

DATA SUMMARY

LOCATION

Date and time	Thursday, 4 August 2011; 17:05 UTC¹
Site	Madrid-Barajas Airport (LEMD) (Spain)

AIRCRAFT

Registration	LX-LGX
Type and model	EMBRAER 145 LU
Operator	Luxair

Engines

Type and model	ALLISON AE3007 A1
Number	2

CREW

	Captain	First officer
Age	42 years old	29 years old
Licence	ATPL(A)	CPL(A)
Total flight hours	6,825:25 h	2,279:49 h
Flight hours on the type	3,988 h	2,050 h

INJURIES

	Fatal	Serious	Minor/None
Crew			3
Passengers			44
Third persons			

DAMAGE

Aircraft	None
Third parties	None

FLIGHT DATA

Operation	Commercial Air Transport – Scheduled – International – Passenger
Phase of flight	Approach

REPORT

Date of approval	30 January 2013
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¹ All times in this report are in UTC unless otherwise indicated. To obtain local time, add 2 hours to UTC.

1. FACTUAL INFORMATION

1.1. Description of the event

The aircraft, an Embraer 145, registration LX-LGX and call sign LGL 3837, was on a flight between the Luxembourg International Airport (ELLX) and the Madrid-Barajas Airport (LEMD) on 4 August 2011.

At 16:57:55, the aircraft was descending in the vicinity of the Madrid-Barajas Airport. It was cleared to flight level 140 and had been informed that it would be making an approach to runway 18L at Madrid-Barajas. At that point, the crew contacted the RES² control sector, which replied³: "LGL3837 MUY BUENAS ON RADAR CONTACT, CONTINUE DESCENT TEN THOUSAND FEET ON QNH ONE ZERO ONE SIX TO BE LEVELED AT TAGOM⁴". The crew acknowledged saying, "DESCENDING FIVE THOUSAND FEET ONE ZERO ONE SIX LEVELED AT... TAGOM LG38... LGL3837".

At 17:00:22 the controller on the RES sector frequency was relieved. At that point the aircraft was above the minimum altitude specified in the standard terminal arrival route, which was 10,000 ft.

There were no more exchanges between the crew and ATC until the aircraft was transferred to the AIS⁵ control sector frequency at 17:04:09. By that point the aircraft had descended below both the minimum STAR⁶ altitude of 10,000 ft and the minimum radar vectoring altitude⁷ of 9,000 ft, and was at 7678 ft⁸.

The crew of the aircraft contacted sector AIS and reported, "LGL 3837 DESCENDING FIVE THOUSAND FEET TO TAGOM". Sector AIS replied, "LGL 3837 RADAR CONTACT MAINTAIN HEADING AFTER TAGOM FOR RUNWAY 18L". At that point the aircraft was at 7,349 ft.

The aircraft descended below the minimum altitudes specified in the STAR, the minimum vectoring altitude and the minimum sector altitude, and continued descending until two EGWPS⁹ warnings were received: "TERRAIN TERRAIN" and "TERRAIN PULL-UP". At that point the crew disengaged the autopilot and started to climb. The aircraft had descended to a minimum altitude of 6,290 ft.

² RES – Madrid Director Sector East.

³ These and subsequent exchanges took place in English (see Appendix B).

⁴ TAGOM: Initial Approach Fix (IAF) for runways 18R/18L for aircraft arriving from the east.

⁵ AIS – Madrid Initial Approach Sector.

⁶ STAR – Standard Terminal Arrival Route.

⁷ MRVA – Minimum Radar Vectoring Altitude.

⁸ All the aircraft track altitude data has been obtained from QAR which is referred to 1,013 hPa (pressure on standard atmosphere on sea level). QNH in Madrid Barajas airport was 1,016 hPa, which matched with a correction of + 90 ft to add to all the altitudes of this report.

⁹ EGPWS – Enhanced Ground Proximity Warning System.

A few seconds later, at 17:06:10, the AIS sector controller instructed the aircraft to turn to heading 260° for traffic separation and, after receiving no reply, to heading 270°. At that point the crew reported "HEADING TWO SEVEN ZERO AND WE'LL MAINTAIN SEVEN THOUSAND FEET DUE TO MOUNTAIN LGL3837". Eventually sector AIS instructed the aircraft to climb to 10,000 ft.

1.2. Personnel information

1.2.1. Crew information

The captain was a 42-year old French national. He had a valid and in force JAR-FCL airline transport pilot license (ATPL(A)) and an EMB 135/145 rating valid and in force. He also had a valid and in force class 1 medical certificate. He had a total of 6,825:25 flight hours, 3,988 of which had been on the type.

The first officer was a 29-year old Belgian national. He had a valid and in force JAR-FCL commercial pilot license (CPL(A)) and an EMB 135/145 rating and in force. He also had a valid and in force class 1 medical certificate. He had a total of 2,279:49 flight hours, 2,050 of which had been on the type.

Both had level 5 English language competency certificates and had taken the training courses approved for the operator pursuant to EU OPS.

The captain had flown to Madrid-Barajas the day before the incident, when the airport was in a north configuration¹⁰. As for the first officer, he had last flown into Madrid-Barajas on 20 July 2011, with the airport in a south configuration¹¹.

1.2.2. Information on ATC personnel

Over the course of the incident, the aircraft was under the control of two ATC stations: RES sector (Director Sector East) and AIS sector (Initial Approach Sector). Each of these stations has, in turn, two control posts, an executive controller and a planner controller.

The controllers, of Spanish nationality, had valid licenses and medical certificates. They had over ten years of ATC experience and the required valid approach rating. They had also taken the courses necessary for this rating. The AIS sector executive controller had a level 6 English language competency certificate, while the other controllers had level 4.

¹⁰ Runways 36L/36R used for landing and 33L/33R for takeoff.

¹¹ Runways 18L/18R used for landing and 15L/15R for takeoff.

1.3. Aircraft information

1.3.1. General information

Aircraft LX-LGX is an Embraer 145 LU, serial number 145147, a maximum authorized weight of 21,990 kg and two ALLISON AE3007A1 engines. The aircraft had valid registration and airworthiness certificates. It also had the corresponding noise limitation certificate.

The aircraft had 28,387.33 h and 26,165 cycles. In keeping with its maintenance program, it had undergone a 100-hour inspection on 22 July 2011 and a C-check on 8 April 2011.



Figure 1. Photograph of the aircraft¹²

1.3.2. EGPWS

The aircraft was equipped with an EGPWS unit. A GPWS is based on radio altitude information. The EGPWS incorporates GPWS functions with additional features. These functions use aircraft geographic position, airplane altitude and an internal database to predict potential conflicts between the airplane's flight path and terrain, and to provide graphic displays of the conflicting terrain.

¹² Image taken from www.airliners.net.

The GPWS/EGPWS has several operating modes that are activated depending on the aircraft's position, descent rate and/or aircraft configuration. Specifically, mode 2, "Excessive Closure Rate to Terrain", provides alerts to avoid impacting the terrain when the aircraft is detected as rapidly approaching the ground. It relies on radio altitude, indicated airspeed, flaps and gear landing configuration and excessive closure rate to terrain. Mode 2, in turn, has two submodes, 2A and 2B.

Mode 2A is active during the climb, cruise and initial approach phases (when the flaps are not in a landing configuration and the aircraft is not in the path). If the aircraft enters the alert envelope, an acoustic "TERRAIN TERRAIN" alarm is sounded and the EGPWS danger lights are illuminated in the cockpit. If the aircraft continues further into the danger zone, the warning lights turn on and the acoustic alarm "PULL UP" is sounded (see Figure 2). This acoustic alarm is repeated until the aircraft exits the danger zone and gains 300 ft in barometric altitude.

Mode 2B has a desensitized alert envelope to allow for normal approach maneuvers without producing unwanted alerts when flying near the ground. This mode is selected automatically when the flaps are in a landing configuration or when conducting an ILS approach with a glide slope and localizer within 2 dots of the centerline. It is also active during the first 60 seconds after takeoff.

If during an approach the aircraft enters the Mode 2B envelope without the gear or flaps in the landing position, the aural alert "Terrain Terrain" is issued and the EGPWS caution lights are illuminated. If the aircraft continues into the envelope, the EGPWS danger lights are turned on and the message "PULL UP" is sounded and repeated continuously until the aircraft exits the warning envelope.

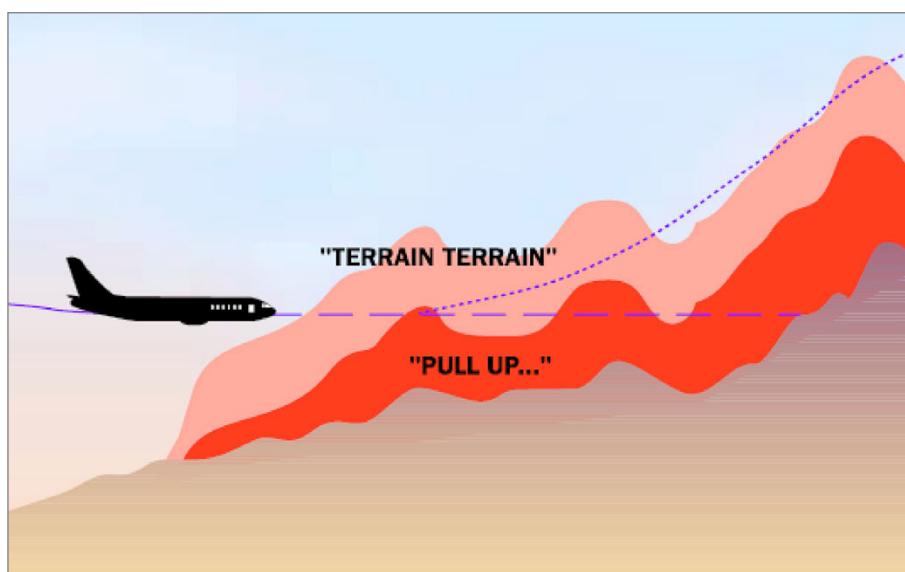


Figure 2. EGPWS alert envelope

If the aircraft enters the Mode 2B envelope with the gear and flaps in a landing configuration, the "PULL UP" message is replaced by a "TERRAIN" message, which is repeated until the aircraft leaves the warning envelope.

Only EGPWS mode provides also alerts on Terrain Awareness Alerting and Warning and Terrain Clearance Floor.

1.4. Meteorological information

The 17:00 METAR reported an average wind speed of 8 kt from 210°, varying from 190° to 260° and gusting to 20 kt. According to the report provided by the Spanish meteorological agency, visibility was in excess of 10 km, there were no significant weather phenomena and the cloud cover did not affect operations.

1.5. ATC communications

The communications held between the aircraft and the different ATC stations are reproduced in Appendix B, with the most relevant exchanges shown in Section 1.1, Description of the event.

1.6. Aerodrome information

The airport has four paved runways: 15R/33L, 15L/33R, 36R/18L and 36L/18R.

When the airport is in a south configuration, runways 18L and 18R are used for landings and runways 15L and 15R for takeoffs.

The AIP¹³ information concerning the "AD 2 –LEMD STAR 2.3" standard approach states that "pilots must plan the descent profile to comply with the following speed and level/altitude restrictions at specific points or equivalent positions".

STAR	POSICIÓN / POSITION	VELOCIDAD / SPEED	ALT / FL
BAN3B	BAN	IAS 250 kt	MAX FL 190
	OBIKI	IAS 220 kt	MAX FL 160
	TAGOM	IAS 220 kt	10.000 ft

Runway 18L has a CAT II/III precision approach and its IAF¹⁴ is TAGOM.

¹³ AIP – Aeronautical Information Publication.

¹⁴ IAF – Initial Approach Fix.

1.7. Flight recorders

The incident was reported to the CIAIAC on 26 October 2011 by the Safety Investigation Authority of Luxembourg, meaning that the information on both the flight data recorder (FDR) and the cockpit voice recorder (CVR) was lost due to the length of time elapsed since the incident. The operator provided the information retrieved from the quick access recorder (QAR) installed on the airplane and which was preserved in its flight data monitoring (FDM) system.

Based on this information, the aircraft descended below the minimum altitude specified for the STAR at 17:02:13, and below the minimum radar vectoring altitude at 17:03:21. The aircraft was subsequently transferred to the AIS control sector by the RES sector controller when the aircraft was at an altitude of 7,678 ft. Sector AIS reported radar contact with the aircraft when it was descending through 7,349 ft.

The EGPWS was triggered at 17:05:06 with an acoustic "Terrain Terrain" warning. A few seconds later, at 17:05:28, the EGPWS issued a "Terrain Pull Up" alert. At 17:05:31, the crew disengaged the autopilot and increased thrust. The minimum altitude reached by the aircraft was 6290 ft (17:05:32), after which the aircraft started to climb (see Figure 3).

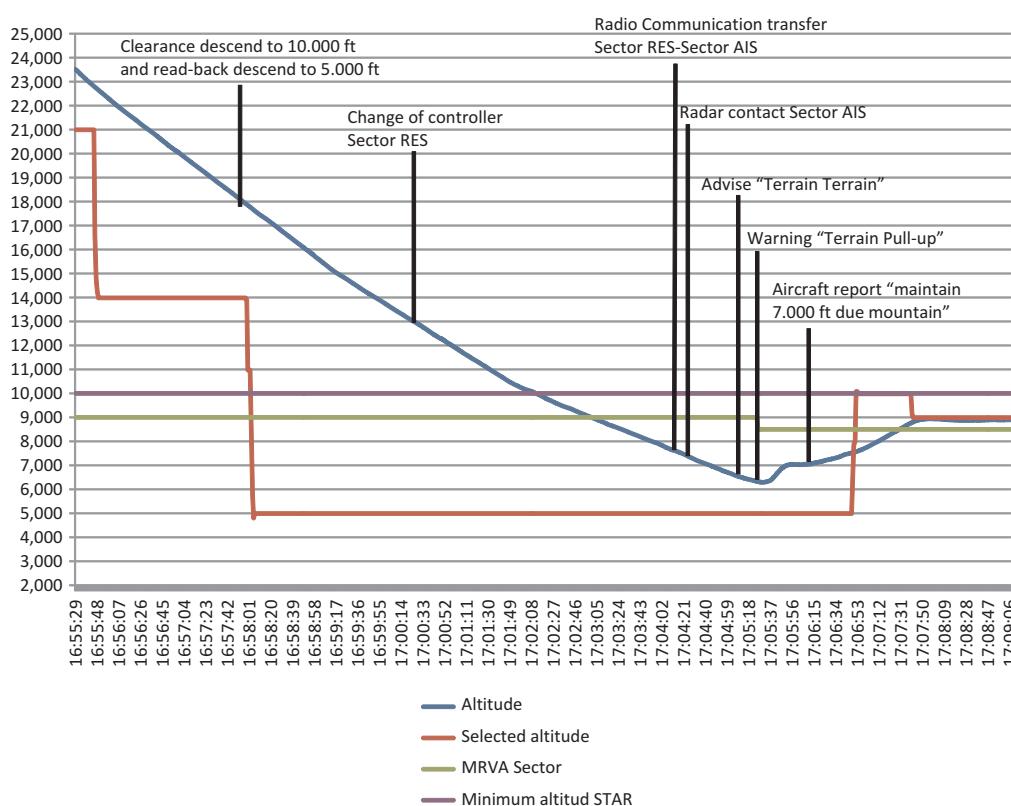


Figure 3. Flight profile of the aircraft during the incident

1.8. Tests and research

1.8.1. Crew's statement

The crew indicated that while flying the standard arrival¹⁵ in preparation for making the initial approach to runway 18L at the Madrid-Barajas Airport, they were cleared to descend to 5,000 ft and proceed directly to the initial approach fix at TAGOM, establishing a descent rate of 1,300 ft/min. Upon starting the approach, they selected Terrain mode¹⁶ on the MFD (multifunction display) and remained in visual contact with the ground at all times. While descending through 6,700 ft they received the EGPWS caution "TERRAIN TERRAIN", followed by "TERRAIN PULL UP". They immediately started to climb and reported the occurrence to the ATC station.

In keeping with their operational flight plan, they had the 16:40 ATIS¹⁷ information L, which informed that the airport was in a south configuration and that runways 18R/L were in use for landings.

During the incident, the pilot flying (PF) was the first officer. In accordance with Luxair's operations manual, the captain (pilot not flying- PNF) was in charge of communications.

Later, after listening to the communications, the crew recognized that it had acknowledged incorrectly. The crew noted that in their experience, it is more common when giving clearances for these altitudes to use the standard phraseology "one zero thousand feet" instead of that used by the RES sector controller of "ten thousand feet".

1.8.2. Information provided by the airline

The operator reported that its pilots fly regularly into Madrid-Barajas and that they are familiar with the airport's two configurations. It noted that the crew prepared for the approach during the flight by using the checklist, in keeping with the company's general procedures. The company's procedure with regard to minimum altitudes is discussed in Section 1.9.1 of this report.

The operator informed that to prepare the descent and approach to the airport, the crew used the Jeppesen 11-1 (ILS or LOC approach RWY 18L) and Jeppesen 10-2B (STAR BAN 3B) approach charts (see Appendix A), the latter of which states that:

¹⁵ STAR BAN 3B.

¹⁶ Graphical representation of the surrounding terrain.

¹⁷ The ATIS (Automated Terminal Information Service) provides continuously updated information that is transmitted on an assigned frequency and details significant aspects of the airport (runway in use, QNH, visibility, wind, transition level, etc.). This information is sent in messages identified with a letter (A-Z) that changes as the information is updated.

Pilots must plan the descent profile to comply with the following speed and level/altitude restrictions at specific points or equivalent positions. If unable to comply advise ATC.

STAR	Position	Speed	FL/Altitude
ADUXO 1B	ADUXO D37.8 RBO BUDOM TAGOM	250 KT 220 KT 220 KT	MAX FL210 MAX FL160 10000'
BAN 3B	BAN OBIKI TAGOM	250 KT 220 KT 220 KT	MAX FL190 MAX FL160 10000'
TERSA 1E	TERSA D37.8 RBO BUDOM TAGOM	250 KT 220 KT 220 KT	MAX FL210 MAX FL160 10000'

The Jeppesen 10-1R approach chart, which shows the minimum radar vectoring altitudes, was not used to plan the descent.

1.8.3. *Statements from ATC personnel*

The sector AIS executive controller reported that the aircraft was transferred to him while supposedly descending through 10,000 ft and that there must have been a miscommunication since he asked the RES sector controller if he had cleared the aircraft to descend, to which he replied no.

The information obtained from the RES sector executive controllers and the planning controllers did not yield anything of relevance to the investigation of the event.

1.8.4. *Radar data*

Based on the radar information, the offgoing RES sector controller noted on the label of the aircraft appearing on the radar (CFL field¹⁸) that he had cleared it to descend to 10,000 ft. When he was relieved, the aircraft was flying above the minimum altitude set by the procedure and the radar label continued to show 10,000 ft as the cleared altitude (see Figure 4).

The CFL field disappeared from the aircraft's label at 17:02:30 once the aircraft descended below 10,000 ft (see Figure 5).

¹⁸ CFL – Cleared Flight Level.

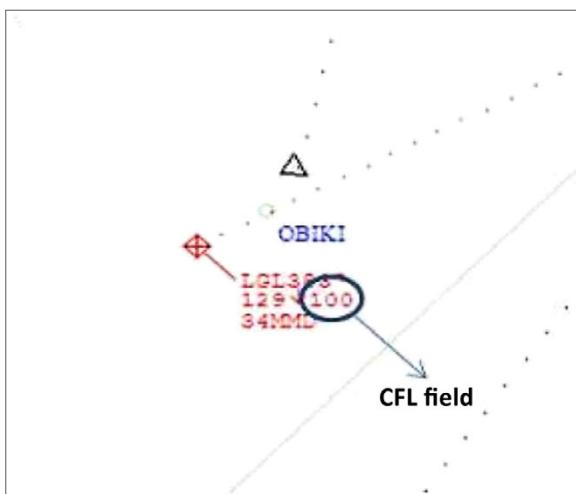


Figure 4. Radar image 17:00:40

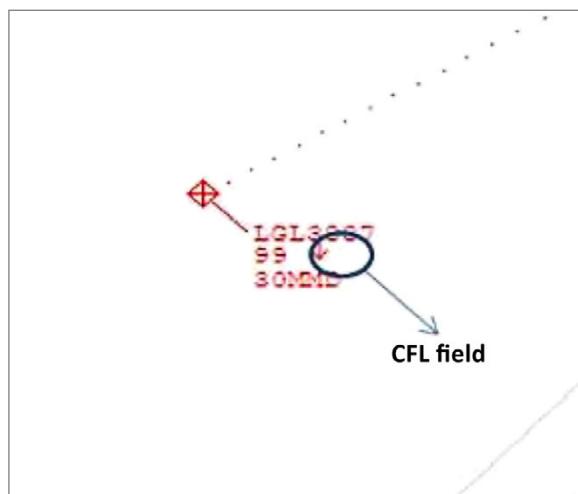


Figure 5. Radar image 17:02:30

By 17:03:45, before it was transferred to sector AIS, the aircraft was already below the MRVA (9,000 ft) and was descending through 8,400 ft (see Figure 6).

The aircraft continued descending until it reached 6,400 ft at 17:05:35, from which point the aircraft began to climb to an altitude of 9,000 ft (see Figure 7).

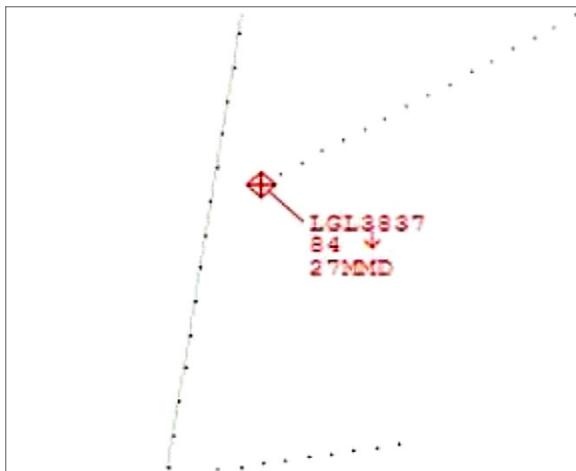


Figure 6. Radar image 17:03:45

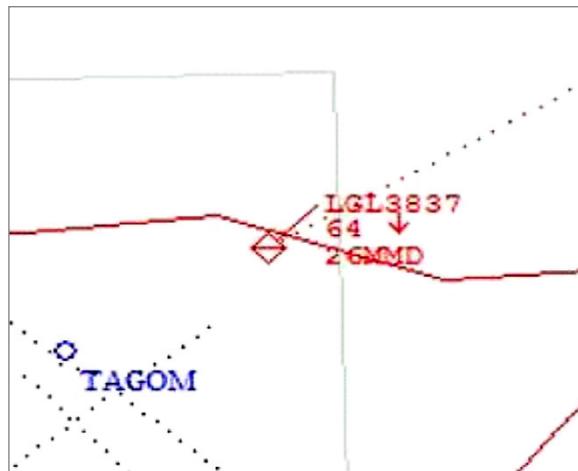


Figure 7. Radar image 17:05:35

1.9. Organizational and management information

1.9.1. Luxair Operations Manual

In Chapter 8.1, in the section "Minimum flight altitudes and en route operating minimums", of Part A of the airline's Operations Manual, crews are reminded that part of the purpose of ATC is not generally to prevent collisions with the ground, and thus

that it is the captain's responsibility to enforce all of the company's requirements in terms of terrain separation.

The section in Chapter 8.3 on "Cockpit approach procedures" notes that premature descents are one of the most frequent causes of accidents, which in most cases can be attributed to overconfidence and navigational errors. Therefore, the minimum flight levels and the minimum en route altitudes must be maintained until both pilots verify or check to their full satisfaction the position of the radio aid associated with the approach or hold procedure.

It also states that safe separation with the terrain must be maintained throughout the approach by using accurate navigation and proper checks. When the minimum sector or safety altitude (MSA¹⁹) is below the minimum altitude (MEA²⁰/MOCA²¹) for a specific route segment, this minimum altitude can be flown if the aircraft can be maintained within the specified sector.

The "Approach preparation" item in Section 8.3.26 states that before starting the approach, the pilot must inform every member of the crew of the planned procedure. One of the topics to cover when preparing the approach is important altitudes, such as the altitude over the outer marker, fix altitudes on stepped approaches, decision altitude/minimum descent altitude/decision height.

In point 300, "Approach preparation", of Section 2.3.5, "Preparations", of Chapter 2, "Normal procedures", of Part B of the airline's Operations Manual, it states that the approach preparation will include, in addition to other considerations, the MSA, initial route and altitudes.

With regard to ATC clearances, Part A of the company's Operations Manual, Chapter 8.3, "Flight procedures", Section 8.3.19, "General cockpit procedures", item 1000, "ATC communications" states that acknowledgments of ATC clearances made by one pilot must be cross checked by the other so as to avoid misunderstandings among the crew. It also notes that any questions regarding clearances must be clarified with ATC, including potential confusion regarding the call sign.

1.9.2. *Information on the air navigation service provider (AENA)*

Based on the information provided, both the RES sector and the AIS sector posts were occupied by an executive controller and a planning controller. When asked about the specific functions of the planning controller, AENA replied that they were not defined.

¹⁹ Minimum Safe/Sector Altitude.

²⁰ Minimum En-route Altitude.

²¹ Minimum Obstacle Clearance Altitude.

Based on the information given, the executive controllers for the RES and AIS sectors had selected on their SACTA screens²² the sector map and the minimum vectoring altitude map.

The SACTA system features a function called "Minimums Alert"²³ that issues warnings when an aircraft descends below the minimum safety altitude. According to AENA, this function is not enabled at any of Spain's control centers because the relevant operational validation to determine which operating parameters are needed for said alert has not been performed yet.

1.10. Additional information

1.10.1. Spain's Air Traffic Rules (RCA in Spanish)

The information contained in the RCA²⁴ specifies that:

3.3.7.3.1.2. The controller shall listen to the readback to ascertain that the clearance or instruction has been correctly acknowledged by the flight crew and shall take immediate action to correct any discrepancies revealed by the readback.

4.2.1.2. The objectives of air traffic control as prescribed in Book Three do not include the prevention of collision with terrain. The procedures described in this Book, therefore, do not relieve pilots of their responsibility to ensure that any clearance issued by air traffic control is safe in this respect, except when an IFR flight is vectored or given a direct routing which takes the aircraft off an ATS route, in which case the procedures in Chapter 6, Section 4.6.6.5.2 apply.

4.4.7.6. Descent below levels specified in a STAR

When an arriving aircraft on a STAR is cleared to descend to a lower level than the level or levels specified in a STAR, the aircraft shall follow the published vertical profile of a STAR, unless such restrictions are explicitly canceled by ATC. Published minimum levels based on terrain clearance shall always be applied.

4.6.1.4. ATS surveillance systems should provide for the display of safety-related alerts and warnings, including conflict alert, minimum safe altitude warning, conflict prediction and unintentionally duplicated SSR codes and aircraft identification.

4.6.4.1. When suitable radar and communications systems are available, information derived from ATS surveillance systems, including safety-related alerts and warnings such as conflict alert and minimum safe altitude warning, should be

²² SACTA – Sistema Automatizado de Control de Tráfico Aéreo (Automated Air Traffic Control System).

²³ MSAW- Minimum Safe Altitude Warning.

²⁴ The correspondence between the RCA items mentioned and ICAO regulations is shown in Appendix C.

used to the extent possible in the provision of air traffic control service in order to improve capacity and efficiency as well as to enhance safety.

10.5.2.1.3.1.2. All numbers used in the transmission of altitude, cloud height, visibility and runway visual range (RVR) information, which contain whole hundreds and whole thousands, shall be transmitted by pronouncing each digit in the number of hundreds or thousands followed by the word HUNDRED or THOUSAND as appropriate. Combinations of thousands and whole hundreds shall be transmitted by pronouncing each digit in the number of thousands followed by the word THOUSAND followed by the number of hundreds followed by the word HUNDRED.

1.10.2. *Measures adopted by the air traffic services provider (AENA) and by the operator (LUXAIR)*

1.10.2.1. Measures adopted by AENA

Over the course of the investigation into this incident, AENA adopted the following measures:

Publication of an "Operational Safety Notebook" for air traffic controllers and distributed to them in January 2012. This document explains the aspects involving faulty readbacks and highlights in detail the factors that cause them and the measures in place to combat them.

Explicit incorporation on read-backs incorporated in safety and new ratings (both en route and approach) training courses as from May 2012.

Aena also reported that they were working to put into operation various safety nets available in the system. In particular they referred that the "minimum alert" or MSAW could be implanted in the month of June 2013.

1.10.2.2. Measures adopted by LUXAIR

For its part the operator, Luxair, decided on the following measures as being the most appropriate for implementation within its organization:

- The Operations Department improved flight preparation procedures and increased awareness among crews in terms of altitude restrictions and limitations.
- The Training Department increased awareness among pilots of MEA (Minimum Enroute Altitude) and MSA (Minimum Safe Altitude) during refresher training.

- The Operational Safety Department, within the Safety Management System, decided to provide internal training to its crews on this event as an example of a lesson learned so as to increase awareness among its crews.

1.10.3. *European Action Plan for The Prevention of Level Bust*

Eurocontrol's "European Action Plan for the Prevention of Level Bust" is a plan for studying the prevention of deviations from cleared levels (level bust). This study recommends that in order to improve communications between pilot and controller, when communications include the altitudes 10,000 and 11,000 ft (and analogously for flight levels 100 and 110), that the following expressions be used to avoid confusion:

- "Altitude one one thousand, that is eleven thousand ft"; and
- "Flight Level one zero zero, that is one hundred".

2. ANALYSIS

The aircraft, with call sign LGL 3837, was on a flight from the Luxembourg Airport (ELLX) to the Madrid-Barajas Airport (LEMD). As it was making a standard approach to the destination airport, the RES sector controller cleared the aircraft to descend to 10,000 ft, entering this into the corresponding field on the aircraft's radar label. The crew acknowledged 5,000 ft. The RES sector controller did not detect the faulty readback. The RES sector controller subsequently transferred the aircraft to sector AIS while it was descending and already below the minimum altitude specified in the procedure and below the minimum vectoring altitude, without either controller noticing it, either from the information on the radar screen or from the communications with the aircraft when its crew reported to the AIS sector controller that it was descending to 5,000 ft. The aircraft was below the minimum altitude in the procedure for about four minutes, and below the minimum vectoring altitude for below three minutes without the RES or AIS sector controllers or the crew itself noticing this. Once the EGPWS issued an alert, the crew acted in accordance with the procedures in its Operations Manual, disengaging the autopilot and initiating a climb.

The RES sector controller cleared the aircraft to descend to 10,000 ft as follows: "LGL3837 MUY BUENAS ON RADAR CONTACT, CONTINUE DESCENT TEN THOUSAND FEET ON QNH ONE ZERO ONE SIX TO BE LEVELED AT TAGOM" ²⁵. This instruction was given clearly and enunciated properly, although the phraseology used was not in accordance with item 10.5.2.1.3.1.2 of the RCA, since the controller said "ten thousand" instead of "one zero thousand". The crew understood and acknowledged

²⁵ All of the communications were held in English. See Appendix B.

5,000 instead of 10,000. This mistake was not detected, or therefore corrected, by the controller. Eurocontrol's "European Action Plan for the Prevention of Level Bust" recommends that to improve communications between pilot and controller, when communications involve the altitudes 10,000 and 11,000 ft (or flight levels 100 and 110), the following expressions be used:

- "Altitude one one thousand, that is 11,000 ft"; and
- "Flight level one zero zero, that is 100".

In this case, it is necessary to remind ATC personnel through refresher training programs of the importance of using standard phraseology in communications with crews, as well of the potential improvement obtained from analyzing already identified situations (as in the case of the Eurocontrol studies). A safety recommendation is issued that is intended to set a uniform stage for all of the parties involved in terms of phraseology and communications.

The crew acknowledged 5,000 ft even though the approach charts specified a minimum altitude for the procedure they were flying of 10,000 ft. Item 4.2.1.2 of Spain's Air Traffic Rules states that the pilot must ensure that any clearance issued by ATC is safe from the standpoint of preventing collisions with terrain except when a direct route is provided that takes the aircraft off an established ATS route. Moreover, as per 4.4.7.6 of the Air Traffic Rules, when an aircraft making a standard approach is cleared to descend to a flight level lower than the level(s) specified in the standard procedure, the aircraft shall follow the vertical profile published in the procedure unless ATC explicitly cancels those restrictions. Published minimum levels based on terrain clearance shall always be applied.

According to the procedures in the airline's Operations Manual on preparing the descent and the approach, the crew must check and learn the most important altitudes, which includes the altitude at which the approach procedure starts, in this case 10,000 ft. Even though the company stated that its pilots followed the company's procedures, the aircraft descended below said altitude, that is, below the profiles published in STAR BAN3B, even though its crew was not explicitly authorized by ATC to cancel the altitude restrictions.

In this regard, during the course of the investigation the operator decided to revise its procedures, to improve its training and to present this incident internally to its crews as a case study to remind them of the importance of increasing their awareness of altitude restrictions and limitations. Thus a safety recommendation is not issued in this regard, since the measures adopted by the company are intended to avoid a future reoccurrence of this incident.

The RES sector controller did not detect the error in the crew's readback and thus did not correct it. He was subsequently relieved by another controller, at which time the aircraft was above the minimum altitude for the approach and above that entered in the CFL field. The oncoming controller did not notice that the aircraft was flying below

the minimum STAR altitude when the CFL field disappeared from the aircraft's label nor when he transferred the aircraft to the AIS sector controller.

In their initial exchange on the AIS sector frequency, the crew reported that it was descending to 5,000 ft. The AIS sector controller confirmed radar contact to the crew without noticing either on the radar or from the crew's report that it was below the minimum STAR and MRVA altitudes. The AIS sector controller subsequently instructed the crew to turn to heading 260° and then to 270° to ensure horizontal separation between the aircraft and other traffic. At that point the aircraft crew notified the AIS sector controller that it was maintaining 7,000 ft to maintain separation with terrain, and it was then that the controller became aware of the situation.

Point 3.3.7.3.1.2 of the Air Traffic Rules states that the controller shall listen to the crew's readback to ensure that the crew has correctly acknowledged the clearance and to correct it if not. In this case there were several reports by the crew to both sector controllers notifying their descent to 5,000 ft, without the controllers noticing the error. In response to this, AENA distributed a so-called "Operational Safety Notebook" to control personnel with information intended to highlight the aspects involved in faulty readbacks. Even in light of this measure, however, the information should be included in refresher training to ensure that all control personnel are made aware of the danger involved in faulty acknowledgments and to take the necessary measures to avoid them. As a result, a safety recommendation that includes this aspect is being issued.

Also worth considering is the fact that the aircraft's path and position were shown on the radar screens at the different controller stations and that there are two controllers at each post in the approach control sectors: an executive controller and a planning controller. Neither of them noticed that the aircraft was descending below the minimum specified in the approach procedure or below the minimum radar vectoring altitude. It is important for ATC personnel to remain vigilant at all times regarding the information displayed on the radar screen (aircraft labels) so as to detect possible deviations by the aircraft from the clearances issued by ATC or from established procedures, particularly when transferring an aircraft or when contacting an aircraft for the first time and reporting radar contact.

In this regard, AENA stated that the functions of the planning controller are not explicitly defined. Planning controllers must be able to proactively identify potential separation problems between aircraft and/or between an aircraft and the terrain, and prepare and analyze the aircraft information to be handled by the executive controller. It is therefore considered essential that suitable documentation be available that lists these functions. A safety recommendation is issued in this regard.

Finally, AENA reported that the SACTA system features a function called "Minimums Alert" that can issue warnings in the event that an aircraft descends below the minimum safe altitude. This function is not currently enabled since the operational

validation to determine the proper operating parameters for said alert has not yet been performed. This has resulted in the issuing of a safety recommendation.

3. CONCLUSIONS AND CAUSES

3.1. Findings

- The aircraft's documentation was valid and in force and the aircraft was airworthy.
- The crew had valid and in force licenses and medical certificates.
- The controllers had valid and in force licenses and medical certificates.
- The aircraft was cleared to descend to 10,000 ft using the phraseology "descend to ten thousand feet". Aircraft LGL erroneously acknowledged that it was descending to 5,000 ft, a readback that was not corrected by the RES sector controller.
- The aircraft was conducting the STAR BAN3B approach and was not instructed to change its flight path.
- The aircraft descended below the altitude specified in this procedure.
- The RES sector controller transferred the aircraft to sector AIS without noticing that at that point the aircraft was below both the minimum altitude in the procedure and the minimum radar vectoring altitude.
- The aircraft contacted sector AIS and reported it was descending to 5,000 ft. The AIS sector controller reported radar contact without noticing that the aircraft was below the minimum radar vectoring altitude.
- The approach control station has an executive controller and a planning controller. The functions of the planning controller are not documented by the service provider (AENA), meaning the exact tasks involved in the planning controller's job are unknown.
- The aircraft was below the minimum altitude in the procedure for four minutes and below the minimum radar vectoring altitude for three minutes. This situation was not detected by the RES or AIS sector controller or by the crew.
- The crew halted the descent after receiving the EGPWS "Terrain Terrain" and "Terrain Pull Up" warnings
- After being instructed to turn for separation, the crew reported to sector AIS that it was maintaining 7,000 ft due to mountains. It was then that the AIS sector controller realized that the aircraft had descended below the minimum altitude specified in the procedure and instructed the crew to climb to 10,000 ft.
- The SACTA system features a "Minimums Alert" function, but it is not currently enabled.

3.2. Causes

The incident occurred because the aircraft descended below the minimum standard terminal arrival route, minimum radar vectoring and minimum sector altitudes. The crew, which was obligated to maintain separation with terrain and know that the minimum

altitude specified by the arrival procedure was 10,000 ft, descended below said altitude without confirming with ATC whether the clearance given was correct.

The RES sector controller used improper phraseology and cleared the aircraft to descend to 10,000 ft. The crew acknowledged descending to 5,000 ft and the controller did not correct the faulty readback. Also contributing to the incident is the fact that the RES and AIS sector controllers did not notice that the aircraft had descended below the minimum altitude in the procedure and below the minimum radar vectoring altitude. The AIS sector controller only realized this fact after being informed by the crew when the aircraft's EGPWS alerted them and they started to climb.

4. SAFETY RECOMMENDATIONS

Among other factors, this incident involved the utilization of non-standard phraseology, a failure to detect a faulty readback and a failure to detect that the aircraft's altitude was below the specified minimums.

The ICAO dictates the standard phraseology to use. Moreover, the studies conducted by Eurocontrol as reflected in the "European Action Plan for the Prevention of Level Bust" have given rise to a series of recommendations for the use of phraseology that aim to set a uniform stage for all of the parties involved and thus avoid potential conflicts, some of which have already been identified. AENA, aware of the problems involved with faulty readbacks, has distributed information among its control personnel in an effort to educate them on the negative effects of failing to detect and correct faulty readbacks. As a result, it is considered worthwhile to issue a safety recommendation to AENA to ensure that control personnel are aware of and remember the need to avoid these possible conflicts.

REC 01/13. It is recommended that AENA evaluate the incorporation of topics involving the use of standard phraseology and the recommendations issued by Eurocontrol, as well as information concerning faulty acknowledgments and its consequences, into the continuing training programs for control personnel so as to raise controller awareness regarding the importance of these aspects.

The RES and AIS sector controllers, both the planners and executives, did not notice that the aircraft was descending through the minimum specified altitudes. There is a "Minimums Alert" function in the SACTA system that is not yet implemented but that would help in detecting these occurrences in time to correct them. Also, although their functions are reflected in the corresponding procedures, such as the Air Traffic Rules, controllers should have a quick access guide detailing the most important aspects of their jobs.

REC 02/13. It is recommended that AENA establish the measures needed to implement the altitude alert function in SACTA, at least in those posts where aircraft separation with terrain could be critical (as is the case of Madrid-Barajas when in a south configuration).

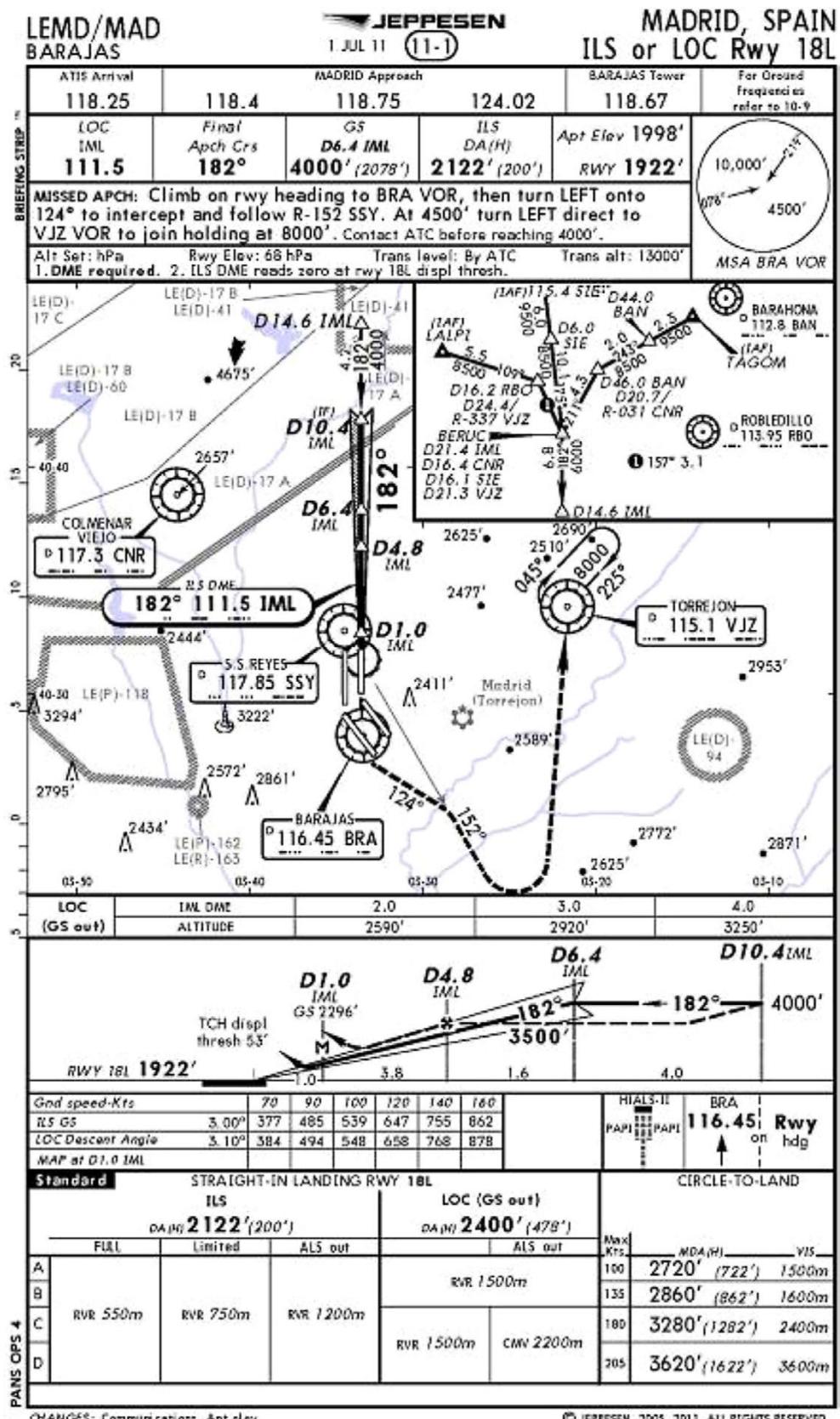
Finally, the investigation confirmed that the job of the planning controller, in terms of organizing information so as to facilitate the executive controller's job of handling aircraft, is not explicitly defined.

REC 03/13. It is recommended that AENA issue a document where the operation procedure be described and the tasks of the planner controllers be defined.

APPENDICES

APPENDIX A

Approach charts



LEMD/MAD
BARAJASJEPPESEN
2 APR 10 10-2B Eff 8 Apr

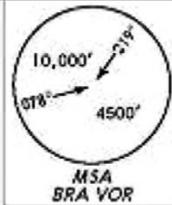
MADRID, SPAIN

STAR

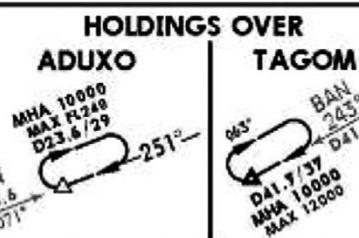
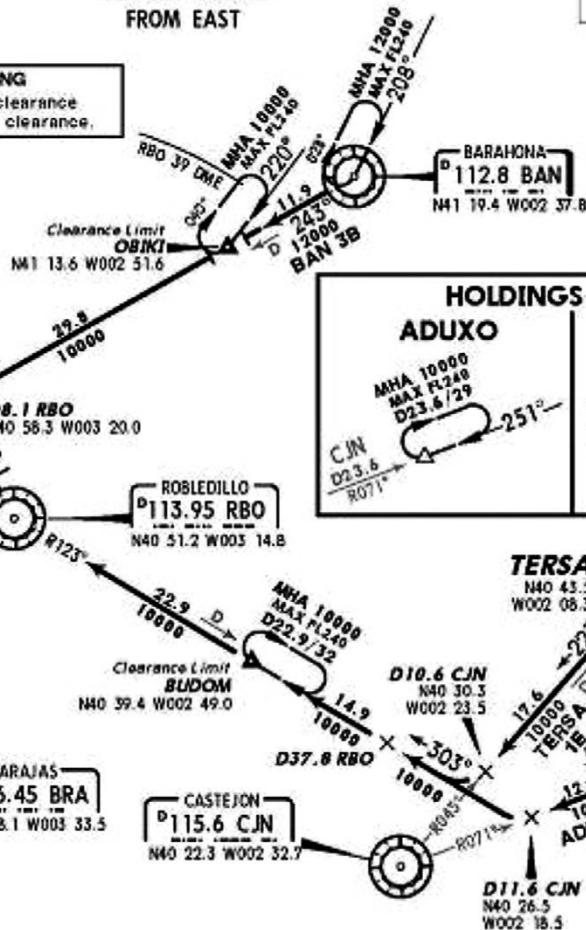
ATIS
118.25Apt Elev
2001'

Alt Set: hPa Trans level: By ATC Trans alt: 13000'

**ADUXO ONE BRAVO (ADUXO 1B) [ADUXO 1B]
BARAHONA THREE BRAVO (BAN 3B)
TERSA ONE ECHO (TERSA 1E) [TERSA 1E]
RWYS 18L/R ARRIVALS
VIA IAF TAGOM
FROM EAST**



WARNING
Do not leave the clearance limit without ATC clearance.



Pilots must plan the descent profile to comply with the following speed and level/altitude restrictions at specific points or equivalent positions. If unable to comply advise ATC.

STAR	Position	Speed	FL/Altitude
ADUXO 1B	ADUXO	250 KT	MAX FL210
	D37.8 RBO	220 KT	MAX FL160
	BUDOM	220 KT	10000'
	TAGOM	220 KT	
BAN 3B	BAN	250 KT	MAX FL190
	OBIKI	220 KT	MAX FL160
	TAGOM	220 KT	10000'
TERSA 1E	TERSA	250 KT	MAX FL210
	D37.8 RBO	220 KT	MAX FL160
	BUDOM	220 KT	10000'
	TAGOM	220 KT	



CHANGES: STAR BAN 3B level restrictions revised.

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APPENDIX B

Communications

ATS time	Station	Content	QAR data (ft)
16:57:55	LGL 3837	... HELLO LGL3837	18,169
16:57:57	Sector RES	LGL3837 MUY BUENAS ON RADAR CONTACT, CONTINUE DESCENT TEN THOUSAND FEET ON QNH ONE ZERO ONE SIX TO BE LEVELLED AT TAGOM	
16:58:06	LGL 3837	DESCENDING FIVE THOUSAND FEET ONE ZERO ONE SIX LEVELLED AT... TAGOM LG38... LGL3837	17,767
17:00:22	—	RELAY	—
17:04:09	Sector RES	LGL3837 ONE TWO SEVEN DECIMAL ONE, BYE	
17:04:13	LGL 3837	TWO SEVEN ONE, GOOD BYE LGL3837	7,678
17:04:21	LGL 3837	... LGL3837 DESCENDING FIVE THOUSAND FEET TO TAGOM	7,548
17:04:24	Sector AIS	LGL3837 RADAR CONTACT MAINTAIN HEADING AFTER TAGOM FOR RUNWAY 18L	
17:04:31	LGL 3837	... MAINTAIN HEADING AFTER TAGOM FOR 18L LGL3837	7,349
17:06:10	Sector AIS	LGL3837 FOR TRAFFIC SPACING HEADING TWO SIX ZERO	
17:06:20	Sector AIS	LGL3837 HEADING TWO SEVEN ZERO FOR TRAFFIC SPACING	
17:06:23	LGL 3837	HEADING TWO SEVEN ZERO AND WE'LL MAINTAIN SEVEN THOUSAND FEET DUE TO MOUNTAIN LGL3837	7,147
17:06:28	Sector AIS	LGL3837 YOU WERE CLEARED TEN THOUSAND SIR	
17:06:31	LGL 3837	... WE ARE CLEARED FIVE THOUSAND FEET BY PRECEDING	7,253
17:06:34	Sector AIS	AND WHAT FREQUENCY SIR? HERE I DIDN'T GIVE YOU ANY... CLEARANCE	
17:06:41	LGL 3837	NO, PRECEDING FREQUENCY CLEARED US TO TEN THOUSAND... FIVE THOUSAND FEET ONE ZERO ONE THREE	7,365
17:06:46	Sector AIS	ROGER, IT WAS TEN THOUSAND IS THE MINIMUM SIR, TEN THOUSAND FEET, CLIMB TEN THOUSAND	
17:06:51	LGL 3837	CLIMBING TEN THOUSAND FEET LGL3837	7,525
17:07:22	Sector AIS	LGL3837 LEFT HEADING TWO ZERO ZERO INTERCEPT LOCALIZER 18L	
17:07:27	LGL 3837	... HEADING TWO ZERO ZERO, INTERCEPT LOCALIZER 18L LGL3837 AND FOR INFORMATION YOU SAW ME DESCENDING BELOW TEN THOUSAND FEET ON THE RADAR?	8,349
17:07:37	Sector AIS	LGL3837 YOU CAN MAINTAIN... NINE THOUSAND FEET	
17:07:40	LGL 3837	MAINTAINING NINE THOUSAND FEET LGL3837	8,714
17:07:44	Sector AIS	ROGER SIR, I'M REALLY SORRY BUT THE CLEARANCE FROM THE PREVIOUS SECTOR SHOULD BE... (ININTELIGIBLE) IT MUST HAS BEEN A MISUNDERSTANDING THERE, SPEED TWO ZERO ZERO KNOTS	
17:07:54	LGL 3837	TWO HUNDRED KNOTS LGL3837 AND... NINE THOUSAND FEET MAINTANING	8,925

APPENDIX C
Correspondence between
RCA and ICAO

RCA	DOC. 4444	
3.3.7.3.1.2.	4.5.7.5.2	The controller shall listen to the readback to ascertain that the clearance or instruction has been correctly acknowledged by the flight crew and shall take immediate action to correct any discrepancies revealed by the readback.
4.2.1.2	2.1-Nota 2	The objectives of air traffic control as prescribed in Annex 11 do not include the prevention of collision with terrain. The procedures described in this procedure do not relieve pilots of their responsibility to ensure that any clearance issued by air traffic control is safe in this respect. When an IFR flight is vectored or given a direct routing which takes the aircraft off an ATS route, the procedures in Chapter 8, Section 8.6.5.2 apply.
4.4.7.6.	6.5.2.4	Descent below levels specified in a STAR When an arriving aircraft on a STAR is cleared to descend to a lower level than the level or levels specified in a STAR, the aircraft shall follow the published vertical profile of a STAR, unless such restrictions are explicitly canceled by ATC. Published minimum levels based on terrain clearance shall always be applied.
4.6.1.4	8.1.4	ATS surveillance systems should provide for the display of safety-related alerts and warnings, including conflict alert, minimum safe altitude warning, conflict prediction and unintentionally duplicated SSR codes and aircraft identification.
4.6.4.1	8.4	The information from ATS surveillance systems, including safety-related alerts and warnings such as conflict alert and minimum safe altitude warning, should be used to the extent possible in the provision of air traffic control service in order to improve capacity and efficiency as well as to enhance safety.

RCA	Annex 10 Vol. II	
10.5.2.1.3.1.2	5.2.1.4.1.2	All numbers used in the transmission of altitude, cloud height, visibility and runway visual range (RVR) information, which contain whole hundreds and whole thousands, shall be transmitted by pronouncing each digit in the number of hundreds or thousands followed by the word HUNDRED or THOUSAND as appropriate. Combinations of thousands and whole hundreds shall be transmitted by pronouncing each digit in the number of thousands followed by the word THOUSAND followed by the number of hundreds followed by the word HUNDRED.