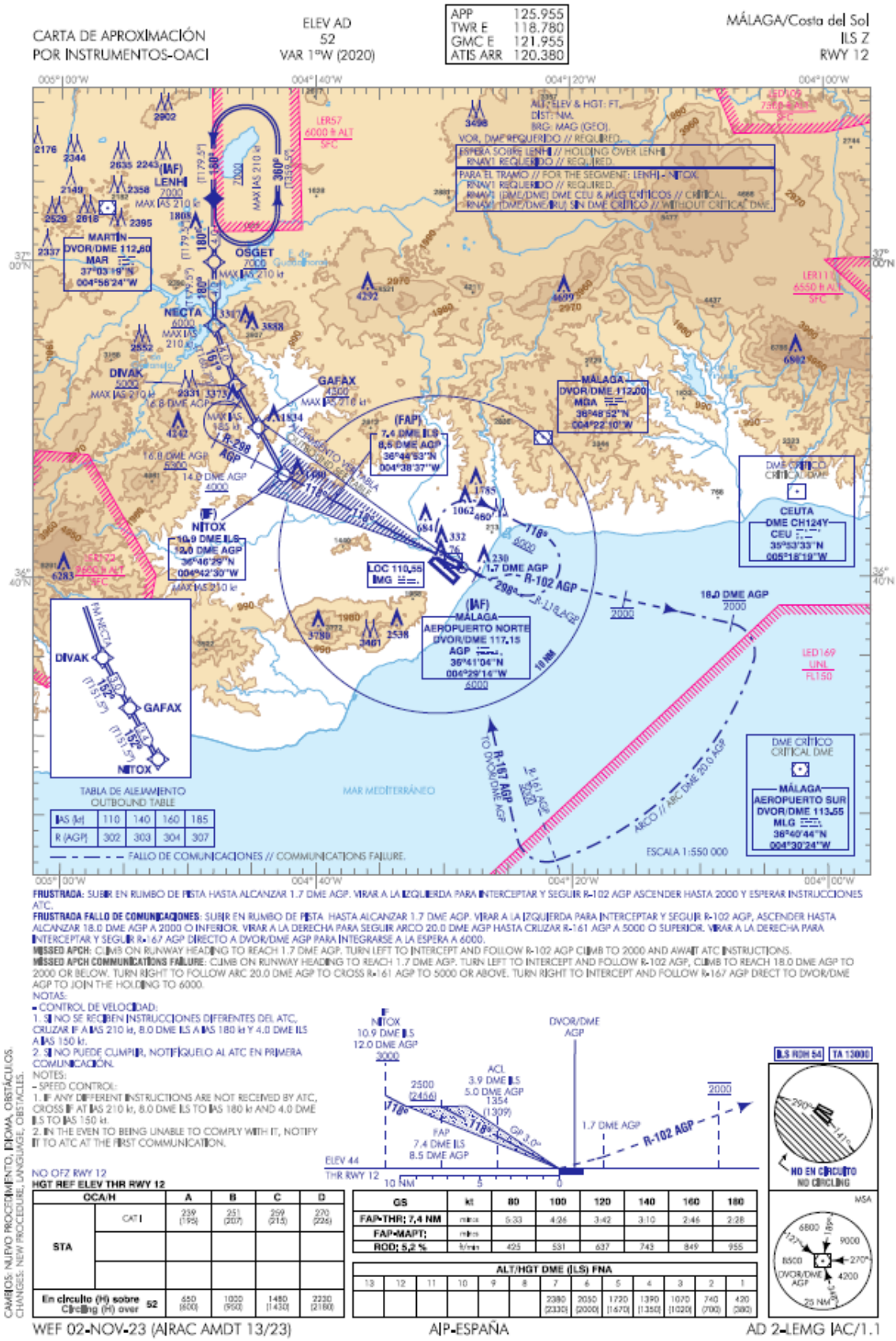
Note: The terrain escape maneuver is executed immediately** and without discussion on receipt of any EGPWS PULL UP warning regardless of inflight conditions or airplane configuration.

Note: ** Deviation from this policy needs to be approved by NPFO and where applicable included in revised Airfield Briefs or as a Crew Bulletin in the Company NOTAM section of the briefing pack.

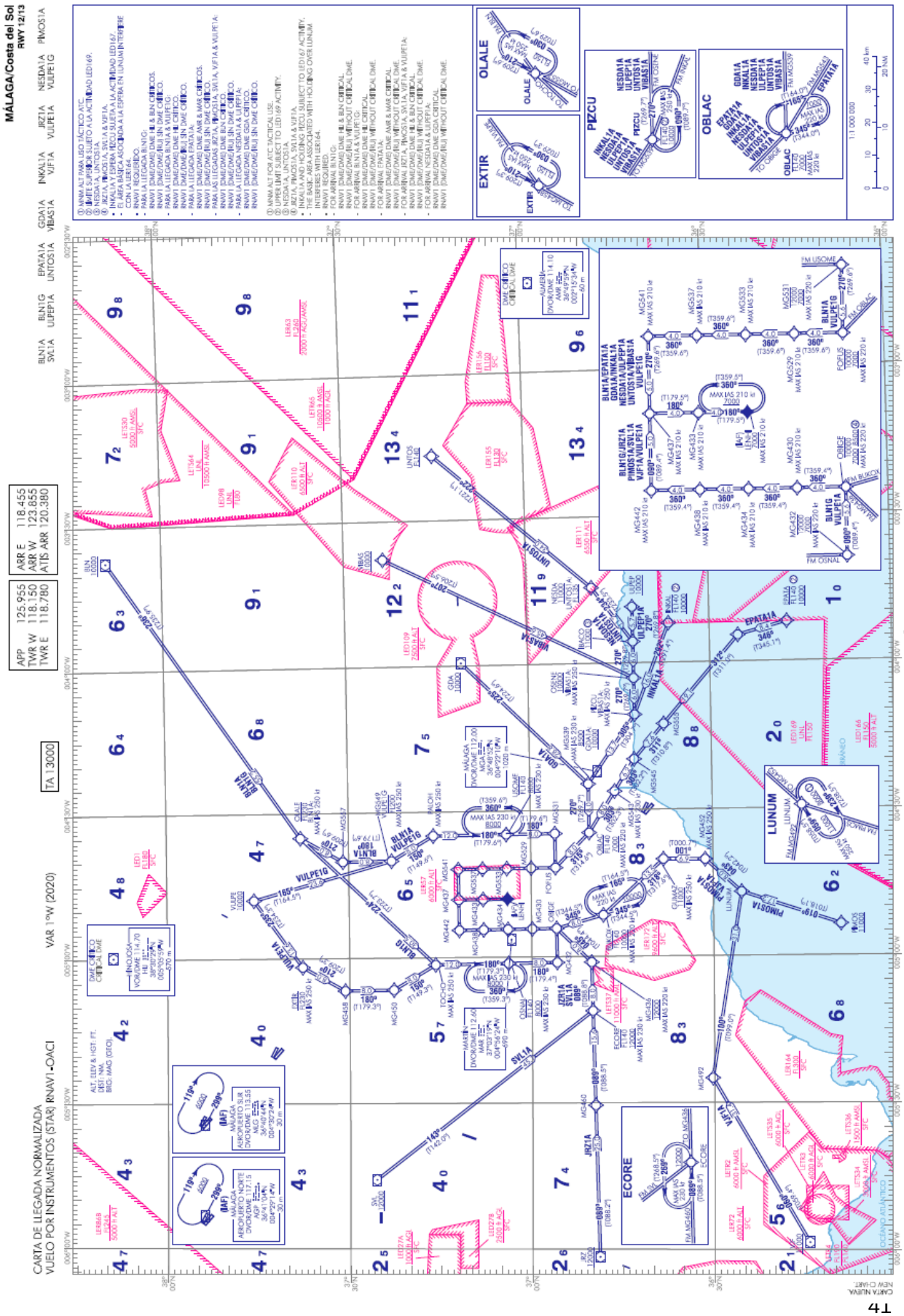
5.2. ILS Z approach chart for Málaga runway 12 (as at the date of the incident)



5.3. ILS Z approach chart for Málaga runway 12 (as of 02-Nov-2023)



5.4. STAR to Málaga runways 12 and 13 (as of 02-Nov-2023)



5.5. ATC-ICAO minimum surveillance altitude chart (as of 02-Nov-2023)