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pour la sécurité de l'aviation civile

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SAFETY INVESTIGATION REPORT

Serious incident

to the Boeing 737- 809
registered **EC-NGC** operated by Albastar
and to the Embraer 190
registered **F-HBLD** operated by HOP!
on 21 July 2023
in cruise close to Limoges VOR/DME

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December 2025

BEA2023-0320

SAFETY INVESTIGATIONS

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BEA investigations are independent, separate and conducted without prejudice to any judicial or administrative action that may be taken to determine blame or liability.

SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.

CONTENTS

GLOSSARY

Abbreviations	Meanings
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance – Broadcast
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service (DSNA)
AMC	Acceptable Means of Compliance
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ARTAS	ATM suRveillance Tracker And Server
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM/ANS	Air Traffic Management and Air Navigation Services
ATPL	Airline Transport Pilot Licence
CAUTRA	Automatic air traffic coordinator
CDC	Control and Detection Centre
CESNAC	Central air navigation systems operating centre
CFR	Code of Federal Regulations
CIAIAC	Spanish safety investigation authority
CNOA	National air operations centre
CNS	Communications, Navigation and Surveillance
CPA	Closest Point of Approach
CS	Certification Specifications
CVR	Cockpit Voice Recorder
DF	Downlink Format (Mode S message)
DGAC	French civil aviation authority
DSAC	Civil aviation safety directorate
DSEC	Safety directorate
DSNA	Air navigation service provider
DSR	Resources and strategy directorate
DTA	Air transport directorate
DTI	Technical and innovation directorate

Abbreviations	Meanings
DYP	DYnamic Presentation
EASA	European Union Aviation Safety Agency
EEE	ERATO Electronic Environment
EPAS	European Plan for Aviation Safety
ERATO	En-Route Air Traffic Organizer
ETSO	European Technical Standards Order
FAA	Federal Aviation Administration
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
FHA	Functional Hazard Assessment
FIM	Fault Isolation Manual
FIR	Flight Information Region
FL	Flight Level
FPASD	Flight Plan Air Situation Display
Ft	Feet
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ITES	Safety occurrence processing body
JAR	Joint Aviation Requirements
kt	Knots
LKP	Last Known Position
LT	Lost Track
MTBF	Mean Time Between Failure
MTBUR	Mean Time Between Unscheduled Removal
NM	Network Manager (Eurocontrol)
NTSB	National Transport Safety Board
OD	Operations Directorate
ODS	Operational Display System
PCO	Planner controller
PCR	Tactical controller
PF	Pilot Flying
PM	Pilot Monitoring
PSSA	Preliminary System Safety Assessment
QAR	Quick Access Recorder
RA	Resolution Advisory
RRM	Risk Reduction Measures
RVSM	Reduced Vertical Separation Minimum

Abbreviations	Meanings
SMI	Separation Minimum Infringements
SMS	Safety Management System
SSA	System Safety Assessment
STCA	Short Term Conflict Alert
TA	Traffic Advisory
TCAS	Traffic alert and Collision Avoidance System
TLB	Technical LogBook
UE	Unit Endorsement
UF	Uplink Format (Mode S message)
UPS	Unit Proficiency Scheme
UTC	Universal Time Coordinated
UTP	Unit Training Plan

SYNOPSIS

Time	Around 08:50[1]
Operators	Air France
Type of flights	Commercial air transport of passengers
Persons onboard	Flight LAV4651: Captain, co-pilot, 4 cabin crew and 185 passengers Flight AFR21YB: Captain, co-pilot, 2 cabin crew and 94 passengers
Consequences and damage	None

Undetected in-flight transponder failure, following of a conflicting flight path in RVSM airspace without radar contact

In cruise at FL 350, on flight LAV4651 carried out by the Boeing 737-809 operated by Albastar between London-Stansted airport (United Kingdom) and Tarbes-Lourdes-Pyrenees airport, the transponder, switched on by the crew, ceased transmitting any information in reply to interrogations from the ground radar stations and Airborne Collision Avoidance Systems (ACAS) from aircraft nearby. This malfunction meant that radar contact with flight LAV4651 was lost and that the ACAS systems on the aeroplanes flying nearby and the Short Term Conflict Alert (STCA) systems available to controllers were not able to detect or monitor it.

Neither the crew of flight LAV4651 nor the air traffic controllers of the control sector in which the aeroplane was flying perceived or took into account the systems designed to alert them in the event of a transponder failure:

- the crew did not see the amber **ATC FAIL** light on the ATC Control Panel situated between the two crew seats which probably lit up during the flight according to the examinations carried out during the investigation;
- the air traffic controllers did not perceive the various visual warnings which were displayed on their screens and acknowledged them by deleting the marker which indicated a loss of radar contact.

Radio contact in the vicinity of the compulsory reporting point BALAN, situated at the boundary between the ACC/west and ACC/south sectors, constituted a possibility of recovering the situation. The PCR asked the crew to head directly to this point, defined as a compulsory reporting point. The crew, in the absence of an explicit request from the controllers to contact them on approaching BALAN, continued their route as set out in the flight plan.

[1] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC). Two hours should be added to obtain the legal time applicable in Metropolitan France on the day of the event.

Around 20 min after the transponder failure, the Boeing 737 crossed the route of an Embraer 190 operated by HOP! (Flight AFR21YB) at the same flight level, with a minimum horizontal separation of 2.6 NM for a required minimum distance of 5 NM. Despite the failure of the transponder, the Boeing 737's TCAS functioned. Based on the information received from the transponder and from the TCAS of the Embraer 190, the algorithm of the 737 TCAS determined that there was no threat of collision with the Embraer. As a consequence, no Traffic Advisory (TA) or Resolution Advisory (RA) was transmitted on board the Boeing 737. However, the crew of the Embraer 190 had had no information about the position and path of the Boeing 737 and were therefore surprised to see it cross their route ahead of them at the same flight level.

At the same time, a military air traffic controller in the Cinq-Mars-La pile military detection and control centre detected the flight on the primary radar and after several coordination actions between ACC/south-west and ACC/west, and after the loss of separation between the two aeroplanes, radar contact with flight LAV4651 was recovered and the flight was able to continue to destination without any other anomalies.

The BEA has issued four safety recommendations relating to the following topics:

- Certification Specifications for Airborne Communications, Navigation and Surveillance;
- systems for attracting the air traffic controllers' attention;
- overall management of safety risks by the air navigation service provider in France;
- compulsory reporting points.

ORGANISATION OF THE INVESTIGATION

The DSNA informed the BEA of the occurrence of the serious incident on Friday 21 July 2023.

Based on the initial factual information gathered, the BEA opened a safety investigation into this occurrence which was classified as a serious incident. In accordance with Annex 13 to the Convention on International Civil Aviation and Regulation (EU) No 996/2010 concerning the investigation and prevention of accidents and incidents in civil aviation, the BEA informed the following parties of the opening of the safety investigation:

- the Spanish investigation authority, the CIAIAC as State of Registry and State of the Operator;
- the American investigation authority, the NTSB, as the State of Design and State of Manufacture of the Boeing 737 and the transponder equipping this aeroplane;
- the French Air Navigation Service Provider, the DSNA;
- the French oversight and certification authority, the DSAC;
- the Embraer 190 air operator, HOP!; ;
- the European Union Aviation Safety Agency, EASA;
- the International Civil Aviation Organization (ICAO);
- Eurocontrol.

The CIAIAC and the NTSB appointed accredited representatives accompanied by advisers from the air operator, Albastar for the CIAIAC and from the aeroplane manufacturer Boeing and equipment manufacturer Honeywell for the NTSB.

The draft final report was submitted to the accredited representatives and their advisers for consultation, in accordance with article 6.3 of Annex 13 to the Convention on International Civil Aviation. It was also sent to EASA, the DSAC, the DSNA, ICAO and Eurocontrol.

1. FACTUAL INFORMATION

1.1 History of the flight

Note: the following information is principally based on flight data recorders, statements, radio communication recordings and radar data.

1.1.1 Acceptance of flight LAV4651 in ACC/west control sector

The crew of the Boeing 737-809 registered EC-NGC and operated by Albastar, flight LAV4651, took off from London-Stansted airport at 07:55, nearly 55 min behind schedule, bound for Tarbes-Lourdes-Pyrenees airport.

A very short time after taking off, the air traffic controllers in the London control centre asked the crew, as specified in the filed flight plan, to climb to FL 350 and then head towards SITET reporting point (see paragraphs 1.17.5.3 and 1.18.1) at the boundary between the London and Brest FIR.

At 08:17:33, at the request of the air traffic controller in the London control centre, the crew contacted the tactical controller[2] (PCR) in the QXI sector[3] of ACC/west and reported that they were stable at FL 350 en route to SITET (see **Figure 2**, point 1). In reply, the PCR asked the crew to head directly towards Amboise (AMB) DME.

Around two minutes later, the PCR accepted the request from the crew of an Airbus A320 operated by British Airways Euroflyer (radio call sign Griffin), flight EFW3HY, who wanted to fly at FL 350 for the en-route phase. To ensure the horizontal separation between flights LAV4651 and EFW3HY which were following the same route, at the same flight level, to AMB, the PCR asked the crew of flight LAV4651 to follow a direct route to BALAN compulsory reporting point (see paragraphs 1.17.5.3 and 1.18.1) situated around 220 NM to the south and to hold a speed of more than 0.77 Mach. He also asked the crew of flight EFW3HY, behind flight LAV4651, to hold a speed of less than 0.76 Mach (see **Figure 1**). The PCR singled out the Mach numbers of the two flights which highlighted this information on the display.

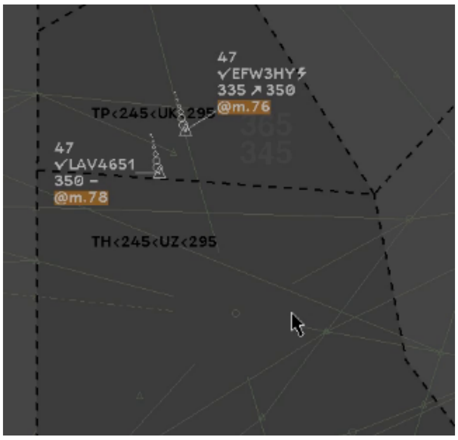

Figure 1: part of PCR screen
(Source: PCR screen recording, DSNA)

[2] See paragraph 1.17.2.3 with respect to the tasks shared between the PCR and PCO positions.
[3] Combination of two control sectors for flight levels between FL 345 and FL 365 (see paragraph 1.17.5.3).

From 08:27:04 and for 4 min 15 s, no radio or telephone message regarding the QXI sector was transmitted or received. During this period, the cursors which follow the movements made by the mice of the PCR and the planner controller (PCO) did not move on the screen of each control position. Six aeroplanes were on the frequency and managed in the QXI sector at the time.

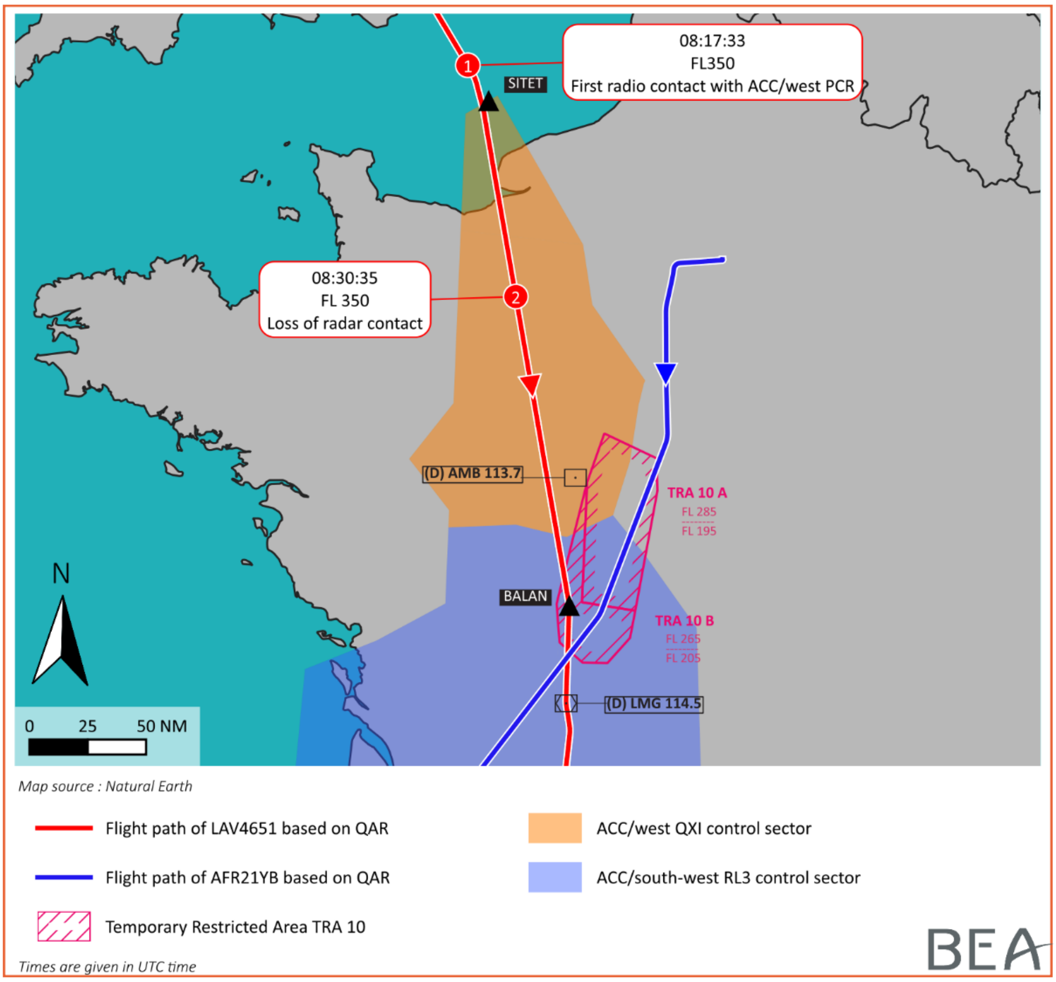

Figure 2: flight paths of LAV4651 and AFR21YB

1.1.2 Break in the Boeing 737-809's transponder transmissions

From 08:30:35 (point 2), the transponder of the 737 ceased transmitting replies to the interrogations from ground radar stations and ACAS systems.

Between 08:30:47 and 08:30:59, in response to the transponder malfunction, several alert messages and symbols appeared on the label of flight LAV4651 and in the windows containing information about the flight on the screens of the two QXI sector controllers. The 737 was then around 130 NM north of BALAN. The alerts warned the controllers of the loss of certain correlation functionalities between the information from the aeroplane's flight plan and that received from the transponder (see paragraph 1.17.3.6). At 08:30:58, the track of flight LAV4651 was replaced by a track marker[4]  (see **Figure 3**) and its label was also modified. A "Flights without track" window drawing attention to the flights which have an active flight plan but no associable track information also appeared on the screens of the two controllers, on the right side of the track marker.

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[4] Symbol which displays the last known position of the aircraft, see paragraph 1.17.3.6.

Figure 3: track marker and "Flights without track" window (Source: DSNA)

None of these alerts were perceived by the two QXI sector controllers. The PCR screen was organised as follows:

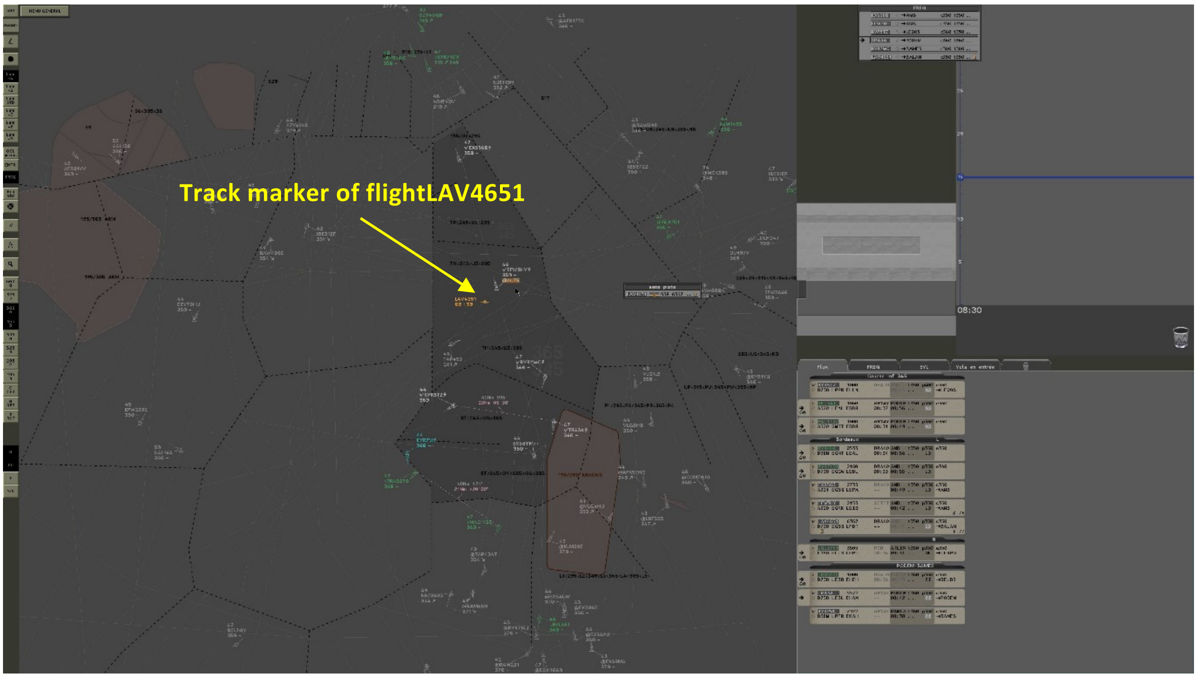

Figure 4: control screen of QXI sector PCR (Source: DSNA)

The PCO screen was organised in almost the same way.

At 08:31:20, the PCR replied to a crew and carried out actions with the mouse to take into account these exchanges. Two minutes later, the PCR moved the "Flights without track" window to the right side of his screen. This window only contained information about flight LAV4651.

At 08:33:48, the PCR deleted the track marker associated with flight LAV4651 by making a right click. Less than a minute later, the PCO also deleted the track marker of flight LAV4651 on his screen. In both cases, the mice of the two controllers did not pause on the track marker (less than one second between the pointer coming onto the track marker and the deletion click).

At around 08:38, the PCR deleted the highlighting which increased the visibility of the Mach 0.77 speed that he had asked the crew of flight EFW3HY to comply with.

At 08:40:56, the crew of the Embraer 190 registered F-HBLD and operated by HOP!, flight AFR21YB which had taken off from Paris - Charles de Gaulle airport bound for Bilbao (Spain), contacted the PCR of the RL3 sector[5] of ACC/south-west and informed him that they were at FL 350 en route to Limoges (LMG) VOR-DME.

At 08:41:02, as flight LAV4651 was supposed to have left the limits of the QXI sector, the "Flights without track" window disappeared from the screens of the two QXI sector controllers. Flight LAV4651 was still displayed in the "Aeroplanes on frequency" window and the flight information was still present on the right side of the PCR and PCO screens (see **Figure 5**).

Figure 5: "Aeroplanes on frequency" window (on left side) and LAV4651 flight information after disappearing from the "Flights without track" window (on right side) (Source: DSNA)

At 08:44:20, the PCR of the RL3 sector of ACC/south-west moved the "Flights without track" window which was displayed a few seconds earlier on the screens of the two sector controllers, the sole flight displayed being LAV4651.

1.1.3 Identification of loss of radar detection and in-flight loss of separation

At 08:48:18, the crew of flight LAV4651 passed overhead the BALAN point (see **Figure 6**, point 3) and, in accordance with their flight plan, continued their route to LMG located 42 NM to the south. The crew did not contact the PCR of the QXI sector over the radio to report that they had passed BALAN.

Twenty seconds later, a military controller from the Cinq-Mars-La-Pile CDC contacted the ACC/south-west control room supervisor to inform him of the transponder anomaly of flight LAV4651, the aeroplane's position and its destination. He also specified that he was going to contact the national air operations centre (CNOA[6]).

At the same time, at around 08:50, the two QXI sector controllers were relieved.

At 08:50:27 (point 4), the distance between the Boeing 737 and the Embraer 190, both flying at FL 350, was less than 5 NM (the minimum regulatory separation in this airspace, see paragraph 1.18.2).

From 08:50:47, the RL3 sector PCR tried to contact the crew of flight LAV4651 on the sector frequency, and looked for, without finding, the flight track on his screen.

[5] Combination of sectors R and L for flight levels between FL 345 and FL 365 (see paragraph 1.17.6.2 for more information).

[6] Since October 2024, the CNOA has become the operations and air defence planning and management air centre - national territory (CAPCODA TN).

At 08:51:07, the information regarding flight LAV4651 was deleted from the windows on the ACC/west QXI sector controller screens. Fifteen seconds later, the ACC/south-west control room supervisor contacted the ACC/west control room supervisor and asked him if he had knowledge of flight LAV4651. The ACC/west control room supervisor rapidly looked for the flight, without success, and told the ACC/south-west control room supervisor that he would call him back as soon as he had more information.

At 08:51:28 (point 5), the distance between the two aeroplanes reached a minimum distance of 2.6 NM.

A few seconds later, and for around 45 s, the QXI sector and RL3 sector controllers along with the Cinq-Mars-La-Pile CDC controllers coordinated together to determine the precise position of flight LAV4651. From 08:52:21 onwards, the QXI sector controller in ACC/west tried to contact the crew of flight LAV4651 on the sector frequency. At 08:52:23, the crew of flight AFR21YB contacted the RL3 sector PCR in ACC/south-west and informed him that there was an aeroplane at around 3 NM on their right-hand side, at the same flight level, and that it was not displayed on their ACAS system.

At 08:53, the crew of a fighter plane carrying out exercises was sent to intercept the 737 at the request of the CNOA (standard procedure in the event of a loss of radio and radar communication).

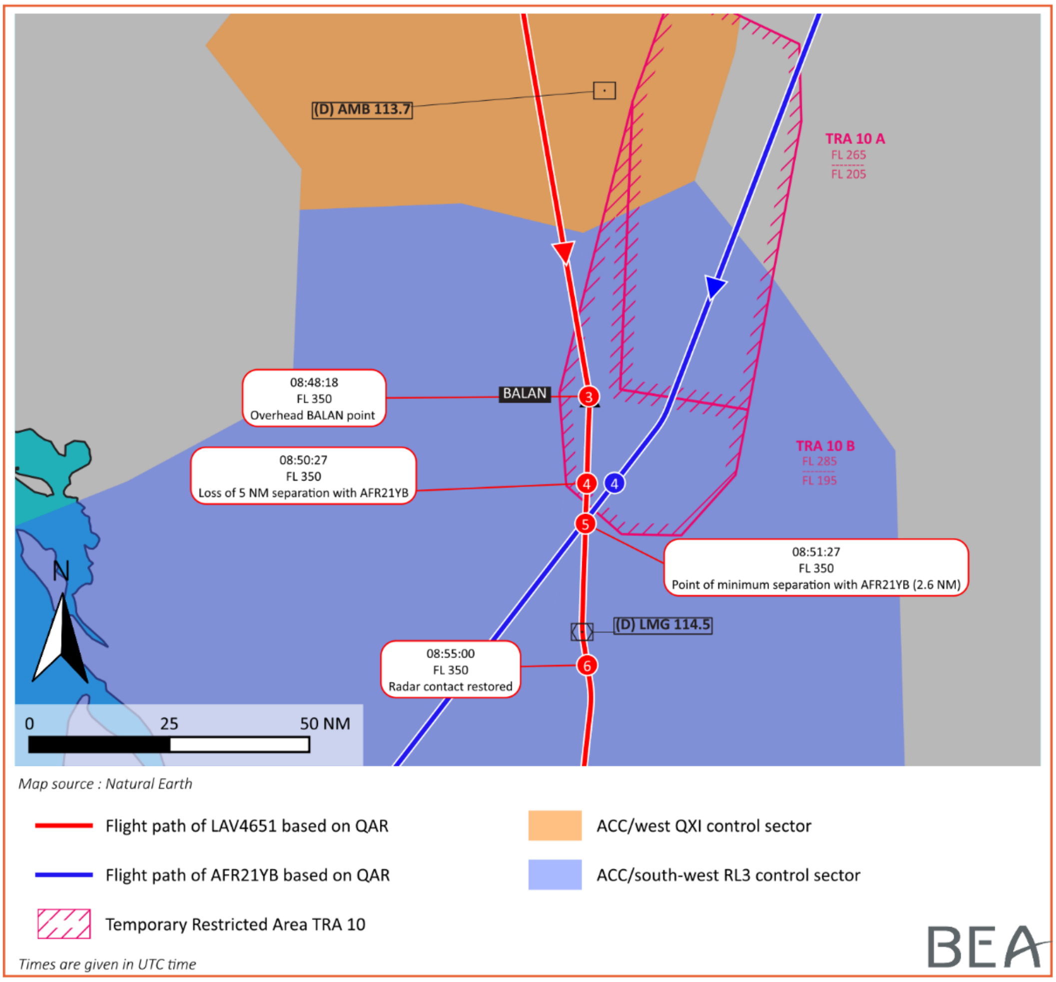

Figure 6: flight paths of LAV4651 and AFR21YB

1.1.4 Recovery of radar and radio contact with crew of flight LAV4651

The crew of flight LAV4651 replied to the QXI sector PCR's attempts to contact them on the sector frequency. As there was no response due to the limited radio range, the crew made a general call at 08:53:24 on the emergency radio frequency 121.5 MHz. The call was received by the Cinq-Mars-La Pile CDC controller and by the ACC/south-west control room supervisor who transferred them to the RL3 sector frequency. The PCR of this sector asked the crew to select the transponder code again and to change transponder channel. Radar contact was re-established from 08:55 onwards (point 6).

The crew continued the flight to Tarbes airport without any other incident.

1.2 Injuries to persons

Not applicable.

1.3 Damage to aircraft

Not applicable.

1.4 Other damage

Not applicable.

1.5 Personnel information

1.5.1 Flight crew of Boeing 737- 809

The two Spanish crew members each held an Airline Transport Pilot Licence (ATPL(A)) and a Boeing 737 rating.

The first flight of the day was a ferry flight between Madrid-Barajas and London-Stansted airports. The crew specified that passenger boarding at London had taken some time due to the twenty or so passengers with reduced mobility travelling to Lourdes. As a consequence, the crew took off for Tarbes airport nearly an hour late. During the flight, the captain and co-pilot were respectively PM and PF.

The crew indicated that after receiving instructions to directly head towards BALAN, a period which they thought to be around 15 min elapsed before the calls from the controllers at around 08:53. The captain commented to the co-pilot about this long period without radio contact. The co-pilot explained that at one point, the captain had warned him of the presence of an aeroplane behind them (flight AFR21YB), displayed by a white lozenge on the TCAS. As there were no TCAS alerts nor instructions from the air traffic controllers, the crew indicated that they considered that the separation was ensured with flight AFR21YB.

A short time after the captain's comment, the crew heard the QXI sector controller trying to contact them. The quality was quite poor. The crew could not remember the position of the aeroplane when the controller made the calls. The captain replied to the controller's calls. He quickly understood, however, that the controller was not receiving his messages due to the radio's range.

He then transmitted on the emergency radio frequency 121.5 MHz. A controller in ACC/south-west replied to him and transmitted the new frequency to be contacted to continue the flight. The ACC/south-west controller informed the crew of the loss of radar contact for the last several minutes. Radar contact was re-established after selecting the second transponder.

According to the crew, there were no alerts relating to a transponder malfunction. The crew specified that they did not see the amber **ATC FAIL** light (see paragraph 1.6.1.1) illuminated during the flight.

The captain explained that the ACC/south-west controller gave him no other information about the loss of radar contact[7]. He added that he heard, without understanding the meaning of the discussions, the ACC/south-west controller and the crew of flight AFR21YB discussing in French, the loss of radar contact and the loss of separation.

After landing at Tarbes, the co-pilot checked the operation of the TCAS. He specified that he probably only tested transponder 1. During the return flight between Tarbes airport and London-Stansted airport, the captain was the PF and transponder 1 was selected.

1.5.2 Flight crew of Embraer 190

The two French crew members each held an Airline Transport Pilot Licence (ATPL(A)) and an Embraer 190 rating.

The crew indicated that they saw the Boeing 737-809 operated by Albastar pass in front of them on a right-hand converging track and a bearing of approximately 35°. The crew specified that the aeroplane was not displayed on the TCAS and that they mentioned this on the radio.

1.5.3 Air traffic controllers in charge of QXI sector at the time of the loss of radar contact with flight LAV4651

1.5.3.1 Tactical controller (PCR)

The PCR held an air traffic controller's license, with valid unit[8] (MU), instructor[9] (MI) and language[10] (ML) endorsements. He had been qualified at ACC/west since 2009. He held a valid class 3 medical certificate.

1.5.3.2 Planner controller (PCO)

The PCO held an air traffic controller's license with valid MU, MI and ML endorsements. He had been qualified at ACC/west since 2008. The PCO was also the control room supervisor since May 2023 and head of the unit training plan (PFU since 2017). He held a valid class 3 medical certificate.

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[7] The ACC/south-west sector PCR asked the crew to continue to Agen (AGN) DME after informing them that he had recovered radar contact and before specifying that they had lost contact with them a long time previously.

[8] Authorization shown on a license indicating the ICAO location indicator and the sector, group of sectors or work positions in which the holder is qualified to operate.

[9] Authorization shown on the license indicating that the holder is qualified to provide on-job training and simulation tool training.

[10] Endorsement on a license indicating the holder's language skills.

1.5.3.3 Shift and rest periods

The duty roster drawn up by ACC/west ensures that there are alternating duty and rest periods and is based on the time of year. The day of the serious incident, the PCR and the PCO, in the same team, were on the same shift. This shift, programmed after three days of rest, is the shift which starts the earliest.

The PCR and the PCO had come on duty at different times as per the duty roster:

- half of the team (and the control room supervisor) started at 04:30 (case of PCR);
- the other half started at 05:00 (case of PCO).

The breaks for the first half of the team were programmed between 06:30 and 07:00 and then between 10:30 and 11:00. For the second half, only one break was shown on the duty roster, between 06:00 and 06:30. The shift finished at 12:00 for the first half of the team and at 12:30 for the second half.

The PCR got up between 02:45 and 03:00 after around 4 h 30 min to 5 h of sleep. He considered that he had slept will (in terms of quality). He arrived at ACC/west for his shift after a 25-min commute by car from his home. The PCR had been on holiday for the six days preceding the serious incident.

The PCO got up at 02:45 and indicated that he had had a sufficient quantity of sleep. He specified that he had not felt tired. He arrived at ACC/west for his shift after a 45-min commute by car from his home. The PCO had been on a rest period for the three days preceding the serious incident.

1.5.3.4 Statements

1.5.3.4.1 PCR

The PCR indicated that he started with a first control sequence for a sector with quite a high workload. He then took a break between 06:00 and 07:00 before resuming duties for the QXI sector with a first PCO. The PCR specified that traffic management in this sector is more lateral than vertical as there are only two flight levels to manage, FL 350 and FL 360. He explained that the start of this new sequence was dense, not in terms of the number of aeroplanes to be managed, but due to this limitation in flight levels which leads to a lot of heading/speed instructions. The PCR indicated that at 08:15, there was a change in PCO and, at the same time, a reduction in the workload in the sector with only approximately seven aeroplanes to be managed. The controller considered that he may have been drowsy or at least, he may have wanted to recuperate during this second part of the sequence. He specified that he had also talked with the PCO. He added that the workload did not require any particular attention, and that there was no difficulty in detecting and managing conflicts.

The PCR explained that after the crew of flight EFW3HY asked for clearance to climb to FL 350, he separated the path of this flight from the path of LAV4651 on parallel routes at FL 350 with a view to transferring them to the ACC/south-west. He added that, to avoid any conflict and to facilitate coordination with the next ACC/south-west sector, and in view of the flight plans and destinations of the two aeroplanes, he placed:

- flight LAV4651 on “a traffic flow” westwards to take it to the Agen (AGN) DME station, via BALAN (first point in next sector of Bordeaux);
- flight EFW3HY on “a traffic flow” eastwards to take it to the Gaillac (GAI) DME station.

The PCR indicated that the controllers rarely coordinated the instruction to take a direct route to BALAN with the ACC/south-west sector. He explained this by the fact that the aeroplane did not penetrate a sector that was not specified in the flight plan and that BALAN was close to the boundary between the ACC/west and ACC/south-west sectors.

He added that he then forgot that these two aeroplanes were on parallel flight paths at the same flight level. He also indicated that pilots sometimes contact controllers when passing waypoints transmitted during instructions, and that on the day of the serious incident, the crew of flight LAV4651 did not do so when passing BALAN.

The PCR indicated that he did not see any of the alerts displayed on the screen and characteristic of a loss of radar contact. When the track marker appeared on the screen, he did not immediately pay attention to it and he then deleted it out of habit, without looking at the other flight information present on his screen.

The PCR explained that a certain number of track markers regularly appeared on the screens, mainly related to aircraft which did not concern the control position, such as:

- aerodrome inbound or outbound traffic;
- transatlantic flights;
- flights outside sectors to be managed;
- military flights.

The PCR considered that these track markers are generally systematically deleted out of habit by a right-hand click on the mouse. He added that there was no coordination with the PCO to delete these track markers. He indicated that he had deleted two or three track markers in the morning of the day of the serious incident.

The PCR was relieved at around 08:50 before going to eat at around 09:00.

From a work methods perspective, the PCR indicated that the size of the traffic flow boxes (at least four for the QXI sector) increased with the traffic to be managed. For this reason, he moved them to make room on his screen and only kept the frequency box (aeroplanes on frequency). Moreover, he considered that with the ERATO (*En-Route Air Traffic Organizer*) electronic environment (see paragraph 1.17.3) and in particular the CPDLC[11], the PCO may be less aware of what the PCR is doing due to a reduction in the coordination actions.

1.5.3.4.2 PCO

On starting his shift, the PCO relieved another PCO for a sector before becoming PCR on this sector at around 05:45 and being relieved around 30 min later. He took a break until around 07:00. He was then PCO for a sector before being relieved and becoming PCO for the QXI sector at around 08:10. He considered that at this time, the sector was at the bottom of the workload curve. He indicated that he quickly realised that there was no traffic management difficulty in the sector. He added that he and the PCR were conscious that they were in control of the situation, with a low workload that could have led to a drop in vigilance. He explained that it was for this reason that he and the PCR were talking.

[11] *Controller Pilot Data Link Communications*. Two-way data link between air traffic controllers and flight crews.

The PCO remembered coordinating with the controller of a sector of ACC/south-west so that another Boeing 737 operated by Albastar (not flight LAV4651) could climb to FL 370. He indicated that when he was relieved, he mentioned this coordination. After being relieved to go and eat, he was called by the control room supervisor at around 09:05 - 09:10 because of a problem with an Albastar flight. The PCO explained that he was convinced it was related to the coordination with the ACC/southwest sector. He was surprised to find that it was flight LAV4651, which he had no recollection of.

The PCO considered that track markers are frequently deleted by controllers. He added that in the context of a low workload and potentially reduced vigilance, he probably did not pay attention to the track marker for LAV4651 and instinctively deleted it.

He specified that in training, on detecting a track marker, they are asked to carry out a double-check. He added that a button can even be used to acknowledge all the track markers with a single action.

The PCO also specified that as PCO, the traffic, when it is light, is often globally integrated, based on the controllers' acquired experience, unlike in a training context where attention is focused on the specific difficulties of each session.

1.6 Aircraft information

1.6.1 Information on the Boeing 737 - 809 registered EC-NGC

Manufacturer	Boeing
Type	737 - 809
Serial number	28236
Registration	EC-NGC
Entry into service	2001
Airworthiness review certificate	27 March 2023 (valid until 15 April 2024)

1.6.1.1 Air Traffic Control (ATC) system

The Boeing 737-809 ATC system is composed of the following equipment:

- two transponders;
- an ATC/TCAS control panel (ATC Control Panel);
- two antennas;
- two ATC coaxial selectors.

The ATC control panel (see **Figure 7**) is situated between the two pilot seats on the aft electronic panel. It is used to select one of the two transponders for the flight (transponder 1 associated with the captain and transponder 2 with the co-pilot according to whether they are PF or PM).

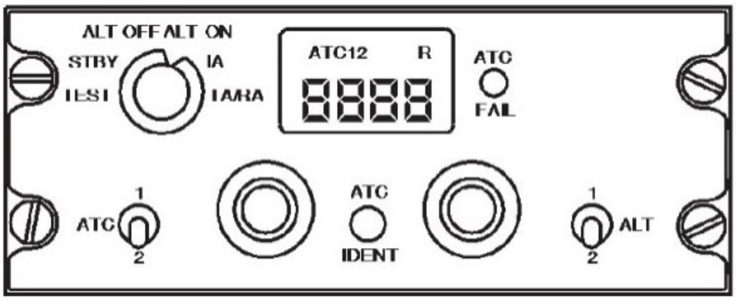

Figure 7: ATC Control Panel (Source: Boeing)

An amber **ATC FAIL** light lights up if there is a failure on the selected transponder.
The antennas situated on the top and bottom of the fuselage are used for transmitting and receiving messages exchanged with the transponder selected by the crew, via coaxial selectors (see **Figure 8**).

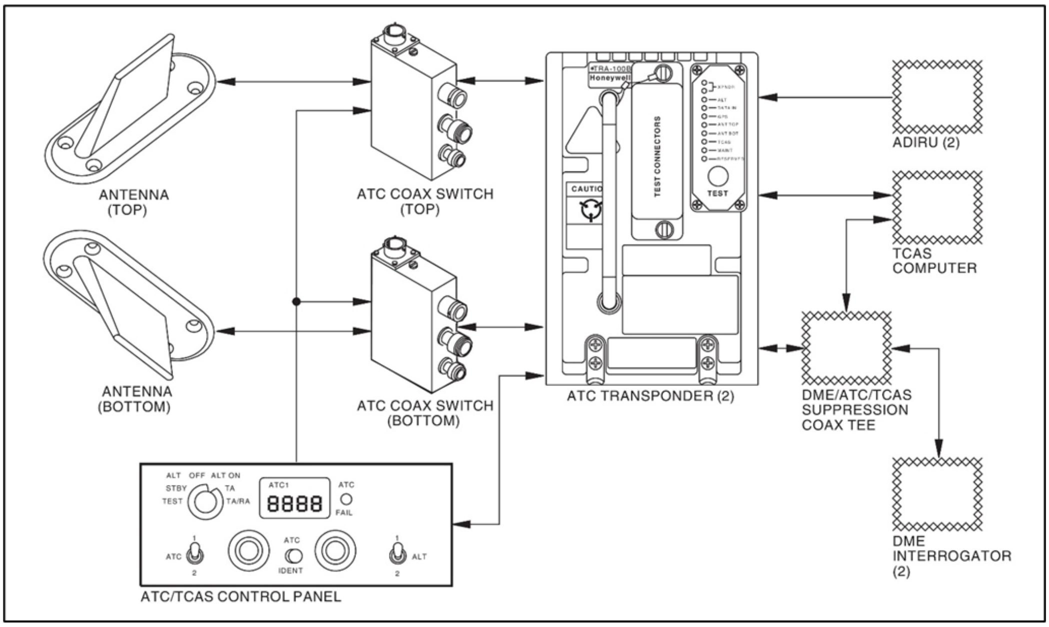

Figure 8: schematic diagram of ATC system (Source: Boeing)

The table below gives the dates of installation and of modifications made to both transponders, to the ATC control panel as well as to the antennas of the Boeing 737 - 809 system (the grey row corresponds to the transponder that failed during the serious incident flight).

Model and position	Make Type	Serial number	Installation	Replacement	Flight Hours/cycles
Transponder 1	HONEYWELL TRA-100B 066-01212-0301	S17254950	24 May 2019	25 July 2023	6925 / 3547
Transponder 2	HONEYWELL TRA-100B 066-01212-0301	S17254946	24 May 2019	25 July 2023	6925 / 3547
ATC Control Panel	HONEYWELL CTA-81A 071-01503-2601	23498	15 March 2023	25 July 2023	1081 / 440
Top antenna	DM1601354-001	91623	15 February 2019	29 July 2023	6979 / 3568
Bottom antenna	DM1601354-001	91625	15 February 2019	Still on the aeroplane on 29 July 2023	6979 / 3568

1.6.1.2 Maintenance operations related to the ATC system

1.6.1.2.1 Three months prior to and including 20 July 2023

No element related to the aeroplane's ATC system was recorded in the Technical Logbook (TLB) of the Boeing 737, on the pages of the three months before the serious incident flight.

1.6.1.2.2 21 July 2023

After the flight between London and Tarbes, during which the transponder failed, the crew did not record anything in the TLB.

The same crew then took off at approximately 12:00 from Tarbes bound for London. The captain stated that he was PF and that transponder 1 had therefore been selected for this flight. Having encountered no particular problem, the crew did not record anything in the TLB for this flight.

A different crew then took off at approximately 17:00 from London Stansted bound for Lourdes. Nothing was reported by the crew. While taxiing at Lourdes, at around 21:35, this same crew reported a malfunction of the TCAS and the ATC 1 and ATC 2 systems. When the aeroplane was back at the parking stand, the "ATC Transponder BITE Procedure" applied by the maintenance organisation at Tarbes did not reveal anything.

When the same crew resumed taxiing at approximately 22:10, they detected another malfunction of the TCAS and the ATC 1 and ATC 2 systems. When the aeroplane arrived back at the parking stand, the maintenance organisation at Tarbes carried out the same troubleshooting procedure, which did not reveal anything. As the procedure states if no failure is detected, the conclusion indicated in the TLB was that this was an intermittent failure.

At approximately 23:30, the same crew resumed taxiing at Tarbes and, once again, detected the same malfunctions. The maintenance organisation at Tarbes then deferred the processing of the malfunction so that the aeroplane could take off the next day under MEL provisions.

1.6.1.2.3 22 July to 5 August 2023

Two flights were carried out on 22 July. No particular item was recorded in the TLB. On 23 July, the procedure in the Fault Isolation Manual to be applied in the event of the illumination of the amber light on the ATC control panel was carried out and revealed a malfunction on the two transponders. With no spare transponders available, the aeroplane was cleared to resume flights under MEL provisions. The cables in interaction with the transponders were also checked.

Five flights were then carried out during the day. After the last flight, a functional check of the ATC 1 and ATC 2 systems revealed that the ATC 1 system was operational and that the ATC 2 system was faulty. On 24 July, no mention specific to the ATC systems was recorded in the TLB for the five flights made. Both transponders and the ATC control panel were replaced on 25 July. Following the replacement, and up to and including 27 July, 13 flights were carried out, with no mention related to the aeroplane's ATC systems made in the TLB. After the first flight on 28 July, at approximately 10:30, the crew recorded in the TLB that they saw the ATC FAIL light illuminate after landing, whichever of the two transponders was selected. The aeroplane was then able to carry out a further two flights that day under MEL provisions. Before the first flights on 29 July, the ATC system antenna located on the top of the aeroplane's fuselage was replaced. After the sixth flight of the day, the crew recorded in the TLB that the TCAS was faulty, specifying that the traffic advisories (TA) were working correctly, contrary to the resolution advisories (RA). A ground test carried out by the maintenance organisation did not confirm the malfunction. The aeroplane took off again for the last flight of the day. The TCAS was replaced on 5 August in compliance with the work order issued following the check on 29 July. Thirty flights were carried out between this check and 5 August, with no mention of a TCAS malfunction being recorded in the TLB for this period.

1.6.1.3 Transponders

Source: Component Maintenance Manual (CMM), ATA 34-54-01, produced by Honeywell (issue No 5 dated 19 November 2018)

1.6.1.3.1 Description

The two TRA-100B type transponders provide the Mode S Transponder function as per the European specifications ETSO-C112d. The installation of these transponders complies with the certification specifications CS-ACNS (see paragraph 1.17.1.2).

The TRA-100B transponder comprises the following main modules:

- a chassis;
- an input/output data processor (DPIO);
- a module for the receiving and transmission functions (RF);
- an alternating current power supply (ACPS);
- a direct current power supply (DCPS).

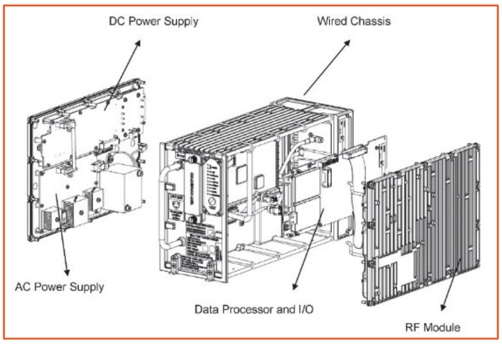

Figure 9: transponder modules (Source: Honeywell)

The chassis provides all the mechanical functions and electrical connections between the modules. The ACPS is supplied via the chassis and generates a 28 V power supply transmitted to the DCPS, which supplies the other modules.

The TRA-100B transponder also has two connectors (see **Figure 10**):

- a main connector on the rear panel for the data and to test the Inputs/Outputs;
- a test connector on the front panel for transponder maintenance operations.

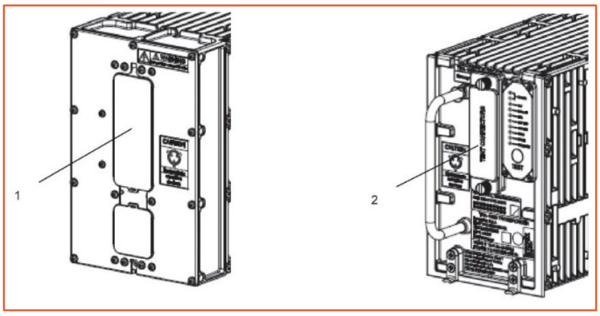

Figure 10: TRA-100B transponder connectors (Source: Honeywell)

An ARINC 429 bus[12] enables the transponder to exchange information via its main connector with the TCAS in particular. Two main connector pins each transmit a discrete parameter indicating a failure of the transponder to the ATC control panel, to illuminate the **ATC FAIL** light.

The transponder CMM indicates that the transponder can assure its ATC functions, with or without the TCAS. The manual specifies that the TCAS, however, is unable to assure its functions without the transponder.

1.6.1.3.2 Scheduled transponder maintenance

The transponder CMM indicates that no scheduled maintenance operation is required. The replacement of the transponder can be considered in the event of a failure or fault after completing the troubleshooting procedure.

1.6.1.3.3 Troubleshooting

The TRA-100B transponder has an inbuilt test function not only to signal the failure of a transponder to the crew but also to identify the origin of a failure at the transponder or at the system wiring on the aeroplane. This function provides information to target the maintenance or repair operations to be carried out.

[12] Data transfer standard used in avionics.

The diagnosis of each flight segment or of ground tests are stored in an internal memory. Internal transponder failures and failures detected at exterior sources are saved. The transponder also has a set of LEDs (see **Figure 11**) on its front panel, which provide information about the state of the transponder itself and about the status of its interfaces.

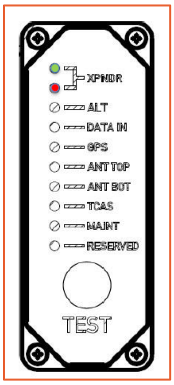

Figure 11: set of LEDs on transponder front panel (Source: Honeywell)

The troubleshooting procedure, "ATC Transponder BITE Procedure" consists in pressing the TEST button on the transponder's front panel with the aim of checking the transponder's internal circuits and the information provided by the systems that interact with this transponder (e.g. antennas, GPS and TCAS). If the check detects a fault, a LED light associated with this fault illuminates on the transponder's front panel. The illumination of a light refers to a specific procedure in the Fault Isolation Manual (FIM).

1.6.1.3.4 Reliability

According to the specifications pertaining to the version of the TRA-100B transponder equipping the Boeing, the target Mean Time Between Failures (MTBF), excluding voluntary or scheduled shut-down, which only takes into account the removal of equipment in the event of a failure, should be more than 36,000 flight hours. The target Mean Time Between Unscheduled Removal (MTBUR)[13], which includes all equipment removals, with detected or suspected failure, should be more than 30,000 flight hours.

On 1 June 2023, and over a period of 12 months, the MTBF and MTBUR monitored by HONEYWEL for the TRA-100B transponders was less than the MTBUR of 30,000 flight hours established during design, but more than the 5,000 hours required (ACNS.D.ELS.045 requirement, see paragraph 1.17.1.2).

1.6.1.3.5 Examinations

Data recorded by the two transponders equipping EC-NGC was read out. In the absence of a centralised maintenance system on board the Boeing 737, it was not possible to correlate this data with either the data recorded by the flight recorders or the aeroplane's TLB entries.

Tests and examinations were also conducted with the aim of determining the origin of the transponder malfunction during the serious incident flight. No fault or anomaly was found for transponder 1.

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[13] The MTBUR constitutes an operational measure. It is shorter than the MTBF due to the standard removals carried out by the maintenance organisations in operation. Over time, the MTBUR tends to converge towards the MTBF based on the upgrades made to the equipment.

It emerged from the data recorded by transponder 2 (the transponder selected by the crew during the serious incident flight) that between the serious incident flight on 21 July 2023 and the replacement of the transponders on 25 July 2023, several failure messages were recorded. They showed a malfunction of an electronic component (a transistor) in the transponder's +50 VDC power supply circuit. This electrical circuit provides, in particular, the energy required to transmit messages (interrogations and replies). This fault therefore resulted in no interrogations and replies in Mode S format being transmitted by the transponder. However, the transponder was still able to receive messages from ground stations and transponders on other aircraft.

The tests performed on transponder 2 also confirmed the transmission of a signal to the ATC control panel to trigger the illumination of the **ATC FAIL** light.

1.6.1.3.6 Service Bulletin

In 2022, Honeywell was informed of TRA-100B transponder malfunctions, with respect to the +50 VDC power supply circuit, with the same failure messages as those identified during the examinations of EC-NGC transponder 2. At the end of June 2023, 44% of transponders sent back to Honeywell were returned due to a transistor problem, while 34% were due to other causes and 22% had no identified fault.

Honeywell's analysis concluded that these malfunctions were due to an operating fault on a transistor in the conditions of use of the transponder. The analysis also revealed that the design margins relating to transistor heat dissipation requirements were insufficient.

Based on this analysis, Honeywell developed a technical solution that was the subject of a Service Bulletin[14] issued on 23 August 2023. One of the main modifications was the replacement of some components on the DC power supply sub-assembly. Since this date, Honeywell has not received any new reports of malfunctions with respect to the power supply of transponders.

1.6.1.4 TCAS equipment

In compliance with the regulation in force[15], the aeroplane was equipped with a Honeywell TCAS II version 7.1.

When there is a TCAS failure or it cannot operate, an amber TCAS FAIL message is displayed on the left side of the navigation display[16] screen.

1.6.1.5 Systems for attracting the crew' attention

The Boeing 737-809 Flight Crew Operating Manual (FCOM) specifies that two amber MASTER CAUTION lights, associated with pushbuttons, illuminate in conditions that require a certain level of attention from the crew outside the crew's normal field of vision. These lights remain illuminated as long as the conditions exist or until the crew deal with the situation or press one of the pushbuttons. The FCOM specifies that a simple fault in certain redundant systems does not illuminate the MASTER CAUTION light. For example, this is the case with a transponder failure.

[14] Navigation – Modification (MOD 8) to TRA-100B, PN 066-01212-0301, replacement of the DC power supply due to the TR44 component field failure of the TRA-100B transponder.
[15] Requirement AUR.ACAS.1005 of consolidated regulation (EU) No 1332/2011 ([Version in force on the day of the serious incident]).
[16] Navigation Display

1.6.1.6 Operating procedures

The failure of a transponder is only mentioned in the "***ADS-B Out Failure***" abnormal procedure (see **Figure 12**) in the FCOM, in the event of an ADS-B malfunction. The procedure asks the crew to select the second transponder.

ADS-B Out Failure

Condition: One or more of these occur:
- ATC reports ADS-B Out is lost or degraded
- GPS-L or GPS-R INVALID message is in the FMC scratchpad and the transponder is selected to the related side.
- Transponder is failed

1 Transponder selector. . . . . Select opposite transponder

Figure 12: ADS-B Out Failure – Boeing 737 FCOM QRH procedure (Source: Boeing)

1.6.2 Journey logbook/Flight logbook/TLB

Manufacturer	Embraer
Type	ERJ 190-100 LR
Serial number	19000113
Registration	F-HMLD
Entry into service	2007

In accordance with regulatory requirements17, the Embraer 190 registered F-HBLD was equipped with a TCAS II version 7.1.

1.7 Meteorological information

At FL 350, at the time and in the region in which separation was minimal between the two aeroplanes, visibility was greater than 10 km.

1.8 Aids to navigation

Not applicable.

1.9 Telecommunications - Communications, Navigation and Surveillance (CNS)

1.9.1 Surveillance and collision avoidance system

1.9.1.1 Communication protocols

The surveillance systems used by the air navigation services rely principally (on the date of publication of the report) on Secondary Surveillance Radars (SSR) on the ground. The SSR was designed to provide air traffic controllers with position measurements and additional information using the replies transmitted by a transponder installed on board aircraft.

17 Commission Regulation (EU) 2016/583 amending Regulation (EU) No 1332/2011 (Version in force on the day of the serious incident).

To provide information such as the position, identification or altitude of aircraft, SSR depend on the acquisition of information transmitted by transponders on board aircraft.

Different communication protocols, known as “modes”, were standardised for transponders, three of which for civil aviation:

- in Mode A (also known as 3/A), the transponder transmits a four-digit code, previously assigned by a controller to a pilot or crew, as soon as it receives an interrogation from a secondary radar on the ground;
- in Mode C, the transponder has additional information on the aircraft’s pressure altitude;
- Mode S (S for selective) mitigates a number of Mode A and Mode C limitations (e.g. garbling) and improves the communication capability. Mode S also enables the exchange of a lot of information, in particular for the ACAS[18] and the Automatic Dependent Surveillance Broadcast (ADS-B)[19]. All information exchanged in Mode S is necessarily associated with a fixed ICAO address assigned to each aircraft (unique combination of 24 bits).

1.9.1.2 Mode S

The Mode S communication protocol manages different types of message formats for interrogations (uplink) and replies (downlink). Interrogations are sent over the 1,030 MHz frequency and replies over the 1,090 MHz frequency. Furthermore, each message is defined by an uplink format (UF) number or downlink format (DF) number. Different message data block structures exist depending on the UF/DF number. Each message can be short (coded over 56 bits) or long (coded over 112 bits). They all have the same structure with a header that defines the format number (coded over 5 bits), a data field, then a field to indicate the end of the message.
Thus, some of the aircraft’s parameters are transmitted upon request (interrogation) while others can be transmitted automatically to allow information to be exchanged between different systems (see **Figure 13**):

- the secondary radars that have transmitted an interrogation;
- the ACAS systems of aircraft whose transponders have transmitted an interrogation;
- the ADS-B receivers.

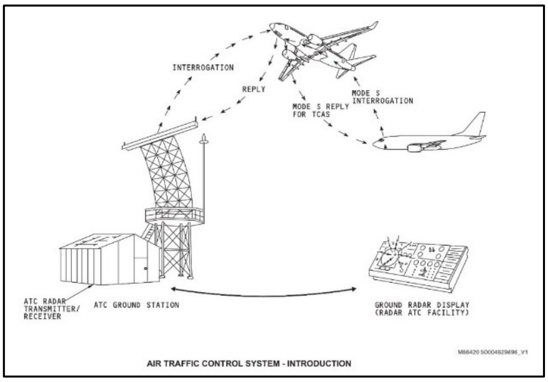


Figure 13: surveillance and collision avoidance (Source: Boeing)

[18] See paragraph 1.9.1.4.
[19] Satellite surveillance system that allows aircraft to periodically transmit parameters without first receiving interrogations.

1.9.1.3 Transponders

Aircraft that enter a Mode S radar coverage area are firstly detected by interrogations in UF=11 format from these radars, to which the transponders respond with DF=11 replies when the aircraft is not on the ground.

The radar thus acquires the aircraft's ICAO address and position, which are then used to transmit selective interrogations to this aircraft (different messages in UF format, see **Figure 15**) for the rest of the flight through the radar coverage area. These selective interrogations are used to:

- update the aircraft's horizontal position;
- ask the aircraft not to reply to non-selective interrogations transmitted by the radar;
- ask for additional information such as the altitude.

Moreover, Mode S transponders also generate spontaneous transmissions (squitters) approximately every second in DF=11 format. These include various information such as the aircraft's address, to enable the passive acquisition of these messages by multilateration[20] (MLat) systems and ACAS systems. These transmissions are generated alternately between Mode S antennas installed on the bottom and on the top (when installed) of the fuselage.

1.9.1.4 Airborne Collision Avoidance System (ACAS)

The ACAS is designed to prevent collisions and loss of separation in flight. There are three types of ACAS systems:

- ACAS I can only generate traffic advisories (TA). The TA indicate the position of intruder aircraft that may constitute a threat and may subsequently generate the display of resolution advisories (RA).
- ACAS II generates TA and RA. These provide indications of vertical manoeuvres to be carried out by the crew to increase or maintain the existing vertical distance and ensure separation with aircraft representing a threat. The RA are transmitted 15 to 35 s before the Closest Point of Approach (CPA) of the two aircraft.
- The ACAS III provides TA and RA in the horizontal and vertical directions. It has not yet been implemented.

Currently, the most common ACAS system is the TCAS[21] II version 7.1, installed on board the LAV4651 and the AFR21YB. This version has been mandatory in commercial air transport (CAT) since 2015.

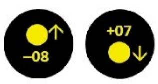
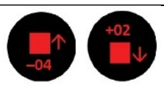
	Other traffic
	Nearby traffic, less than 6 NM away horizontally and less than 1,200 ft away vertically
	TA, generally activated 20 to 48 s before the CPA
	RA, generally activated 15 to 35 s before the CPA

Figure 14: examples of traffic display symbols

[20] Systems that use the difference in arrival times of signals transmitted by a transponder between several receivers on the ground to determine the position of the aircraft (or a vehicle on the ground).
[21] Traffic alert and Collision Avoidance System.

A Mode S transponder of an aircraft must be installed and operational for this aircraft's TCAS II to be operational. TCAS II systems can only generate TA and RA for aircraft equipped with Mode A/C or Mode S transponders signalling the altitude. TCAS II systems cannot track aircraft that are not equipped with transponders or whose transponders are not in use or have failed.
TCAS II systems determine which aircraft represent a potential collision threat using a three-phase process (detection, surveillance and coordination).

Detection

- A TCAS II is unable to detect an aircraft which is not equipped with a transponder, or equipped with a transponder that is not switched on or has failed.
- To detect other aircraft equipped with Mode S transponders, the TCAS II passively captures DF=11 squitters transmitted by these transponders. The reception of these transmissions enables the TCAS to obtain the ICAO address of the aircraft for the next surveillance phase. The TCAS II can also capture ADS-B messages transmitted approximately four times per second by the transponders of other aircraft in DF=17 format, identical to DF=11 squitters but with an additional message field that can be used to send some additional information.

Surveillance

- When an aircraft's TCAS II detects the presence of an aircraft in its detection area (approximately 30 NM), it transmits a short UF=0 message to track this aircraft. The transponder of this aircraft replies with a DF=0 messages that contains different information, such as the altitude or the maximum true air speed, when this is available.
- The TCAS II also periodically transmits (via its associated antennas) specific uplink UF=16 surveillance messages for aircraft located in the surveillance area. These broadcast interrogation messages transmitted by the TCAS[22] enable an aircraft to signal its presence to other nearby aircraft equipped with a TCAS. These interrogations are sent every eight to ten seconds by the TCAS.
- The TCAS II individually process each reply received and establish altitude, range, bearing and proximity information based on the replies received to determine whether the aircraft constitutes a threat.

Coordination

- The coordination between TCAS II systems is assured by transmissions that use interrogations and replies in UF=16 and DF=16 formats. The UF=16 interrogations used for coordination contain, among other things, information[23] that can be used to ensure additional evasive manoeuvres by limiting the choice of manoeuvres available for the TCAS (TCAS resolution advisory).
- A coordination reply in DF=16 format constitutes an acknowledgement of receipt, which informs the TCAS which transmitted the coordination message that its interrogation was received by the Mode S transponder of the other aircraft.
- Replies to UF=16 interrogations are transmitted in DF=16 format to guarantee coordination between TCAS systems that ensure compatibility of resolution advisories transmitted by both aircraft.

[22] There are three types of TCAS interrogation messages. TBIM (TCAS Broadcast Interrogation Messages) constitute the first type of message.
[23] Vertical Resolution Advisory Complement, VRC

The TCAS systems have an automatic surveillance software that continuously and automatically monitors their status and their performance as soon as they are switched on[24]. In particular, this software must enable the TCAS to detect a loss of integrity of the data received from other on-board systems or equipment. The TCAS monitors and validates the transponder data link using various ARINC protocols from buses between the transponder and the TCAS.

1.9.2 Monitoring of surveillance system performance

With the aim of improving the management of air traffic and air navigation services in Europe, the "Single European Sky" initiative was established based on a set of measures to optimise airspace, on performance targets and on development projects of new systems.

Eurocontrol[25] was appointed as Network Manager of air traffic for the "Single European Sky" and, within this context, is responsible for the design and management functions of this network. These network functions[26] concern:

- the European Route Network Design (ERND);
- the Air Traffic Flow Management (ATFM);
- the coordination of radio frequencies within aviation frequency bands used by general air traffic and of the radar transponder codes.

The implementation of these network functions requires Eurocontrol to perform a certain number of tasks[27], including monitoring of:

- 1,030 and 1,090 MHz frequencies and interoperability of surveillance systems;
- ACAS systems.

To this end, Eurocontrol uses two tools that enable it to monitor transponder activity and to detect detection losses (incorrect aircraft identification, incorrect aircraft address, etc.) from a set of eighty 1,030/1,090 MHz receivers deployed in Europe and surveillance data supplied by European state radar or surveillance systems.

By means of these systems and the reports from different Air Navigation Service Providers (ANSP), transponder problems are analysed with operators, ANSP and equipment manufacturers in order to identify the origin of these problems and to envisage corrective measures (transponder failures impacting a single aircraft, design issues, lack of compliance with regulatory requirements).

Based on the different recordings available, it was possible to determine that the transponder on the Boeing 737-809 operated by Albastar transmitted a number of squitters and replies before the complete cessation of transmissions over the 1,090 MHz frequency from 08:30:35. For example, no reply to the ground radar interrogations (DF=11 format) and no periodic ADS-B messages (DF=17 format) were received by the Eurocontrol monitoring system between 08:30:35 and 08:54:39.

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[24] In compliance with the provisions of EUROCAE document ED-143 - *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II* (TCAS II).
[25] European organisation for the safety of air navigation.
[26] Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions (Version in force on the day of the serious incident).
[27] Article 7 of Regulation (EU) 2019/123.

However, Eurocontrol stated that during the period of around 25 min of no transponder transmissions, periodic messages in TCAS broadcasts using UF=16 continued to be transmitted by the TCAS 737-809. These TCAS broadcasts indicate that the TCAS continued to operate during the interruption of transponder transmissions. The read-out of these messages indicated that the messages exchanged remained in the surveillance phase and that a coordination phase did not occur at any time (see paragraph 1.9.1.4). Moreover, the TCAS on board the Embraer 190 also regularly transmitted messages in reply to the messages transmitted by the TCAS on board the Boeing 737-809.

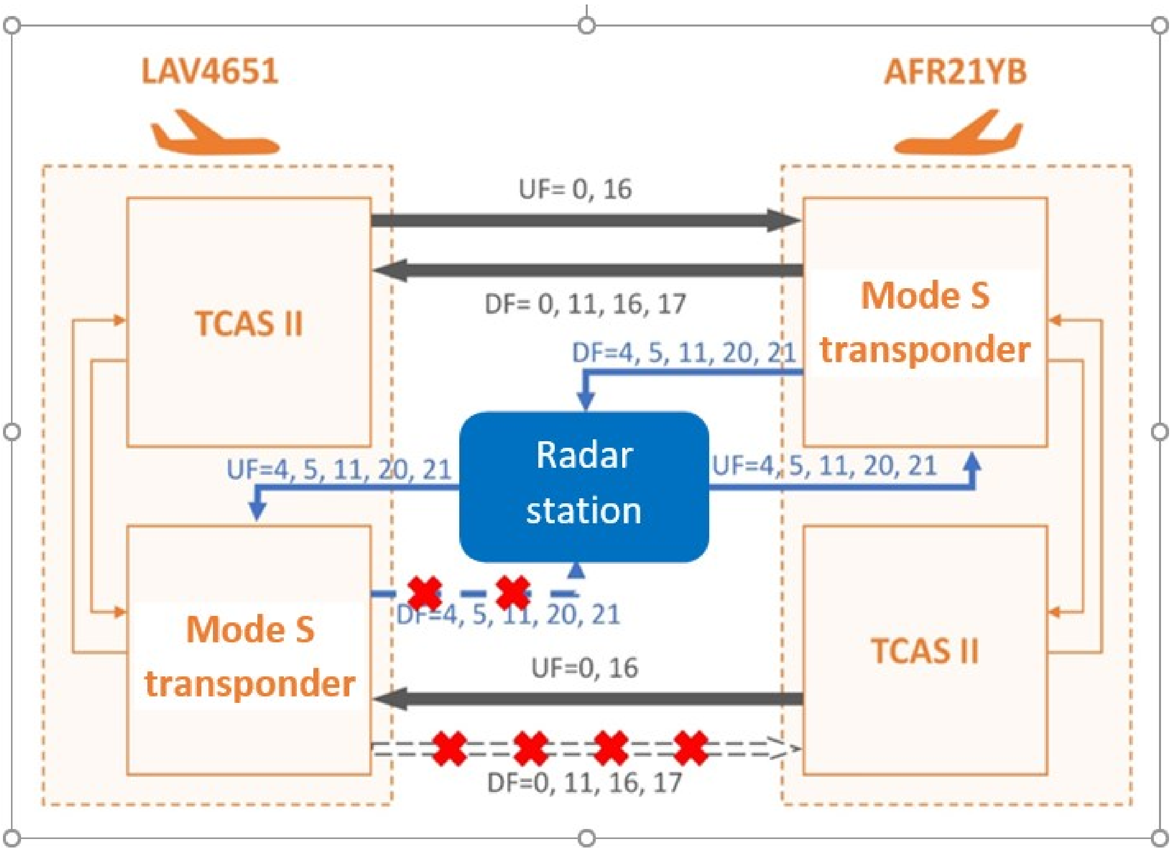

Figure 15: TCAS communication (the red crosses indicate functions lost during the serious incident) (Source: adaptation of figure B-1 of EUROCAE document ED-143 on standards for TCAS II)

1.9.3 TCAS simulation

Data recorded by the QAR on the Boeing 737-809 and the Embraer 190 was replayed using a simulator to determine how the TCAS on board these two aeroplanes would have operated if the Boeing 737-809 transponder had not failed.

The Eurocontrol simulators replayed this data using the TCAS II software and advanced modelling functions. They confirmed the following elements:

- loss of the radar separation standard (5 NM) at 08:50:28;
- the closest loss of separation (distance of 2.6 NM) between the two aeroplanes occurred at 08:51:28;
- no TA or RA was triggered, even with the simulation of no loss of transponder function.

1.9.4 Impact on air traffic control of a transponder malfunction

In 2019, Eurocontrol published a safety study[28] on the impact of a transponder malfunction on air traffic control. The study considered several cases. In particular, it considered the case where the failure occurs when the radar monitoring service is being provided and radio contact is maintained between the controller and the crew. The different scenarios related to a transponder malfunction, with the associated effects, are illustrated in **Figure 16** below.

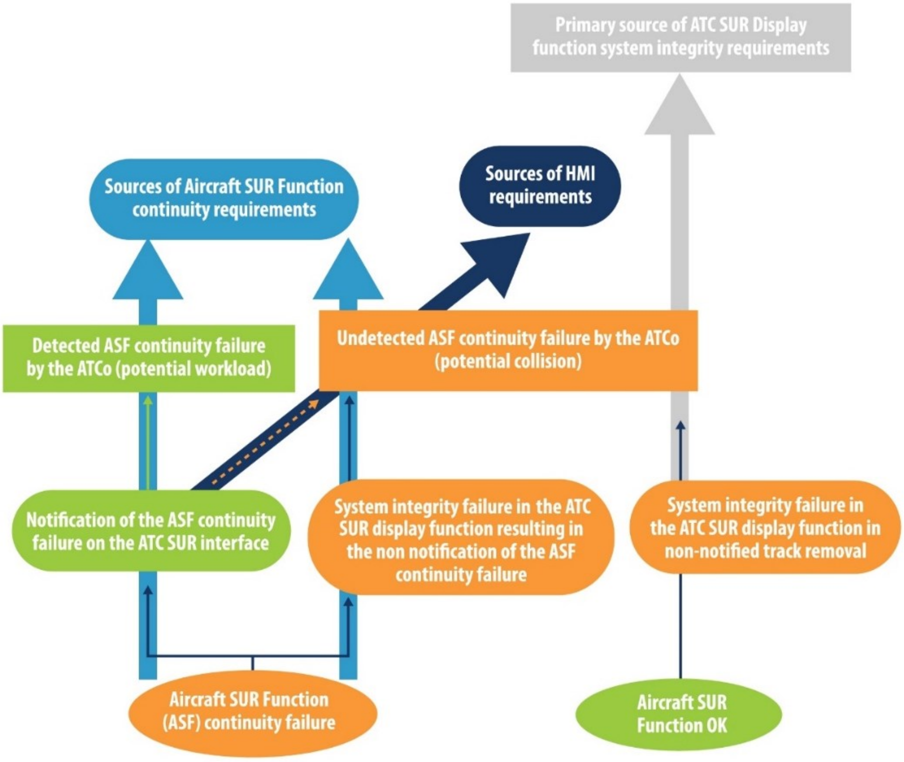

Figure 16: scenarios and consequences related to a transponder malfunction

The left light blue arrow depicts the case of a failure of transponder functions on the aircraft combined with a ground system notification of this failure detected by the air traffic controller. The second light blue arrow shows the case of a failure of transponder functions on the aircraft, combined with a simultaneous failure of the ground system to display the notification. In this case, it is assumed that the loss of transponder function on the aircraft is not detected by the air traffic controller.

The dark blue arrow characterises the risk that an air traffic controller does not detect a loss of a track previously displayed and initially identified by this air traffic controller, despite the presence of alerts characteristic of a loss of radar contact associated with a transponder malfunction.

The safety study states that, "*Once the track has been removed from the display and if undetected by the ATCo*[29]*, there is a risk that only providence can prevent a breakdown of separation*" between the aircraft impacted by the loss of transponder function and another transponder.

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[28] Operational Safety Study on impact on ATC from a loss of aircraft transponder function.

[29] Air Traffic Controller

The safety study specifies that, beyond the improvement of technical aspects relating to the transponder, the key elements to ensure the detection of a transponder malfunction by an air traffic controller as well as the effective and immediate processing of this type of malfunction, rely on mechanisms, such as procedures or an adequate man-machine interface.

1.9.5 Risks associated with a transponder malfunction

In October 2014, Eurocontrol published a study on the risks associated with the operation of an aircraft without a transponder or with a dysfunctional transponder[30]. The introduction of the study indicates that, "*Operations without transponder or with a dysfunctional one constitute a single threat with a potential of 'passing' through all the existing safety barriers*."

In particular, the study describes the means of detecting transponder failures and of mitigating the associated risks. It specifies that if a transponder failure is coming from a technical issue, the transponder design and maintenance procedures are key ways to reduce the risk of failures.

One of the scenarios addressed in this study is the total loss of the transponder, with no information being transmitted to the ground radar stations. The most serious risk is a loss of separation between aircraft due to loss of radar contact with the aircraft with a dysfunctional transponder.

According to the study, the barriers which remain most effective for the scenarios associated with total loss of the transponder are:

- the design and tuning of effective tools for alerting air traffic controllers in the event of a loss of radar contact;
- the use of voice reporting, which is particularly relevant during sector handover, except in the case of silent sector handover.

The study also indicates that the use of Primary Surveillance Radars (PSR) can be an effective barrier. The study specifies that these radars are being taken out of service in the en-route environment and that increased cooperation with the military authorities could help to improve effectiveness in detecting a transponder problem.

Within the scope of the European Plan for Aviation Safety (EPAS) safety issues pertaining to air navigation (*Safety Issue SI-2002: Deconfliction with aircraft operating with a malfunctioning/non-operative transponder*[31]), EASA assesses the risk of airborne collision or terrain collision as the result of incorrect information being transmitted by a dysfunctional transponder.

1.9.6 Recording of the aural environment of control positions

ICAO Annex 11 pertaining to air traffic services recommends the following: "*Air traffic control units should be equipped with devices that record background communication and the aural environment at air traffic controller work stations*." Annex 11 specifies that these recordings should be retained "*during at least the last twenty-four hours of operation*."

[30] Eurocontrol safety study, issue 1.0 of 7 October 2014.
[31] EPAS Volume III 'Safety Risk Portfolios' 2025 Edition, page 72.

This ICAO recommendation is repeated in Regulation (EU) No 2017/373[32] known as "ATM-ANS", which introduces, in certain conditions, a requirement to record the aural environment and background communication (requirement ATS.OR.460):

> *"Unless otherwise prescribed by the competent authority, air traffic services units shall be equipped with devices that record background communication and the aural environment at air traffic controller's, or the flight information service officer's, or the AFIS officer's work stations, as applicable, capable of retaining the information recorded during at least the last 24 hours of operation.*
> *b) Such recordings shall only be used for the investigation of accidents and incidents which are subject to mandatory reporting."*

In France, an Order dated 9 June 2020, amended by an Order dated 8 February 2022, states that up to 31 January 2025, aerodrome control, approach control and en-route control service providers delivering general air traffic control services are not required to equip their units with means to record background communication and the aural environment at air traffic controller work stations. This Order was amended by the Order dated 29 January 2025:

- up to 31 January 2026[33], the DSNA is not required to equip its units with means to record background communication and the aural environment;
- before 1 December 2025, the DSNA must submit an installation schedule for these recording means for approval by the DSAC. The DSAC has two months to express its opinion on this schedule.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The serious incident was identified a few days after it occurred and the CVR data was no longer available for EC-NGC and F-HBLD.

Data from the unprotected Quick Access Recorders (QAR) on both aeroplanes, which is similar to the FDR data, as well as audio and radar data from the air navigation services, was retrieved and synchronised with the radar data time base. Based on this data, it was determined that the horizontal distance between the two aeroplanes reached a minimum of 2.6 NM when these two aeroplanes were at FL350.

The flight paths of these two aeroplanes had a constant bearing of 35° for the three minutes preceding the closest loss of separation.

1.12 Wreckage and impact information

Not applicable.

[32] Implementing regulation (EU) 1/2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight (version in force on the day of the serious incident).
[33] 31 January 2030 for the units at Saint-Barthélemy, Saint-Pierre-et-Miquelon, in the Wallis and Futuna islands, in French Polynesia, in New Caledonia and in the French Southern and Antarctic Lands.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Not applicable.

1.17 Organisational and management information

1.17.1 Certification Specifications

1.17.1.1 Type certification for Boeing 737-809 aeroplanes

The type certification for aircraft is essentially based (with a few exceptions) on airworthiness certification specifications applicable to an aircraft and in force on the date on which the certificate was requested by the designer of this aircraft.

As Boeing aeroplanes are designed in the United States, the certifying authority for these aeroplanes is the FAA. The certification basis for the Boeing 737-809, such as EC-NGC, therefore meets the certification requirements of versions 1 (date of entry into force 7 July 1965) to 77 (date of entry into force 29 July 1992) of Part 25 of title 14 of the United States CFR[34] (14 CFR Part 25, also known as FAR 25) drawn up by the FAA and applicable to air transport aeroplanes. Some special conditions and exemptions are also provided and indicated on the type certificate for these aeroplanes.

The equivalent certification basis in Europe for the Boeing 737-809 is version 14 of JAR 25 dated 27 May 1994 with similar special conditions and exemptions.

Note: Joint Aviation Requirements (JAR) were issued by the Joint Aviation Authorities (JAA) and monitored by the civil aviation authorities of each European Union member state prior to the creation of EASA in 2002, which transposed them into Certification Specifications (CS). JAR 25 and subsequently CS 25 apply to air transport aeroplanes with a maximum take-off weight of more than 5,700 kg.

[34] Code of Federal regulations.

1.17.1.2 Requirements applicable to transponders

On 21 July 2017, the FAA updated a circular[35] to guide type certificate holders through the certification process for TCAS II installations and Mode S transponders on board aircraft. The provisions described in this circular cover design aspects, system and equipment characteristics, tests to be performed, and the urgency in the event of a failure of TCAS II systems and associated transponders. These provisions correspond to Acceptable Means of Compliance (AMC) to obtain these approvals.

It is worth mentioning that the circular refers in particular to EASA certification specifications on installation, certification and approval criteria for transponders or aircraft design modifications (CS-ACNS).

The FAA circular makes reference to the investigation into the mid-air collision in 2006 in Brazil (see paragraph 1.18.5), which led to the strengthening of requirements with respect to crew alerting systems in the event of a TCAS malfunction. The circular specifies that for new installations of TCAS II and/or transponders, to meet the requirements for crew alerting, the failure of a transponder or a TCAS (see paragraph 1.17.1.3) "*must be annunciated in yellow/amber in the pilots' primary field of view*." The circular also recommends that these alerts "*be interfaced with the aircraft's master caution and warning system*." However, the circular adds that "*a new installation is considered to be:*

1. *the installation of a Mode S transponder in an aircraft that does not currently have one fitted;*
2. *the installation of a TCAS II system in an aircraft that does not currently have one fitted; or*
3. *a new aircraft, i.e. one that has not received a type certificate*."

These recommendations are not applicable to the installation of a new type of transponder on board a Boeing 737 such as EC-NGC.

In addition to these airworthiness requirements, commercial air transport operators must also comply with a number of operational requirements to fly in European airspace (CS-ACNS and transponder carrying requirements[36].) Therefore, for operators of aircraft of a maximum certified take-off mass exceeding 5,700 kg or that have a maximum cruising true airspeed capability greater than 250 kt and an individual certificate of airworthiness first issued on or after 7 June 1995, transponders must be serviceable and comply with the following conditions:

- compliance with European technical standards ETSO-C112d (or an equivalent standard compliant with ICAO Annex 10) which require, as a minimum, that the standards set out in EUROCAE document ED-73E[37] are met;
- compatibility with the ACAS system if one is fitted on board;

[35] Circular 20-151C

[36] In accordance with the transponder carrying requirements of Regulation (EU) No 1207/2011 which had to be met by 7 June 2023. They are included in a similar manner in Commission Implementing Regulation (EU) No 2023/1770 of 12 September 2023 repealing Implementing Regulation (EU) No. 1207/2011.

[37] *Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders* of May 2011.

- indication of the "*non-operational status or failure of the transponder system without undue delay and without the need for flight crew action*" (requirement CS ACNS.D.ELS.030);
- Mode S Elementary Surveillance (ELS): e.g. transmission of the transponder code used in flight and presented to controllers, of the aircraft's altitude, of the transponder's data link capability or of the flight status (ground/airborne);
- Mode S Enhanced Surveillance (EHS): e.g. transmission of additional parameters, when these are available, such as the altitude selected by the crew, the aircraft's true air speed or its ground speed;
- capabilities for 1,090 MHz Extended Squitter (ES) automatic dependent surveillance-broadcast "out" (ADS-B Out): e.g. transmission, from approved sources, of a number of parameters, such as the aircraft's registration, the four-digit transponder code, the aircraft's ICAO address, the aircraft's GNSS position (latitude and longitude), the pressure altitude, its vertical speed or its route;
- continuity sufficient to avoid presenting an operational risk.

In commercial air transport, some additional capabilities may be required depending on the routes taken.

The CS-ACNS specify that a loss of the ELS and EHS functions is considered to be a "minor failure condition"[38] (CS ACNS.D.ELS.040 and CS ACNS.D.EHS.020 - Integrity).

They also specify a low probability of loss (requirement CS ACNS.D.ELS.045 Continuity) corresponding to a MTBF[39] equal to or greater than 5,000 flight hours.

1.17.1.3 Systems for attracting crew attention

Paragraphs 25.1322 of the FAR 25 and JAR 25.1322[40] versions applicable to Boeing 737-809s such as EC-NGC, indicate that warning, caution and advisory lights installed in cockpits must be:
- red for warnings indicating a hazard requiring immediate action;
- amber for alerts indicating a possible action.

To meet the previous requirements, information supplementing these requirements specifies that:
- caution and warning lights should be located in each pilot's normal field of view and be visible in all light conditions;
- the association of aural signals with red warnings[41] and amber cautions[42] is optional unless required by the authority.

From 2011, as part of harmonisation work between the FAA and EASA, paragraphs 25.1322 of CS 25 and FAR 25 (versions subsequent to the certification basis applicable to Boeing 737-809 aircraft such as EC-NGC) were considerably amended. The colour conventions described in paragraph 25.1322 of version 14 of JAR 25 were not changed.

[38] Condition that does not significantly reduce flight safety and that involves crew action.
[39] Mean Time Between Failure.
[40] Warning, caution, and advisory lights.
[41] Immediate recognition and a corrective action on the part of the crew are required.
[42] Immediate awareness by the crew is necessary and steps must be taken by the crew.

However, crew alerting systems are now required to:

1. provide the flight crew with the information needed to:
   i. identify non-normal operation and
   ii. determine the appropriate actions, if any;
2. be readily and easily detectable and intelligible by the flight crew under all foreseeable operating conditions, including conditions where multiple alerts are provided;
3. be removed when the alerting condition no longer exists.

It is also requested that these systems provide attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications.

AMC are described to demonstrate compliance with requirements pertaining to attention-getting systems. In particular, it appears that:

- it may be difficult for aeroplanes already equipped with flight crew alerting systems to comply with current certification specifications in the case of upgrades or installations of new equipment or on-board systems;
- the aim is to provide an intuitive and consistent location for getting the crew's attention;
- visual-alert information should be located so that both pilots are able to readily identify the alert condition. This information must therefore be located in each pilot's primary field of view (see **Figure 17**).

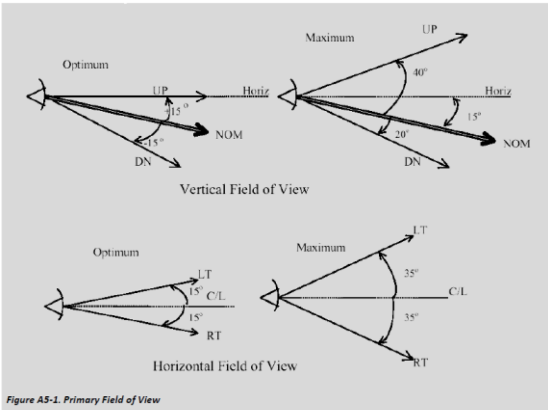


Figure 17: primary field of view (Source: CS25)

1.17.2 DSNA information

1.17.2.1 Organization

The *Direction des Services de la Navigation Aérienne* (DSNA) is the designated air navigation service provider in France. It is one of the three directorates making up the French civil aviation authority (DGAC), with the French air transport directorate (DTA) and the French civil aviation safety directorate (DSAC).

The DSNA is made up of the following four directorates:

- The Safety directorate (DSEC) is responsible, in particular, for:
  - developing and maintaining the safety management system,
  - proposing the DSNA's safety goals and strategy,
  - issuing the necessary or useful recommendations to achieve the DSNA's safety goals,

- studying, developing and promoting methods for analysing changes, processing safety events and managing safety, as well as associated training needs;

- the Resources and strategy directorate (DSR) is responsible, in particular, for managing the DSNA's human and financial resources;
- the Technical and innovation directorate (DTI) is responsible for ensuring the serviceability of the DSNA's equipment and systems, and for developing, as required in partnership with manufacturers, technical retrofit programmes;
- the Operations Directorate (OD) incorporates all air traffic control activities and ensures coordination between the five Area Control Centres (ACC) (see **Figure 18**). The OD also manages the Air Navigation Services (ANS), which group approach control services and control towers by region. It also comprises the Central Air Navigation Systems Operating Centre (CESNAC), which manages the shared communication and IT systems, and the Aeronautical Information Service (AIS), which is responsible for producing and distributing aeronautical information.

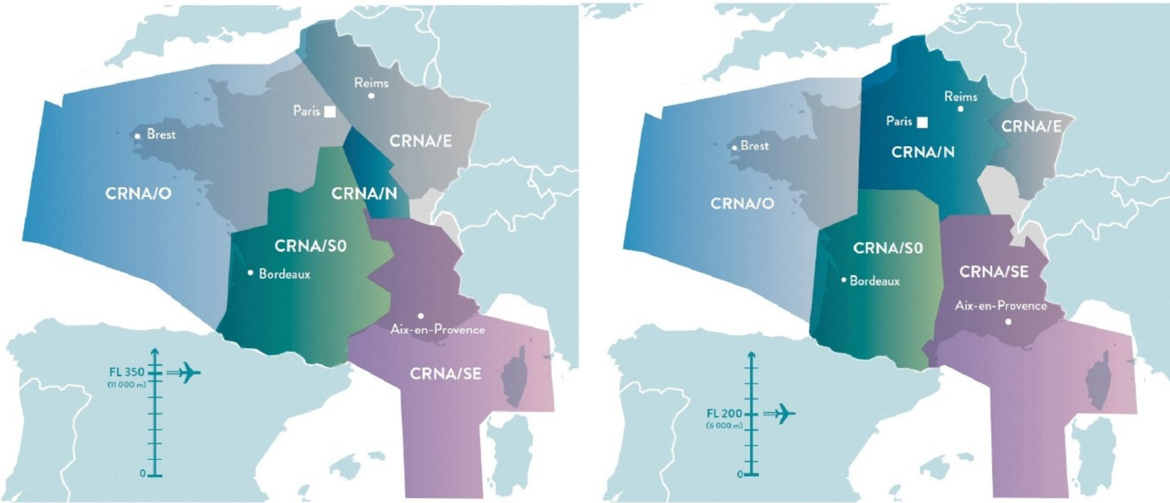


Figure 18: upper and lower airspace supervised by the five ACCs in Metropolitan France (Source: DSNA)

1.17.2.2 ATM/ANS systems

The automatic air traffic coordinator (CAUTRA) system is the air traffic control system developed and used in France for a number of years. To help air traffic controllers with their tasks, CAUTRA comprises several sub-systems, including:

- the Flight Plan Processing System (FPPS), which sends information about flight plans and changes to these plans;
- the Radar Data Processing System (RDPS), which includes the European radar processing system ARTAS[43] provided by Eurocontrol and used at European level;
- a display system;
- a system for printing strips of paper that provide a given amount of information about each flight managed (flight call sign, type of aircraft, destination, route, planned altitude) and that can be used to assimilate flights to be managed (traffic) and to carry out the associated actions.

[43] Air traffic management surveillance tracker and server.

The DSNA implemented the ERATO electronic version of CAUTRA in the ACC/west (in December 2015) and the ACC/south-west (in December 2016) (see paragraph 1.17.3). CAUTRA is due to be replaced by the 4-FLIGHT system in all the ACC in order to modernize the French air traffic control system. 4-FLIGHT (see paragraph 1.17.4) is designed by Thales Air Systems, within the context of a framework agreement in partnership with the DTI. 4-FLIGHT is currently in use at the ACC/east (pilot site for the development programme), ACC/south-east and ACC/north. It is planned to roll it out to the ACC/west and ACC/south-west from 2026.

1.17.2.3 Cooperation/sharing of tasks between controllers of a control position

The controllers in an ACC work in a control position that allows them to manage a sector or a combination of sectors in the airspace. The tasks to be carried out are divided into two main functions: a planning function and a tactical function. Each of these functions is assigned to a controller who is given the generic name of the function for which they are responsible (PCR and PCO).

These cooperative activities and task sharing between PCR and PCO were defined at the national level by a general task-sharing procedure dating from December 1987. The scope of the PCR and PCO roles was not changed with the implementation of the electronic environment. It is adapted and put in place locally by each control unit for the air traffic controllers concerned.

1.17.3 ERATO Electronic Environment (EEE)

1.17.3.1 General description

The ERATO electronic environment comprises a set of integrated tools and functions that did not change the roles and responsibilities of controllers in terms of services rendered. The main change was the deletion of the paper strips board, which led to the implementation of a new interface and a certain number of electronic tools and functions as well as the development of some work methods. The implementation of the operational concepts of the ERATO electronic environment nevertheless relied on the continued sharing of control position tasks, essential air traffic control tasks and the organization and constraints of the airspace.

ERATO is supplied with the CAUTRA radar processing and flight plan processing data and will eventually be replaced by 4-FLIGHT in the ACC/west and ACC/south-west.

ERATO is based on path modelling (forecast of changes to these paths) using different elements:

- specific parameters associated with operational practices in the sector and flight plan data;
- aircraft performance;
- instructions transmitted and entered in the interface by controllers;
- actual aircraft positions.

Planned changes to these paths are continuously updated. The observation of actual positions allows for the detection of deviations from the paths modelled by ERATO and the triggering of position alerts. These alerts signal both a deviation from the planned behaviour and a deterioration in the service provided by ERATO.

1.17.3.2 Control positions in the ERATO electronic environment

A control position is made up of two (or three in the case of on-job training) control modules (see **Figure 19**).

Figure 19: control module (Source: ACC/west)

Each controller communicates with the air traffic control system via an Operational Display System (ODS), which provides the controller with a dynamic graphic display of air traffic in the sector(s) for which they are responsible and the means to interact with this display. This visual display is established based on information from:

- the RDPS;
- the FPPS;
- the ERATO server;
- map information about the type of controlled space: static and dynamic sector base maps (activation situation status) and air routes.

1.17.3.3 Layout of the main screen of a control position

The ODS main interface in the ERATO electronic environment comprises a single 43" screen in 16/9 format. The main interface components are as follows (see **Figure 20**):

- a constant main radar image with a vertical control strip on the left-hand side;
- a DYnamic Presentation (DYP) table, located on the right-hand side and at the bottom of the screen. A DYP is a partial view, which varies in size depending on the format and displays flight information in text format;
- a system alert area, located above the DYP table, which alerts the controller in the event of a system error;
- a DYP info area, located above the system alert area. The DYP info area displays all elements of a flight plan in particular;
- lists of flights depending on the air traffic situation and the status of each flight in the system. These lists may include the following:
    - lists of incoming flights, which contain the flights expected over the frequency in the position,
    - the FREQ list, which contain the flights in radio communication,
    - the list of flights with no tracks, which contain the flights with an uncorrelated, active flight plan.

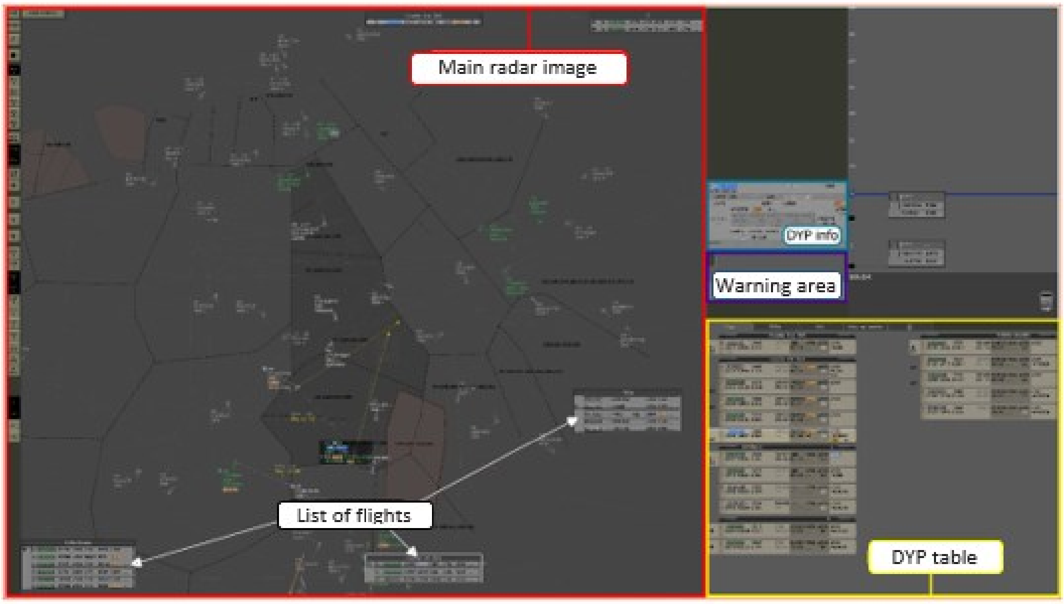


Figure 20: main ODS screen (Source: DSNA)

1.17.3.4 Description of radar tracks and labels on the main radar image

Each flight is represented on the radar image by way of a track and a label (see **Figure 21**).

Figure 21: example of radar track and label (Source: DSNA)

The track is the graphic representation of a flight. This track represents the summary of several pieces of information:

- a symbol showing the last track position (track head symbol);
- a speed vector (if available). The size represents the distance travelled by the aircraft at constant speed in a given time. The direction of the speed vector represents the flight heading (information based on RDPS tracking);
- past flight positions. The past positions are represented by circles decreasing in size.

The track head symbol is connected to the radar label using a fixed length leader line. This radar label combines a certain amount of flight data. It may include information coming from the RDPS, the FPPS, or managed by the ODS. Its format is defined by configuration and can vary depending on the flight status or when the mouse pointer is over the label (moving the mouse over it).

1.17.3.5 Track ageing mechanism on ODS

When the dating of the last track information is too old, an ageing mechanism is activated (see **Figure 22**). This leads to:

- the progressive loss of past positions;
- the change of track head symbol as different losses are detected.

The number of losses is configurable and is fewer than the maximum number of past positions. An extrapolated track head position results in the track head symbol being displayed differently.

At the end of the ageing process, the track can be replaced with a track marker.

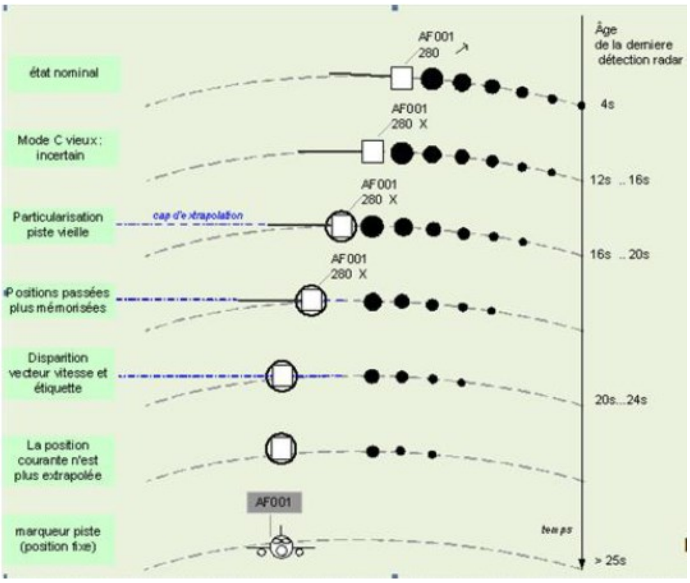


Figure 22: track ageing mechanism on ODS
(Source: DSNA)

1.17.3.6 Air traffic controller alerting systems[44]

Note: the information presented is principally based on the ODS EEE (MUT ODS) Main Display User Manual, version 7.7V1R0_V21R0.

A number of visual systems exist on the ODS, governed by priority rules. These systems are used to warn controllers about information updates that are deemed to be important.

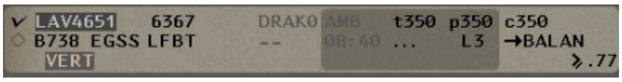
Some of these systems associated with the loss of track display are described below.

[44] The DSNA uses the term “stimulus” in safety files to indicate and describe all systems designed to attract the air traffic controller’s attention.

VERT

VERT is a warning from the ERATO service that is displayed on the first row of the label, on flight lists (**V** warning) and on the associated DYP. This warning appears for a flight taken into account when the system notices a deviation from the flight path in relation to its planned modelling in the vertical profile. In particular, this warning is displayed for the five seconds which precede the disappearance of a track. When this warning appears, the controller is expected to check the consistency between the aeroplane's actual flight level, the flight level transmitted during the last instruction and the flight level when the aeroplane exits the sector.

Display examples:



F

F is a warning from the ERATO service that is displayed on the first row of the label, on flight lists (**F** warning) and on the associated DYP. This warning appears when some ERATO services are no longer available for a given flight. The controller must pay special attention to such a flight when it is integrated and as it flies through the sector, in order to prevent any conflict with another aircraft.

Display examples:

SFL absent

The SFL[45] absent  warning is displayed on the first row of the label when the selected flight level is not received. It is used to inform the controller that the aeroplane's downlink parameters via Mode S are no longer available.

Display examples:

[45] Selected Flight Level, corresponds to the flight level selected by the pilot.

List of flights with no track

The list of flights with no track highlights flights with an active flight plan to which no track information can be associated. The list of flights with no track is displayed if it is not empty. This window has five fields:

- the flight number;
- the “flight with no track” symbols including:
  - the  symbol if the flight is associated with a track marker;
  - if not, the  symbol;
- the Mode A code;
- the Annotation indicator which shows the presence of an annotation added by the controllers to record specific information about a flight;
- the ERATO warning.

When this window appears, the controller is expected to look for the uncorrelated track in question.

The “List of flights with no track” window automatically disappears from the screens after a given length of time, when the flight is supposed to have exited the limits of the last sector of the position according to its flight plan estimates.

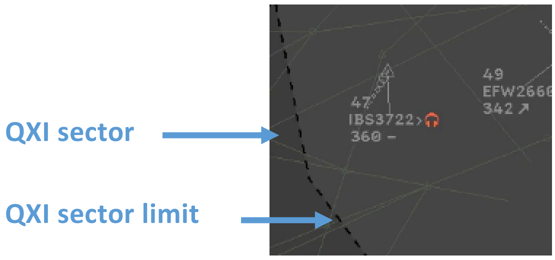
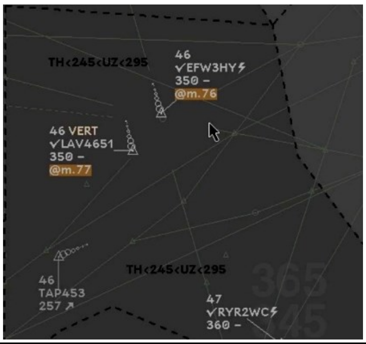
Display examples:

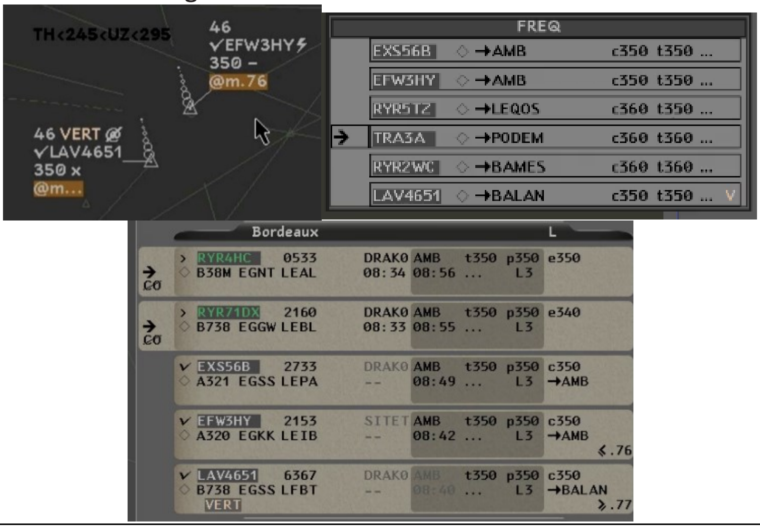
Track markers
Track markers are used to represent a flight that is important for air traffic control and not reported by the radar system. Track markers are automatically created by the ODS. The display of track markers is automatically forced. They are represented by an aeroplane symbol (front view) showing the last known track position. The track marker can be deleted independently from the PCO and PCR ODS screens by a right-click. Display examples:    The display mechanism and the presentation of certain traffic flows to controllers can cause track markers to appear which do not concern the position. There are several types of track markers, with varying degrees of criticality: ▪ those generated following the non-refreshment of a track, which are not covered by a valid flight plan for this position. They are not associated with a symbol in the list of flights with no track. They can be military or civil flights that do not concern the sector or the ACC; ▪ those forming part of the context of the controller's position. They are accompanied by a symbol in the list of flights with no track The controller is expected to verify whether the display of a track marker corresponds to a loss of visualisation of a flight in their sector.

1.17.3.7 Main alerts displayed on the controllers' screens during the incident

The information below was taken from the video recordings of the PCR and PCO screens for the QXI sector of the ACC/west and the RL3 sector of the ACC/south-west. Only the most important elements are indicated.

Note: the Boeing 737 (flight LAV4651) and the Embraer 190 (flight AFR21YB) were equipped with the Controller-Pilot Data Link Communications (CPDLC) application. This function was available in the airspace of the ACC/west and ACC/south-west. Neither aircraft was communicating using this function in these airspaces.

Time	Position *Sector*	Display
08:22:40	PCR and PCO *QXI*	The transfer of flight IBS3722 via CPDLC link by the PCR from the QXI sector to another sector failed, leading to the display of the  symbol on the right-hand side of the flight label.  A “Specific flights” window appeared at the same time as the  symbol:  This window and the symbol remained displayed for 4 min and 20 s before disappearing with no inputs from the PCR or the PCO.
08:30:47	PCR and PCO *QXI*	**VERT** message appeared on the LAV4651 label. 

08:30:48	PCR and PCO *QXI*	Loss of downlink parameters and the trend bar on the LAV4651 label. ▪ **VERT** message displayed on the label ▪  symbol crossed out on the label ▪ **V** message in the FREQ box ▪ **VERT** message on the DYP 
08:30:53	PCR and PCO *QXI*	A circle appeared around the LAV4651 radar track. 
08:30:58	PCR and PCO *QXI*	The track for flight LAV4651 was replaced by a track marker  and its label was also changed. A “Flights with no track” window appeared at the same time to the right of the track marker. 
08:30:59	PCR and PCO *QXI*	The **F** message replaced **V** in the FREQ and “Flights with no track” windows as well as on the DYP for flight LAV4651. 

08:31:21	PCR *QXI*	Input on the mouse that had not been moved since 08:27:04.  *Position of the mouse in relation to the label for LAV4651 at the time of the PCR's input*
08:33:19	PCR *QXI*	Movement to the right of the "Flights with no track" window screen.
08:33:48	PCR *QXI*	Track marker deleted by right-clicking on the mouse. Flight LAV4651 remained displayed in the FREQ window and the **F** alert was associated with it. 
08:44:20	PCR *RL3*	Movement of the "Flights with no track" window which appeared a few seconds earlier on the screens of both sector controllers, showing flight LAV4651 only.  The **F** alert (filtering unavailable) appeared approximately 3 min later. 

1.17.4 4-FLIGHT environment

4-FLIGHT (see paragraph 1.17.2.2) incorporates the following functionalities:

- ARTAS;
- a new-generation flight plan automatic processing system (Coflight);
- an all-electronic (stripless) man-machine interface supplied by Thales;
- a number of peripheral devices for air traffic controllers.

In the event of the loss or lack of radar correlation, a blue-framed label associated with a marker, known as FPASD[46] (see **Figure 23**), is used to show the theoretical position of an aeroplane based on the flight plan. This is not a radar track. This label is displayed on the controller's screen for a flight plan that is not correlated with a track in the system. Similar to a track, it also progresses geographically, although this progression is only based on estimated flight plan data (not radar data). When a FPASD appears, it allows controllers to detect a loss of correlation, or even a lack or loss of radar track (loss of radar detection or tracking failure or incorrect transponder code or radar coverage).

[46] Flight Plan Air Situation Display.

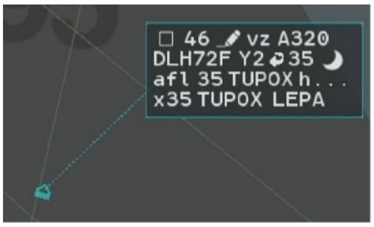


Figure 23: FPASD (Source: DSNA's 4-FLIGHT User Manual)

A list, known as the "Lost List" (see **Figure 24**), informs the controller of a loss of correlation for a previously correlated flight. This window opens automatically when a loss of correlation for a flight occurs. It contains various information about the flight. The display of this window is usually associated with a FPASD being displayed until the track is reacquired and correlated.

Figure 24: Lost List (Source: DSNA's 4-FLIGHT User Manual)

When a flight is no longer being detected by radar (loss of radar track), a marker appears on the screen instead of the last known track position.

- if the track was already correlated, an amber Last Known Position (LKP) marker (see **Figure 25**) appears. A FPASD also appears nearby;
- if the track was not correlated, a grey Lost Track (LT) marker (see **Figure 25**) appears.

Figure 25: LKP marker (on the left) and LT marker (on the right)

These markers allow controllers to detect the disappearance of a track (in the event of a radar detection problem), and to benefit from information about its last known position.

In some situations, LKP can appear for tracks that do not necessarily concern the sector. These LKP can, for example, be the consequence of local configurations in each ACC. These LKP may then be managed in a similar way to track markers in ERATO.

1.17.5 ACC/west information

1.17.5.1 Operations Manual for air traffic controllers

The Operations Manual for air traffic controllers includes a chapter on transponders. Following a general description of this type of equipment, transponder failures are addressed in a specific section that only specifies cases of failure detected by the crew or by controllers.

1.17.5.2 Work methods in ERATO electronic environment

Work methods in the ERATO electronic environment, drafted by the ACC/west for air traffic controllers, describe the procedures and methods of use of the associated functionalities. The version in force at the time of the serious incident was dated May 2021. It specifies that work in an electronic environment is based on the following principles:

- The controller provides information to the system:
    - each control input/instruction is processed by the system to provide the best possible service, especially in terms of coordination (PCO/PCR, adjacent sectors, etc.);
    - information must be provided to the system as actions are undertaken (control instructions, radio communications, coordination, etc.).
- In return, the system provides assistance to the controller:
    - automatically: the controller must take into account information sent back by the system, respond to stimuli and process them as soon as possible;
    - at the request of the controller (e.g. filtering).
- Controllers work together: oral communication and cross-checking are essential.

Task sharing

The sharing of tasks between the PCR and the PCO described in the document incorporates the elements of the Instruction dated December 1987 (see paragraphs 1.17.2.3 and 1.17.5.2), taking into account the specificities of the ERATO electronic environment (e.g. integration of DYP). The tasks described therefore concern the management of each control position by each controller and are presented below.

Sector sweep

The document indicates that the sector sweep comprises the following elements:

- The sector sweep must be exhaustive and cyclic.
- Sector sweep by the PCR:
    - sweep for flights on the frequency;
    - taking into account of the schedule;
    - scanning of lists of incoming flights and integration.
- Sector sweep by the PCO:
    - scanning of lists of incoming flights (integration, detection, materialisation of conflicts and outputs), correlation with radar labels;
    - following of the schedule and oral communication of conflicts not recognised by the PCR;
    - sweep for flights on frequency recommended.
- In order to perform an exhaustive sweep of the sector, it is advisable to keep lists and tabs that enable the display of the DYP of all flights open, without having to switch between tabs.

Coordination between adjacent sectors

A "silent radar handover" procedure can be applied when separations are assured based on the radar. The procedure does not provide for any telephone coordination between the sector controllers of different organisations in the following conditions:

- both aircraft are stable;
- the aircraft are following the same route;
- the aircraft are correctly correlated;
- the corresponding DYP are correctly entered;
- there is no closing-in between the aircraft and the distance between the aircraft is equal to or greater than 10 NM or 15 NM depending on the receiving organisation during the handover period.

Response to alerting systems[47]

In general, in an electronic environment, it is expected that each alerting system will be analysed and processed appropriately, which may include the alerting system being deleted by an air traffic controller action. Air traffic controllers are therefore expected to monitor flight activity within the sector they are managing and address any display issues.

For track markers and "Flights with no track" windows, the document indicates that they correspond to a loss/lack of radar display for a flight. The various cases where track markers are displayed are not specified. In the event of the display of track markers and "Flights with no track" windows, controllers are asked to:

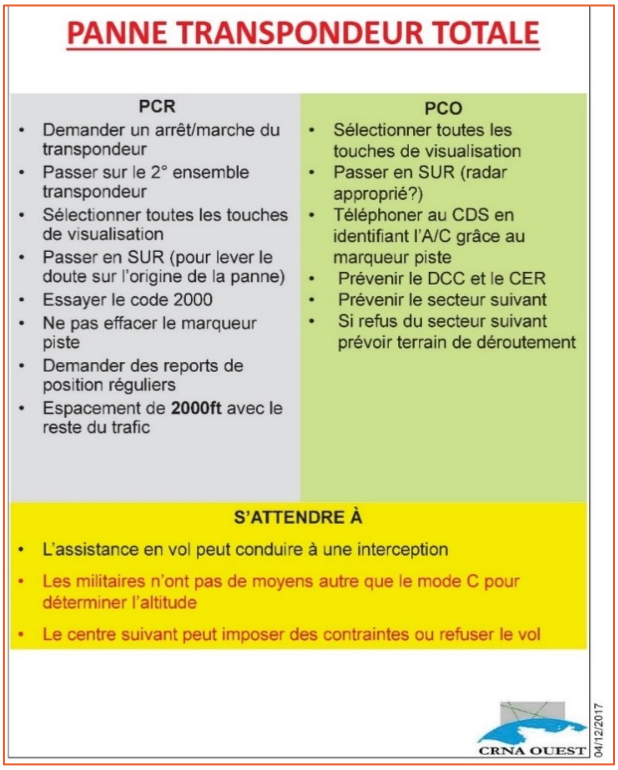
- check whether it is a case of a loss of display of a flight in the sector, and, if this is the case,
- comply with the relevant quick-reference card[48].

Complete transponder failure

In the event of transponder failure, the document specifies referring to the associated procedure, which states not to delete the track marker (see **Figure 26**).

[47] See para. 1.17.3.6 for more information about each alerting system.

[48] The title of the quick-reference card was not indicated. It is in fact the complete transponder failure quick-reference card.



PANNE TRANSPONDEUR TOTALE

PCR

- Demander un arrêt/marche du transpondeur
- Passer sur le 2° ensemble transpondeur
- Sélectionner toutes les touches de visualisation
- Passer en SUR (pour lever le doute sur l'origine de la panne)
- Essayer le code 2000
- Ne pas effacer le marqueur piste
- Demander des reports de position réguliers
- Espacement de **2000ft** avec le reste du trafic

PCO

- Sélectionner toutes les touches de visualisation
- Passer en SUR (radar approprié?)
- Téléphoner au CDS en identifiant l'A/C grâce au marqueur piste
- Prévenir le DCC et le CER
- Prévenir le secteur suivant
- Si refus du secteur suivant prévoir terrain de déroutement

S'ATTENDRE À

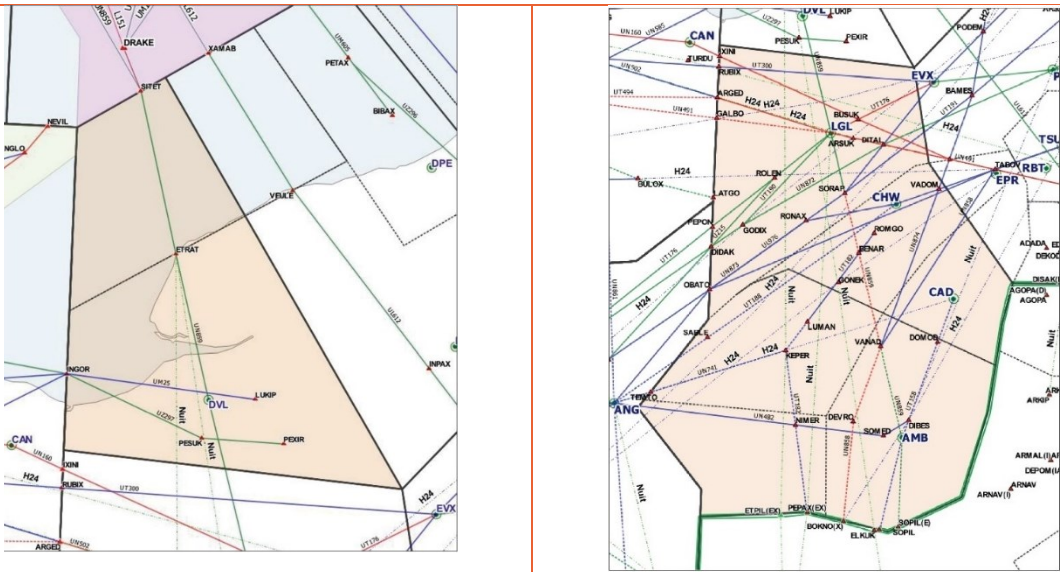
- L'assistance en vol peut conduire à une interception
- Les militaires n'ont pas de moyens autre que le mode C pour déterminer l'altitude
- Le centre suivant peut imposer des contraintes ou refuser le vol

CRNA OUEST 04/12/2017

Figure 26: ACC/west checklist for complete transponder failure (Source: ACC/west)

1.17.5.3 XI and QI sectors

The ACC/west QI and XI sectors were combined on the position occupied by the PCR and PCO and therefore formed the sector referred to as QXI (see **Figure 27**). The characteristics (flight levels and coordinates) for these sectors are available in the AIP[49]. The vertical range of these two sectors is between FL 345 and FL 365.



QI sector	XI sector

----------- itinéraires à double sens
----------- itinéraires sud/nord PAIR
----------- itinéraires nord/sud IMPAIR

Figure 27: QI and XI sector charts (Source: ACC/west)

49 ENR 2.2 OTHER REGULATED AIRSPACE

1.17.5.4 Frequency engagement and volume of traffic of the control position

The QXI sector frequency was engaged 28% of the time (79 messages) for the period during which both controllers were present at this control position.

The volume of traffic in the QXI sector was low during the 20 min before the transponder transmission of replies to interrogations from ground radar stations stopped at 08:30:35. The volume of traffic remained reasonable (below the volume threshold for which a split of the control position must be assessed) between 08:30 and 08:50, when the PCR and PCO were relieved.

The workload at the work position depends on this volume of traffic and the complexity associated with management of this traffic. Based on previous elements, the workload was therefore low before the transponder transmissions stopped, then reasonable based on the traffic to be managed.

1.17.5.5 Air traffic controller training

Air traffic controller training is specific to each control centre. The ACC/west has a Unit Training Plan (UTP), which is revised every three years and which takes into account measures outlined in the ATCO[50] regulation. The aim of the UTP is to ensure the acquisition of unit endorsements (UE) for all ACC/west control positions when new controllers take up their posts as trainees.

When controllers are qualified, a Unit Proficiency Scheme (UPS), which takes into account measures outlined in the ATCO regulation, describes:

- the elements required for revalidation of unit endorsements of air traffic controllers already qualified at the ACC/west: refresher training and conversion training;
- the minimum conditions associated with exercising the privileges of air traffic control licence holders and recording the number of hours exercised;
- the revalidation conditions for the unit, instructor and examiner endorsements;
- the provisions associated with a temporary incapacitation.

The UPS is revised every three years by the ACC/west training subdivision and submitted to the DSAC, as the oversight authority, for approval.

Within the framework of the UE revalidation procedure, air traffic controllers must attend all training provided for by the UPS. This training, entailing a minimum of six days of training for a three-year period, must cover the following subjects:

- at least one-and-a half days of Standard Practices and Procedures (SPP);
- two days of training covering human factors;
- one half-day per year of Abnormal and Emergency Situations (AES) training during which local and/or national feedback can serve as training content;
- at least one half-day of continuation training out of the training proposed within the context of the winter programme.

[50] Commission Regulation (EU) 2015/340 of 20 February 2015 laying down technical requirements and administrative procedures relating to air traffic controllers' licences and certificates (version in force on the day of the serious incident).

AES training aims to enable controllers to better understand, analyse and manage occurrences of abnormal and emergency situations. An AES training session incorporates:

- a theoretical component on some of the following subjects: reminder of the different quick reference cards, actions to be carried out in the event of unusual situations, revision of English terms associated with emergencies or local and/or national feedback;
- simulator exercises with PCO and PCR with a post-exercise debriefing.

AES training for the 2022-2023 period included a theoretical transponder failure component. This training referred to the content of the "Transponder failure" quick reference card, which assumes that the transponder failure was identified by at least one of the two position controllers and requires in particular that the PCR does not delete the track marker. The training also included an aeroplane transponder failure exercise in the simulator with display of a track marker.

The PCR attended AES training on 10 March 2023, and the PCO attended this training on 25 November 2022. In his statement, the PCO indicated that he instinctively deleted the track marker during the AES training exercise.

1.17.6 ACC/south-west information

1.17.6.1 Operations Manual

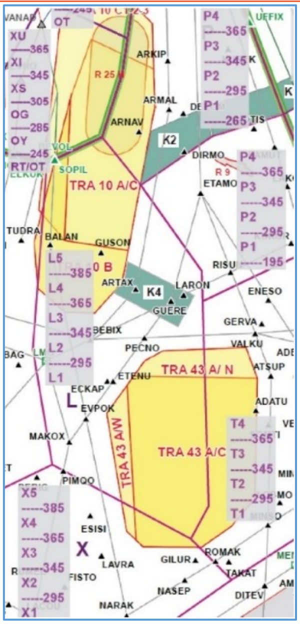
The ACC/south-west Operations Manual for air traffic controllers (version dated 4 July 2023) contains, as in the ACC/west manuals, different sections including those relating to task sharing, shift changes, the different functionalities offered by the electronic environment and the associated work methods. Overall, its content is the same as that of the ACC/west Operations Manual. However, it is important to note that the section on the "Flights with no track" window[51] contains the following additional elements:

- the window is positioned by default at the top right of the radar image;
- a left-click on the track marker symbol in the list acknowledges the symbol;
- a right-click on the acknowledged mini-DYP deletes the mini-DYP and the track marker;
- caution: controllers must carry out a cross-check before making inputs on the mini-DYP and the track marker.

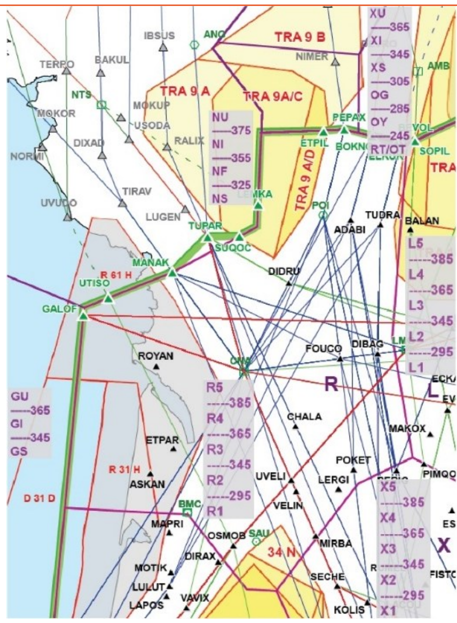
1.17.6.2 R3 and L3 sectors

The R3 and L3 sectors of the ACC/south-west were combined between FL 345 and FL 365 and formed the sector referred to as RL3 (see **Figure 28**). The characteristics (flight levels and coordinates) for these sectors are available in the AIP[52].

[51] The RL3 sector position screens did not show the track marker relating to the loss of radar contact for flight LAV4651. Only the "Flights with no track" window appeared.
[52] ENR 2.2 OTHER REGULATED AIRSPACE.



L Sector



R Sector

Figure 28: L and R sector charts (Source: ACC/south-west)

1.17.7 Control and Detection Centre (CDC) at Cinq-Mars-La-Pile

1.17.7.1 Organization

Entrusted to the French Air Defence and Air Operations Command (CDAOA), the Continuous Aviation Safety Strategy (PPS-A) is a priority and permanent mission of the French Air and Space Force (AAE). It is a 24/7 strategy that guarantees the sovereignty of French airspace through three missions: detect, identify, take actions. The three French military Control and Detection Centres (CDC) present over the territory have the following missions:

- continuously monitor the airspace, which involves detecting and identifying aircraft, as well as potential anomalies;
- search and rescue crews of aircraft in distress, both civil and military;
- control military aircraft which, for operational reasons, do not use civil air navigation services, in specific airspace managed by the department of Defence (TRA and R zones), or during the radar vectoring of interceptor flights.

The Cinq-Mars-La-Pile CDC (call sign RAKI) covers a large north-western quadrant of France. In the event of a suspicion or a known threat, the National Air Operations Centre (CNOA) is contacted to possibly initiate measures to identify an aircraft, to observe its behaviour, to provide assistance to the aircraft or to impose an obligation, restriction or ban on it, to warn it with a warning shot, or to destroy it if the aircraft is classified as “hostile”.

1.17.7.2 Detection of loss of radar contact

One of the controllers at the Cinq-Mars-La Pile CDC detected the lack of transponder code for the Boeing 737-809 registered EC-NGC (flight LAV4651) on the primary radar when the aeroplane was approaching Temporary Restricted Area (TRA) 10. TRA are reserved for specific users for a determined period of time, and other aircraft may receive clearance to fly through these. TRA 10 (see **Figure 28**) is made up of a number of sections (A, B and C) and has a floor at FL 195. Its ceiling is higher than FL 265 depending on the section of TRA 10.

1.17.8 The DSNA’s Safety Management System (SMS)

1.17.8.1 Regulatory framework and general principles

At the international level, ICAO Annex 19 stipulates that all service providers, including the ANSP implement a SMS. This consists of a systematic approach to safety management, including the necessary organizational structures, accountability, responsibilities, policies and procedures.

At the European level, when the ERATO electronic environment was implemented, the SMS requirements for the ANSP were defined in Regulation (EU) No 1035/2011 regarding the provision of air navigation services. It was repealed by Regulation IR ATM-/ANS[53], applicable in nearly its entirety since January 2020 and applicable during the implementation of the 4-Flight service.

The SMS of an ANSP is based on four components:

- safety risk management: the service provider identifies the hazards associated with its services and assesses and controls the risks linked to the identified hazards;
- safety assurance: these are the means implemented to monitor and measure the effectiveness of all the risk control measures.

The other two components are the safety policy and safety promotion.

The DSNA's SMS is part of an Integrated Management System comprising four areas (safety, security, environment and quality). It is based on processes described in an integrated management system manual and supplemented by procedures and methodology documents.

1.17.8.2 Risk Mapping

In 2010, the DSNA drew up a risk map of its organization, which has not been supplemented or updated since its creation. It did not define safety barriers or preventive measures aimed at preventing the occurrence of the identified adverse events. This observation was noted in the BEA's investigation report on the near-collision with the ground during the approach to Paris-Charles de Gaulle in May 2022[54], which mentions the absence of a comprehensive risk management process by the DSNA. In particular, as indicated in the report, the DSNA had not implemented a risk representation model with the definition of safety barriers and then the assessment and verification of their reliability and effectiveness. The DSNA stated during the investigation that it had accelerated the implementation of such a process. During the investigation into the serious incident of 21 July 2023, the DSNA informed the BEA that a new model was being tested, without providing further details.

1.17.8.3 Management of changes to functional Systems

For any change made to the air traffic management functional system, the regulations (see paragraph 1.17.8.1) stipulate that the ANSP must ensure that the identification of hazards and an assessment and mitigation of the risks are systematically carried out.

[53] Op. cit., paragraph 1.9.6.

[54] Serious incident to the Airbus A320 registered 9H-EMU operated by AirHub on Monday 23 May 2022 on approach to Paris-Charles de Gaulle airport.

The DSNA has developed a specific procedure and methodology. These outline the process for conducting "safety studies" to ensure that the safety level achieved associated with the change, is at least the acceptable safety level defined for the DSNA. For substantial changes, the safety study is formalized through a "safety file".

1.17.8.3.1 EEE safety file

As specified by the procedures mentioned below, the safety file (last updated in October 2015) compiled by the DSNA with a view to implementing the ERATO electronic environment includes three phases (see **Figure 29**):

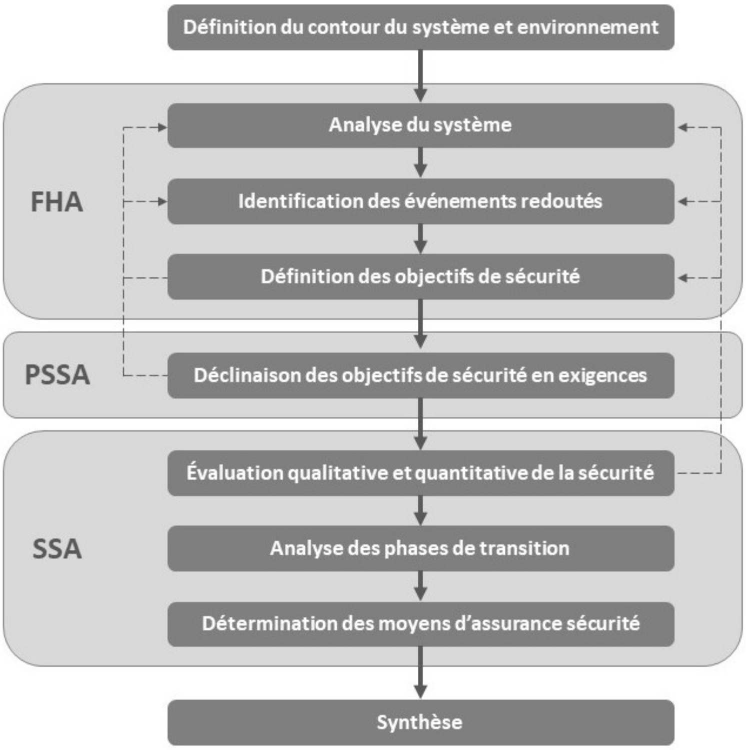


Figure 29: EEE safety study phases (Source: DNSA)

During the Functional Hazard Assessment (FHA), Risk Reduction Measures (RRM) are defined for each undesired event.
Moreover, the safety file is divided into two complementary and interdependent components, each containing all of the steps of the safety study (FHA/PSSA/SSA):

- a "technical" component focusing on system failures and failure modes;
- an "operational" component that is based on all activities implemented by air traffic controllers to meet operational objectives.

Technical component

Three main undesired events related to the serious incident:

- Lack of knowledge of the modification of a flight that concerns the position
  - this undesired event occurs when the controller is not aware of a modification to a flight that he had previously integrated;
  - one of the possible causes mentioned is lack of awareness of an alert announcing modification of the flight.

- <u>Disappearance of the flight from the controller's mental image</u>
    - this undesired event occurs when the controller is no longer aware of the existence of a flight that he had previously integrated;
    - one of the possible causes mentioned is the controller forgetting the flight after the disappearance of the flight track (work method error or failure).
- <u>Disappearance of the track</u>
    - the disappearance of the track includes situations where the symbol showing the flight's current position disappears from the radar image;
    - one of the possible causes is transponder failure.

The technical component provides several RRM associated with the serious incident and the aforementioned undesired events:

- consultation of "DYP info": to view all flight plan information for the new flight or all modified flight plan information;
- sector sweep: to detect any traffic management anomaly, error or omission. The FHA specifies that this risk reduction means is deemed effective in preventing the controller's loss of memory or lack of knowledge of a flight;
- cooperation between the PCR and PCO: to detect a wide range of undesired events, in particular through cross-checks;
- path check: to detect a deviation in the behaviour of the flight in relation to the expected behaviour and to warn the controller via the **VERT** and **HORIZ** warnings;
- list of flights with no track: this can highlight for the controller a flight for which a flight plan was received without any track being associated with it;
- "Flight with no track" alerts displayed on the DYP: valid for flights at the position which are not removed by filtering. These display information for flights not detected by the radar or without Mode C;
- track markers: these display the last known position for the flights;
- moving the mouse over the flight number: this highlights all occurrences of the flight to enable the controller to rapidly retrieve, without ambiguity, all information about the flight, from the different resources available (radar image, lists of flights, schedule);
- ERATO alerts: these warn the controller when a flight does not benefit from ERATO services (e.g. no filtering (F) service, see paragraph 1.17.3.6).

It is specified (see **Figure 30**) that the causes of the lack of detection of track markers and of the list of flights with no track were not impacted by the changes resulting from the implementation of the ERATO electronic environment, insofar as these track markers already existed with the previous functional system, in a paper environment.

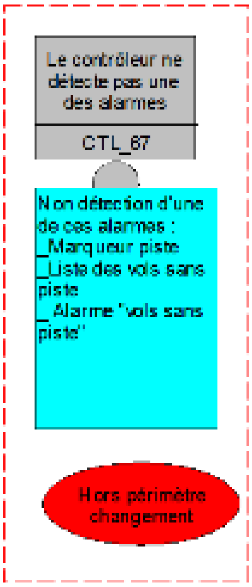


Figure 30: non-detection of warnings outside of the scope of change (Source: DSNA)

Operational component

The main risk situations[55] established in the operational component and associated with the serious incident were as follows:

- lack of detection and recognition of a non-conformity regarding the behaviour of the flight;
- lack of detection and recognition of alerts concerning subsequent actions to be taken;
- lack of awareness and recognition of ERATO warnings (**E**, **F**, **NQ**) for one or more flights.

The various associated RRM are functional or focused on work methods:

- Functional RRM:
  - duplication of essential information in different tools;
  - display of path monitoring warnings (**VERT**, **HORIZ** and **H+V**);
  - display of ERATO warnings (**F**, **E**, **NQ**);
  - flight highlighting function;
  - specific colour coding;
  - singling out function.
- Work method RRM:
  - monitoring to detect sector anomalies and omissions/errors, in particular using the colour coding of the **VERT**, **HORIZ**, **H+V** and **F** warnings: the controller must have completed a specific training course on this work method and the key information about these warnings;
  - monitoring to identify the next actions to take: the controller is expected to rely on his memory, on the scanning of the various lists (in particular the list of flights on the frequency (FREQ list)) and on information available to identify the actions to take. It is specified that the FREQ list keeps a record of flights for which the track marker was deleted too quickly (as was the case with flight LAV4651). The controller must have completed a training course on this work method and on the usefulness of scanning the various lists.

[55] Referred to as "*problématiques de sécurité*" (safety issues) in the EEE safety file.

The operational assessments carried out showed, for the aforementioned risk situations, that:

- the **HORIZ**, **VERT, E** and **F** warnings were detected by the controllers, which led to the conclusion being drawn that the risk situation was dealt with;
- the list of flights on the frequency enabled the controllers to easily update their representation of the traffic situation, thus enabling them to identify the actions to be taken.

It is worth noting that the operational component provides for a specific safety requirement regarding the scan pattern, considered to be a work method RRM.

The operational component also comprises a section on the management of air traffic by controllers in the event of degraded operational situations due to technical failures of the ERATO electronic environment. Other degraded situations (e.g. due to the failure of equipment on board aircraft) are not studied.

The operational FHA relating to degraded situations (in the event of ERATO electronic environment failures) describes the impacts of the implementation of this environment on the controllers' activity:

- The strips board appears more effective than the head down display (HDD) or the EEE flight lists as the electronic tools (TDS, lists and track markers) automatically manage the positioning of DYP based on criteria not related to the actual position of aircraft.
- The EEE interface appears less effective than the strip as a memory aid by noting geographical elements relating to the position of aircraft.
- The "Flights with no track" window displays the list of call-signs for flights with no track on the screen, along with a symbol representing this flight (the track marker). While it is useful during nominal system operation to detect a flight with no track, this interface allows rapid deletion of a track marker, which may subsequently impact the management of this flight.

It also specifies that, in the event of a loss of the main and backup radar image, the deletion of a track marker by left-clicking on the flight call-sign may also result in the controller losing memory of the flight. This situation was not the subject of a specific RRM. The instinctive deletion or deletion due to click error of a track marker is not mentioned in other safety study documents and in particular during normal operation of the functional system.

1.17.8.3.2 4-FLIGHT safety file[56]

To comply with the European regulatory requirements IR ATM/ANS, the structure of the safety studies and the associated safety files were updated by the DSNA. The 4-FLIGHT safety file is organised into two separate components: an operational component and a technical component:

[56] Version dated 28 June 2021 used during the investigation.

Concerning the operational component, two problematic situations are directly linked to the serious incident on 21 July 2023:

1. <u>Non-detection and/or incorrect processing of a loss of correlation or a loss of track</u>

Several occurrences may be precursors to this problematic operational situation. In particular, the cause may be:

- a loss of radar track;
- a loss of correlation for a flight;
- the presence of uncorrelated/decorrelated flights or flights with no track.

This situation may result in a lack of detection of the correlation anomaly (consequence on the task) or an awareness of the erroneous situation (impact on mental workload).

2. <u>Loss or lack of awareness of a flight in the sector</u>

This situation can occur in a normal context and in a shift change context. One of the precursors to this situation is the presence of uncorrelated/decorrelated flights or flights with no track. This situation may result in a lack of awareness of a flight or an erroneous awareness of the situation.

All RRM to reduce the level of severity of the problematic situations identified are divided into three categories: functional, knowledge, work methods. Those relevant to the serious incident on 21 July 2023 are as follows:

- <u>Functional RRM</u>
    - display of a FPASD label for an uncorrelated flight;
    - display of the last known position via the LKP and/or LT marker.
- <u>Knowledge RRM</u>
    - know the specific details and limits of uncorrelated tracks;
    - understand what the FPASD represents, know the corrective actions to be implemented and know the associated use limitations to correctly manage a correlation problem;
    - understand what LKP and LT represent, know that the Lost List contains the PLN for decorrelated flights and know the corrective actions, as these elements correspond by construction, to a flight related to the position.
- <u>Work method RRM</u>
    - recorrelate the flight before acknowledging the LKP symbol, as the acknowledgement deletes the track marker and therefore the only representation of the flight on the IR. If the symbol is acknowledged beforehand, in the event of an interruption, the recorrelation may be overlooked. It is specified that the LKP is the only marker than can be used to materialise the last location at which the track disappeared, it is therefore necessary in the event of a search. If it is accidentally acknowledged, the controller must[57] to redisplay it;
    - processing following the detection of a lack or loss of correlation.

1.17.8.3.3 Post-commissioning change monitoring

The procedure for assessing and mitigating the risks from changes made to the DSNA's functional system stipulates that a safety review be conducted at the end of a defined period following commissioning. During this period, the assumptions and effectiveness of the RRM are evaluated based on safety events reported by operational staff. The review consists of presenting the observed results.

[57] In the French text, there is no word written between “must” and “to” in this sentence.

The safety review of the ERATO electronic environment was conducted six months after commissioning. Monitoring of the RRM or undesired events mentioned in paragraph 1.17.8.3.1 was not planned during this period. Therefore, no results are associated with this review.

1.17.8.4 Analysis and follow-up of safety occurrences by the DSNA

1.17.8.4.1 General principles

The DSNA's Integrated Management System manual includes a specific procedure for the processing of findings and actions, supplemented by a methodology to process safety occurrences.

The analysis of safety occurrences by the DSNA is based on operational staff reporting events (via an Event Notification Form, FNE), as stipulated in Regulation (EU) No 376/2014[58], which differentiates between events where reporting is mandatory and those where reporting is voluntary.

Under this regulation, events related to in-flight collision risks must be reported. The risk assessment prior to notification is left to the controller's discretion. These events include Separation Minimum Infringements (SMI). Risk management measures are derived from the analysis of the reported events.

At the local level, the SQ (Service Quality) entities are responsible for handling occurrences. The analysis of the occurrences aims to identify the causes and contributing factors and to implement, as required, corrective and preventive measures. Depending on the relevance or severity, some occurrences are examined by specific follow-up bodies such as the Safety Follow-up Group (SFG) or the Local Safety Commission (LSC).

At national level, the purpose of the DSNA's Safety occurrence processing body (ITES) is to process occurrences or topics at national level where the air navigation malfunction is deemed to be very important. It draws up and proposes targeted actions at local level - in addition to those already implemented - or at national level, in order to prevent a recurrence of this type of event. The ITES completes the local analysis by adding insights on the examined occurrence(s) with the relevant experts from the DSNA's centres or central offices, as well as with the ITES experts. A dedicated ITES steering committee meets twice a year to decide on actions to be undertaken and to then monitor the actions. These actions are assigned to local or national entities.

The DSNA indicated that the ITES is a means of assessing the effectiveness and questioning the RRM identified in the safety files.

1.17.8.4.2 Special cases for processing "Statements of requirements"

Following the analysis of a safety occurrence[59], a local or national DSNA entity may submit a request for a technical change to the DTI (see paragraph 1.17.2.1). This request is transmitted directly by the entity to the DTI in the form of a "Requirements" document via dedicated software.

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[58] Regulation of 3 April 2014 on the reporting, analysis and follow-up of occurrences in civil aviation.

[59] Safety occurrences are not the sole source for generating statements of requirements.

1.17.8.4.3 Analyses relating to the incorrect processing of a loss of radar contact

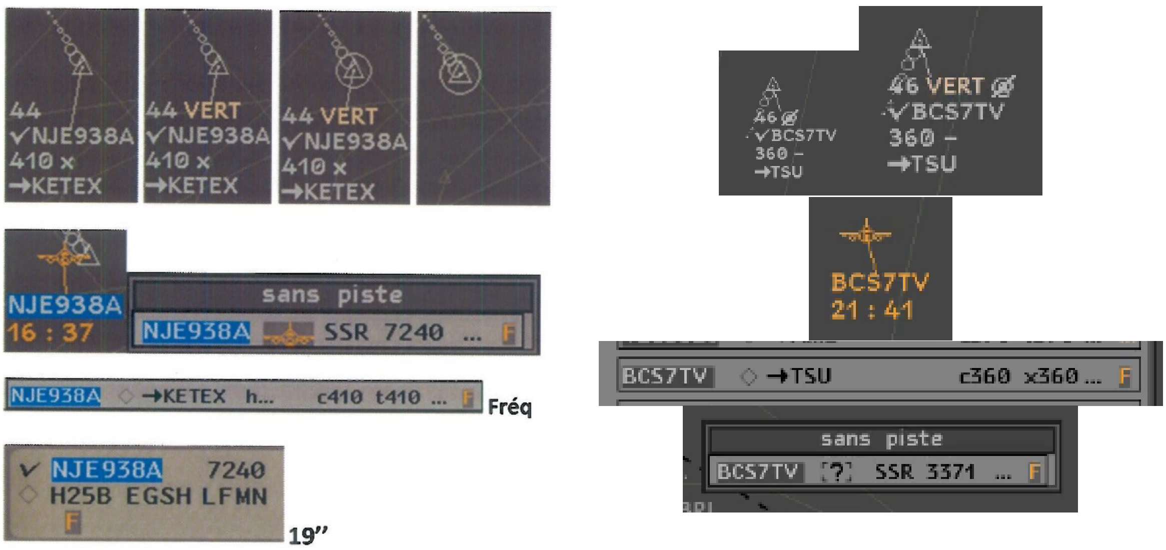
Within the context of the investigation, the DSNA reported three major events that occurred in airspace managed by an ACC with electronic environments (two events with the ERATO electronic environment in the ACC/west and one with 4-FLIGHT in the ACC/south-east). These occurrences were the subject of a notification by the air traffic controllers concerned, followed by an analysis by the DSNA.

During these occurrences, all associated with the loss of radar contact due to transponder failures:

- alerts corresponding to flight modifications and non-conformities were not perceived and taken into account by the controllers;
- the track marker (EEE) or the LKP (4-FLIGHT) was deleted.

Occurrences in the ERATO electronic environment

The two events occurred in May 2017 and June 2023. For both occurrences, different alerts were displayed for around 15 s maximum, in a sequence similar to that of the serious incident on 21 July 2023 (see **Figure 31**). In both cases, track markers were deleted a few seconds after they appeared, despite the presence of “Flights with no track” windows. The other alerts were not perceived.



Event in May 2017 *Event in June 2023*

Figure 31: alert display sequence (Source: DSNA)

In May 2017, the loss of the radar track lasted for 27 min and until the crew contacted the PCR for the sector in question. The situation was recovered five minutes after this radio contact, after three radio frequency transfers and one transponder refresh by the crew.

- <u>DSNA processing/analysis:</u> following the analysis of the event, the ACC/west SQ issued internal feedback to controllers regarding the signs of a loss of track and the need to pay attention to alerts by checking for the presence of a DYP in the event of a track marker and by asking the crew to refresh the transponder if necessary. The SQ also published operational instructions reminding controllers of the principle of the “Flights with no track” window.

In June 2023, the PCR went off shift around two minutes after the appearance of the "Flights with no track" window (the track marker had already been deleted). Three minutes after the shift change, video recordings of the controllers' screens showed the PCR's mouse was active for around five seconds on the call-sign of the flight on which the transponder had failed, in the "Flights with no track" window. The PCR then moved the "Flights with no track" window closer to the FREQ window (13 flights were displayed in this window at this time, characteristic of a heavy workload). Almost eight minutes later, the PCR positioned his mouse on the flight DYP in the FREQ window before contacting the flight crew to ask for their position. The flight label reappeared on the screen after the crew selected the second transponder. Seventeen minutes elapsed between the appearance of the first alerts and the recovery of the situation.

- DSNA analysis/processing: Following the analysis of the event, the ACC/west SQ issued internal feedback to controllers[60] (see **Figure 32**) reminding them that all warnings must be analysed, even if some may be irrelevant. A decision was also made to issue a reminder about warnings for flights with no track and deleting warnings during weekly briefings.

Une alarme est parfois non pertinente, mais dans tous les cas elle doit être analysée.

Ne cédez pas aux sirènes de l'habitude

DANS LE DOUTE, JE LÈVE LE DOUTE

Figure 32: feedback issued to ACC/west controllers in June 2023
(Source: ACC/west)

Occurrence in a 4-FLIGHT environment

In August 2023, around ten minutes after the initial contact between a crew and the PCR for the sector in question, a transponder failure on the aeroplane resulted in the display on the screen, of a LKP followed by a FPASD, and the display of the flight in the LT. The PCR, who had "forgotten" the flight (loss of awareness that the flight concerned the sector), acknowledged the LKP a few moments later. Around 15 min after the appearance of the FPASD, the crew called the PCR to request the next frequency. The PCR asked them to activate the second transponder and the track reappeared on the screen.

- DSNA processing/analysis: the analysis conducted by the ACC/south-east QS indicated that the LKP and the FPASD operated correctly, that the colour of the FPASD was not taken into account, possibly due to the influence of many previous FPASD. Reminders were issued as part of the Safety WG, and internal feedback was issued to controllers regarding the role and processing of FPASD and the Lost List. In addition, this feedback referred to an event that occurred in July 2023, with the disappearance of a radar track for 20 min after the pilot made a transponder code error, despite the display of a FPASD and the display of the flight in the LT. This feedback also mentioned a number of different situations that resulted in the appearance of a FPASD (e.g. aeroplane at take-off, aeroplane delayed). It indicated that too many flights appeared unnecessarily in the Lost List and that there were too many unnecessary FPASDs, and it proposed several key ways to prevent this.

[60] The PCR and PCO in charge of the QXI sector during the serious incident on 21 July had knowledge of this internal feedback.

Technical modifications have been made in subsequent versions of the 4-FLIGHT system. Their implementation is being phased in progressively in other ACC equipped with 4-FLIGHT depending on the date that 4-FLIGHT was first commissioned.

1.17.8.4.4 Processing and analysis by the DSNA of the serious incident on 21 July 2023

ACC/west local analysis

The occurrence was first analysed in the LSC on 29 August 2023. The LSC report, drawn up on 12 September 2023, showed the discussions around the operational management of the occurrence with the controllers concerned, and mentioned the causes and contributing factors ratified during the SFG meeting on 8 September 2023. Among other points, the controllers mentioned the frequent display of irrelevant track markers resulting in the unfortunate habit of systematic acknowledgement without in-depth analysis. The report specified that the display of a track marker cannot be considered as a “proven” safety barrier and that it is necessary to verify the relevance of this alert through a check (sector sweep, examination of the list of flights on the frequency). Regarding the “Flights with no track” window, the report indicated that its high display frequency in the ACC/west’s oceanic sectors contributes to it not being associated with an emergency. The report also stated that in the event of a low volume of traffic, the various tools available in the electronic environment are not systematically used.

The LSC report also mentioned that a request for a technical upgrade to the ERATO electronic environment, to separate valid/relevant track markers from irrelevant track markers, had been made at a national meeting. The DSNA, lacking any record of this, considered that this request had not been made.

The following causes were identified in the SFG:

- unsuitable use of information: the information supplied to the controller is ignored or incorrectly used (DYPS, coordination, pilot messages, track marker deleted without check when the flight is assumed to be in the sector, “Flights with no track” window ignored when the flight is displayed in the FREQ box);
- human factors: habit bias, track markers deleted without thinking as there are too many irrelevant track markers;
- workload deemed to be low, situation that can lead to hypovigilance;
- incorrect mental image (there is a flight missing from the controllers’ mental image);
- human factors: unintentional non-compliance with the procedure (no cross-check, alerts not acted on, no sector sweep as recommended in the work method).

The local SQ issued internal feedback following the serious incident (see **Figure 33**), highlighting the different cases of track marker display and specifying the origin of their display. The feedback also indicated that a track marker does not necessarily correspond to the absence of a flight on the screen. It stated that the most common track markers concern flights by aircraft on which the transponder does not transmit the aircraft identifier in Mode S (e.g. military flights) and that are not generally taken into account in the control sector. It concluded by stating that all track markers need to be analysed.

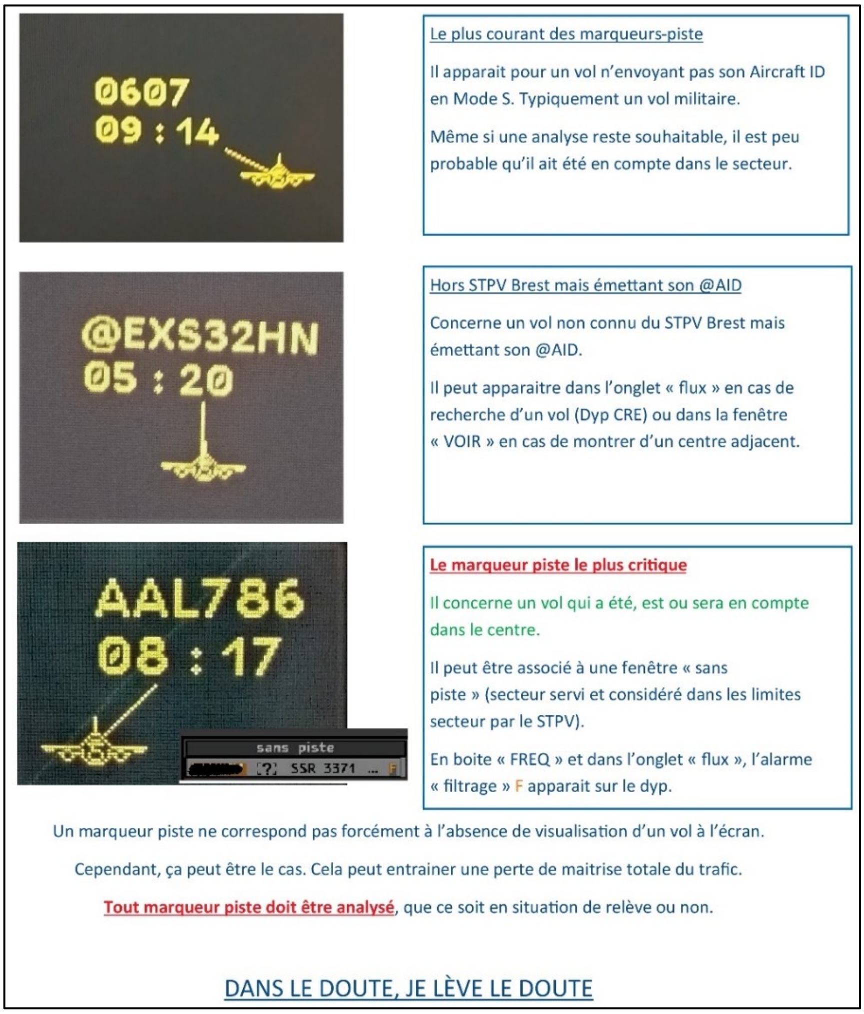


Figure 33: feedback issued to ACC/west controllers in July 2023
(Source: ACC/west)

In addition, the work methods in the ERATO electronic environment, drafted by the ACC/west for air traffic controllers (see paragraph 1.17.5.2), were updated in October 2023 by providing additional information on the conditions associated with the display of “Flights with no track” windows and track markers, as well as on the related expected actions.

AES training (see paragraph 1.17.5.5) for the 2023-2024 period was also updated. Before addressing the actions to be undertaken in the event of detecting a transponder failure, the theoretical component of the AES training focused on the different track markers that can be displayed. The urgency level for these track markers was specified and reiterated the indications from the feedback issued in July 2023:

1. The most common track markers concern flights by aircraft on which the transponder does not transmit the aircraft identifier in Mode S (e.g. military flights) and that are not generally taken into account in the control sector.
2. The most critical markers concern a flight that was, that is, or that will be recognised by the ACC/west and that may be associated with a “Flights with no track” window.

For track markers, the AES 2023-2024 training materials concluded that all track markers must be analysed. The AES training for the 2023-2024 period then covered actions to be undertaken in the event of transponder failure. The materials emphasized the fact that track markers must not be deleted.

ACC/south-west analysis

The following system modification measures were discussed in the local SFG meeting:

- display of the “Flights with no track” window at the expected flight location;
- superimposition of the “Flights with no track” window when the mouse is moved over the DYP for incoming flights (as for radar labels).

The ACC/south-west indicated that these actions had not been considered relevant given the DSNA decision to make no further investment in the ERATO electronic environment with its future replacement by 4-FLIGHT.

The following measures were proposed at local level:

- distribution of internal feedback to all controllers;
- organisation of a meeting with the safety contacts of each team of controllers and the service in order to give detailed information about the sequence of events and explain the conclusions reached during the LSC.

The DSNA indicated that the LSC concerned both the ACC/west and the ACC/south-west. However, the LSC report (see previous paragraph) does not mention the participants, and the ACC/south-west is not among the recipients of the report.

National analysis

An ITES meeting was held on 6 February 2024 and an ITES steering committee meeting was held on 13 February. The reports were issued in July 2024. According to the ITES report, the changes proposed during the discussions were impeded by the fact that the system [ERATO] would only be in use for a few more years and that no time should be invested in developing/improving it.

The reports particularly specified the following points.

- The need for a study into the number of “loss of track” shown to a controller as well as how relevant they were. The ACC/south-west indicated that it was working on incorporating an aural alert into a tool developed locally[61] and not approved at national level, which would sound in the event of a loss of a track relevant to the position. The ITES steering committee then decided to analyse (quantitatively and qualitatively) the validity of the study.
- Work to be carried out regarding the air traffic controllers’ knowledge of the “Flights with no track” window as well as their knowledge and implementation of related work methods. More generally, the question of identifying changes occurring in the implementation of work methods - and therefore the question of developing a study/observation method to detect and differentiate, on some points, deviations from best practices - arose. The on-job observation method was mentioned. During the ITES steering committee meeting, the DSNA committed to identifying the work methods (the implementation of which it wants to examine) in the ERATO electronic environment.

[61] Safety Loop tool.

- The training of controllers (theory, operational time in the sector, number of hours on simulator) on the tools and alerts called upon by the event. A decision was made to provide a report on the number of hours of training completed by ATCOs in 2023, broken down by service and topic, and distinguishing theory hours from simulation hours.

In addition, the ITES report indicated:

- that at the time, it was difficult to make the connection between safety studies and events;
- that it would be necessary to make the connection between the scenarios initially conceived (and the barriers implemented), and what actually occurred.

This reflection did not lead to any actions.

It should be noted that the report did not mention the occurrences of May 2017 and June 2023.

The following ITES steering committee meeting took place in December 2024. The various actions were listed as "in progress," but their progress was not specified.

1.17.8.5 Risk assessment of erroneous handling of a loss of radar contact

1.17.8.5.1 Case count

The DSNA indicated that it was unable to quantify the number of events related to loss of radar contact without prior analysis of the track marker or the LKP by the air traffic controller. Indeed, the reporting of occurrences (see paragraph 1.17.8.4.1) by operational staff is the only means of identifying them. This method does not appear to be a reliable and sufficient source, particularly when the consequences are mitigated by the detection and recovery of the situation.

More generally, the DSNA indicated that it did not have the means to determine how track markers and “Flights without track” windows are handled with respect to the established working methods.

It should be noted that only one requirement was found in the DSNA database regarding the issue of track markers and “Flights without track” windows. The request originated from the ACC/west for a differentiation of relevant track markers. The DSNA's central offices proposed and explained, via the IT tool, the rejection of this request (no technical changes to the ERATO electronic environment were planned). In the absence of a response from the ACC/west, the requirement was not formally closed.

1.17.8.5.2 On-job observation

To date, the DSNA has not implemented any means or methods, such as on-job observation, to enable not only a better perception of weak signals, threats, errors and undesirable events that can impact safety in a given operational context, but also to identify best practices to maintain safety. As stated during the ITES on 6 February 2024, on-job observation could be used to identify deviations in the implementation of work methods pertaining to the use of track markers and the “Flights with no track” window, and thus to envisage measures without waiting for a safety event, such as loss of separation in flight, to occur.

This observation was the subject of a BEA recommendation in 2024, issued in the investigation report concerning the near-collision with the ground on approach to Paris-CDG airport[62]:

- *The BEA recommends that the DSNA introduce methods or tools for the objective assessment of air traffic controllers' on-the-job work for the purpose of improving the safety management system. [Recommendation FRAN-2024-011].*

This investigation report specified that, "*in the scope of a change involving the transformation of working methods, observations of controllers in position were conducted* [by the DSNA] *in the past to determine whether the working methods stipulated prior to the change were applied as expected.*" By way of example, the implementation of 4-FLIGHT was the subject of on-job observation.

On 16 December 2024, the DSNA responded by indicating that the DSEC was mandated to set up a project with the objective of implementing additional safety event analysis means in order to integrate risk management into its Safety Management System. The mandate must define:

- the requirements and objectives of the assessment of the actual on-the-job work of air traffic controllers;
- the methods and means to do this;
- the resources and the organisation necessary to enable the DSNA to implement them sustainably within the framework of the SMS.

The DSNA stated that the on-job observation method was tested in October 2024 at the ACC/east, and that the results enabled it, among other things, to determine the assimilation level of 4-FLIGHT and to highlight non-applicable methods requiring amendment and work methods not applied. The method was deemed relevant and was approved by the purpose-formed working group.

The DSNA plans to include this methodology in a wider organisation that will be defined during 2025 and that will enable the HR impact of these observations to be considered. Meanwhile, a decision was made to continue testing in parallel at the ACC/south-east and the ACC/east, to obtain a more accurate understanding of how to use these observations as part of a national safety follow-up approach, and to reflect on the implementation of a sustainable training strategy for observers.

1.18 Additional information

1.18.1 Waypoints and position reporting

A waypoint corresponds to a geographical location used to define a route that enables air traffic services and the flight path of an aircraft to be ensured as well as the needs of air traffic services to be met. Waypoints are identified by an identifier. These waypoints are established by ANSP. They must be published on aeronautical charts and also appear in the description of routes in the ENR 3 section of the AIP.

Part-FPD of European Regulation IR ATM-ANS[63], relating to the providers of flight procedure design services, specifies that waypoints are used as reporting points in an aim to ensure coordination between air navigation services and crews. Position reporting points may be

[62] Op.cit., paragraph 1.17.8.2.
[63] Op. cit., paragraphs 1.9.6 and 1.17.8.1.

compulsory or “on request”. Compulsory reporting points are used to regularly provide information to air navigation services regarding the progress of airborne aircraft, and their number should be restricted, not only to avoid increasing the workload for air traffic controllers and crews, but also to avoid saturating the radio frequencies used in flight.

A compulsory reporting point is represented on a chart by a solid triangle. An “on request” reporting point is represented by an empty triangle.

▲	△
Compulsory reporting point	“On request” reporting point

Requirement SERA.8025 of European Regulation (EU) No 923/2012 (known as SERA) concerns position reporting. It indicates that flight crews shall report to the air traffic services unit, as soon as possible, the time and flight level on passing each designated compulsory reporting point, together with any other required information. Position reporting may similarly be made in relation to additional points when requested by the air traffic services unit.

The Albastar Operations Manual (Part A, paragraph 12.1.a.4) reiterates this requirement. It also specifies that, in the event of radar monitoring, controllers may ask crews to omit position reporting at compulsory reporting points.

The symbols used to display reporting points on the aircraft navigation displays subject to CS25 certification specifications are generally not those specified in the regulations. There are no certification specifications pertaining to these symbols for aeroplanes.

Around ten French airline pilots were asked about practices pertaining to compulsory position reporting points. As it turns out, unless expressly requested by controllers, pilots do not contact them when passing these points that require a verification on a resource other than the navigation displays. Moreover, the pilots interviewed specified that contact at these compulsory reporting points, not requested by controllers, would considerably increase frequency engagement.

1.18.2 Separation rules

Requirement ATS.TR.210 of the IR ATM-ANS regulation and the associated means of compliance AMC1 ATS.TR.210(c)(2) provide the rules pertaining to separation between aircraft. The horizontal separation standard in en-route radar control to be applied between aircraft without vertical separation is 5 NM. This standard supposes, in addition to the correct operation of the radar processing system, that the aircraft are identified.

1.18.3 Air traffic controller alerting systems

A number of documents, studies and articles were published on the air traffic controller alerting systems provided by functional systems.

In November 2007, the FAA published an analysis[64] of these alerting systems based on a number of research articles and a document published by the US National Transportation Safety Board (NTSB) in 2006 on the basis of 11 safety investigations concerning collisions with the

[64] Human Factors Analysis of Safety Alerts in Air Traffic Control, report No. DOT/FAA/TC-07/22 dated November 2007

ground (without loss of control) or in flight, that occurred between 2002 and 2006. In its document, the NTSB concluded that either air traffic controllers did not see the visual alerts or that they failed to take appropriate action. These findings led the NTSB to recommend that the FAA redesign system alerts to improve their detection by air traffic controllers.

The FAA's analysis indicated that functional systems trigger alerts to capture the attention of air traffic controllers and prompt them to take appropriate action. It specified that the way in which air traffic controllers react to these alerts is influenced by a number of factors, including:

- traffic management activities;
- alert characteristics;
- human activity management processes (e.g. continued awareness of the situation and workload management) that depend both on each individual and the work context.

The analysis also indicated that human error is more likely to occur when similar indications are used to signal situations with different levels of urgency. It specified that an alert can be deleted without analysis of the situation when air traffic controllers are accustomed to treating most of these alerts as non-urgent or low priority.

In an article[65] published in 2014, five alerting system designs were evaluated in their ability to capture attention during an ongoing air traffic control task, as well as their impact on the primary task. This article reiterated the importance of identifying "*an optimal compromise in the tradeoff between alerting task noticeability and ongoing task performance*." The article also explained that radar screens exploit peripheral vision to provide information while minimising disruption to the primary task. It specified that, given the limits of peripheral vision, parameters such as colour, motion, luminance, opacity or size should be taken into account when designing alerting systems. The five alerting systems studied were as follows:

a. Static display of a word in an orange-red colour in the label associated with the aircraft, generally used to signify low-urgency alerts (see **Figure 34)**. This display corresponds to that of alerts characteristic of radar track ageing.
b. Blinking display of a word in an orange-red colour in the label associated with the aircraft, used to signify higher urgency alerts.
c. Animated display with four yellow chevrons placed around the label of the aircraft and static display of a word in an orange-red colour in the label (see **Figure 35)**.
d. Animated display using the opacity of the background of the radar screen to differentiate the aircraft (other aircraft fade out for 300 ms). At the end of the fade-out animation, the label vibrates to catch the controller's eye. The total duration of the animation is 2.56 s, and the radar screen remains darker for 20 s.
e. Dynamic animation that attracts the eye and draws attention away from the main task and onto the area highlighted by focusing circles (Halo).

[65] Jean-Paul Imbert, Helen M. Hodgetts, Robert Parise, François Vachon, Frédéric Dehais & Sébastien Tremblay (2014) Attentional costs and failures in air traffic control notifications, Ergonomics, 57:12, pp 1817-1832, DOI: 10.1080/00140139.2014.952680

Figure 34: static display

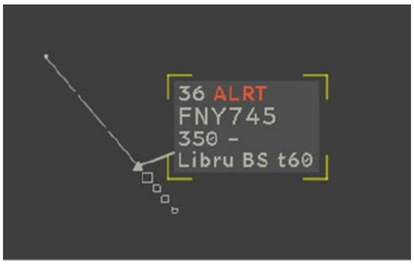


Figure 35: chevrons and static display

(Source: DSNA)

The result of the study was that “*three animated alerts* [**c**, **d** and **e**] *were perceived rapidly and without error.”* By contrast, the colour, even animated (**a** and **b**), “*fared less well [...] and some notifications [went] unnoticed.*” However, alerts **d** and **e** disrupted the primary task, which can also lead to difficulties in some cases.

1.18.4 Detailed rules relating to the ATM/ANS systems

The regulatory framework relating to the certification and declaration of ATM/ANS systems was established in Europe in July 2023[66]. On the date of publication of the report, no production or design organisation and no air traffic management system (including 4-FLIGHT) were certified by EASA according to this new framework.

In October 2023[67], EASA published detailed specifications (DS) based on standards, technical specifications or common practices to serve as a basis for certifying ATM/ANS systems, as with certification specifications (CS) for aircraft.

In terms of the man-machine interface (specification DS GE.GEN.005), and therefore in particular air traffic controller alerting systems, it is requested that aural and/or visual alerts provide indications upon receipt of a message intended for display or to be used by the operator or in the case of ATM/ANS equipment malfunction. There must also be a means for operators to view information, and to create, store, edit or delete information. No standard or specification is specified for the design of air traffic controller alerting systems. By way of comparison, for A-SMGCS[68] systems, many Eurocontrol, EUROCAE or ETSI standards and specifications are listed to serve as a certification basis for these systems.

Based on the strategies defined as part of the EPAS[69] for EASA member states, as well as the main risks identified that can impact the air system, EASA implemented a given number of actions required to mitigate these risks and to improve air safety. One of these actions concerns the regular updating of the detailed specifications for ATM/ANS systems (RMT.0744). Initiated in 2024, this action involves a number of organisations including the ANSP, ATM/ANS system design and production organisations and EASA.

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[66] Commission Delegated Regulation (EU) 2023/1768 of 14 July 2023 laying down detailed rules for the certification and declaration of air traffic management/air navigation services systems and air traffic management/air navigation services constituents.

[67] https://www.easa.europa.eu/en/document-library/agency-decisions/ed-decision-2023015r

[68] Advanced Surface Movement Guidance and Control System.

[69] European Plan for Aviation Safety.

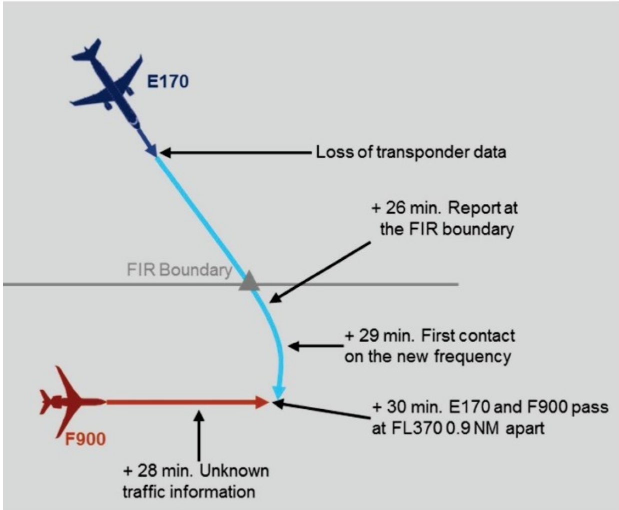
1.18.5 Examples of occurrences reflecting the serious incident of 21 July 2023

On 29 September 2006, a Boeing 737-809 at FL 370 collided with an Embraer Legacy at the same flight level[70]. The crew of the Boeing 737 lost control of the aeroplane, which crashed. All 154 occupants perished in the accident. The crew of the Embraer Legacy were able to divert to a nearby airport and land despite the damage to the aeroplane. The investigation, conducted by the Brazilian investigation authority (CENIPA) revealed that the crew of the Embraer Legacy did not receive any instruction to descend to FL 360 as specified in the flight plan initially filed. It also revealed that shortly after, this crew inadvertently switched off the aeroplane's transponder. This standing by of the transponder - associated with the crew's lack of awareness that the transponder was no longer operating - caused the TCAS on board the Embraer to go into standby mode, rendering it undetectable by the Boeing TCAS (and all of the other aircraft in the vicinity). The air traffic controllers detected the loss of radar contact and assumed that the crew had changed flight level. Despite a number of unsuccessful attempts to establish radio contact between the air traffic controllers and the crew of the Legacy, the latter continued its route until it collided with the Boeing 737.

On 30 June 2015, an Embraer 170 was en route at FL 370 when its transponder failed[71]. The crew did not notice the failure and the air traffic controller did not perceive the loss of radar contact. Shortly after, the air traffic controller went off duty, and the person who relieved him supposed that the Embraer 170 had already exited the sector. This air traffic controller did not therefore take any steps to make radio contact with the crew. The crew then reported their position on the edge of the FIR and the air traffic controller issued an instruction to change frequency, without seeking to identify the aeroplane on the radar. At the same time, in the neighbouring FIR, an air traffic controller who had detected unknown traffic on the primary radar sent a traffic advisory about this unknown traffic to the crew of a Dassault Falcon 900 in level flight at FL 370. Less than one minute later, the crew of the Embraer 170 made a call over the new frequency. The controller was unaware of this aircraft entering his sector and, during prolonged radio exchanges, attempted to check the flight number, the position and the flight level of this aircraft. Less than two minutes after the traffic advisory, the crew of the Falcon 900 reported having passed another aeroplane nearby and stated being surprised not to have seen it on the TCAS screen. One minute later, the controller asked the crew of the Embraer 170 to check their transponder. The crew changed transponder and radar contact was re-established, 31 min after the transponder failure. The investigation conducted by the Bulgarian investigation authority (NTIB) revealed a horizontal separation of 0.9 NM between the two aeroplanes (see **Figure 36**). The transponder on board the Embraer 170 was not working, no TCAS alert was generated on either aeroplane.

[70] Final report of the Brazilian investigation authority (CENIPA) - English version

[71] Investigation report of the Bulgarian investigation authority (NTIB) - English version



1: Event 1: Loss of transponder
2: Event 2: RA due to self-tracking
3: Event 3: Incorrect altitude
4: Event 4: Testing on the ground

Figure 36: loss of separation in June 2015
(Source: ACAS II Bulletin No. 23 dated June 2018, published by Eurocontrol)

1.19 Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1 Introduction

In airspace where the use of a transponder is mandatory, an aircraft flying without radar contact, due to a total or partial failure of the active transponder, will affect both the safety level (increased risk of loss of separation between aircraft and as a consequence, mid-air collisions) and the security level.

In the event of an operating fault, the transponder can detect the anomaly itself and activate the alert system to warn the crew of the malfunction. Surveillance by the ground radar stations also generates alerts for air traffic controllers in the event of a transponder malfunction. According to the crew of the Boeing 737 operated by Albastar, the **ATC FAIL** light situated between the two crew seats did not illuminate to indicate the transponder failure. The two air traffic controllers responsible for the sector in which the Boeing 737-809 was flying did not perceive the successive alerts which were displayed over a period of approximately ten seconds and characteristic of a radar track ageing mechanism. They then deleted the track marker around three minutes after it appeared which, based on other information available on their interfaces, could have enabled them to determine that there was a loss of radar contact and therefore probably, a transponder failure on the Boeing 737-809.

The crew thus continued their route specified in the flight plan without being aware of the transponder failure. The air traffic controllers of the ACC/west sector forgot that they had this flight to manage in their sector and never identified that a flight had disappeared from their sector after deleting the track marker. It should be noted that the TCAS of the Boeing 737 operated by Albastar would have been able to transmit traffic and resolution advisories according to the loss of separation with nearby aircraft equipped with a transponder in operation, in particular with the Embraer 190 operated by HOP! The minimum distance between the two aeroplanes, then at the same flight level, was 2.6 NM for a regulatory minimum separation of 5 NM. The partial failure of the transponder of the Boeing 737 meant that the Embraer 190 TCAS could not detect and track this aircraft, and the transmission of a resolution advisory by the Boeing 737 TCAS would therefore not have been coordinated with the Embraer 190 TCAS.

The detection by military controllers in Mars-La-Pile CDC and the information message from the crew of the Embraer 190 operated by HOP! who saw the Boeing 737 operated by Albastar pass in front of them, meant that, after numerous coordination actions between the various control centres, radio and radar contact was recovered with the crew of the Boeing 737. They were able to continue their flight.

The following analysis covers:

- the cause of the transponder failure;
- the systems to attract the attention of crews in the event of a transponder failure;
- the management of the loss of radar contact by the pair of controllers;
- the ergonomics and certification specifications for air navigation;
- the DSNA SMS;
- compulsory position reporting.

2.2 Cause of the transponder failure and measures taken

The failure of the transponder selected by the crew during the serious incident flight stemmed from a malfunction of a component (transistor) used in the +50 V DC power supply system, which provides the energy required to transmit transponder messages (squitters and replies). This fault was caused by insufficient consideration given to the thermal dissipation margins of the component chosen when designing the transponder (see paragraphs 1.6.1.3.5 and 1.6.1.3.6). As a result of this fault, the transponder did not transmit any Mode *S* squitters or replies to interrogations. However, the transponder continued to operate partially during the flight, receiving messages from ground stations and nearby aircraft transponders.

The transmission by the Boeing 737 TCAS of periodic long uplink messages (see paragraph 1.9.2), as well as the statements made by the aircraft's crew who saw traffic information on the navigation displays, show that the Boeing 737 TCAS automatic monitoring software considered that its level of operation and performance was not affected by the malfunctioning transponder which continued to send it the mode S messages it received from nearby aircraft. In other words, despite its partial failure, the transponder had the possibility of transmitting TA and RA if necessary, but without coordination with the TCAS of other aircraft to determine complementary evasive manoeuvres. Simulations carried out by Eurocontrol based on the Boeing 737 and the Embraer 190 flight paths confirmed the TCAS displays seen by the Albastar crew, and the absence of any need to activate a TA or a RA.

On the other hand, the TCAS of the aircraft in the vicinity of the Boeing 737 were unable to detect its presence due to its transponder not transmitting Mode S messages (squitters and replies), which for these aircraft, was equivalent to the transponder not operating. This was why the HOP! crew were surprised to see the Boeing 737 pass so close in front of them without it being displayed on the TCAS.

Several operators had reported similar transponder failures to Honeywell which led to the issue of a service bulletin to replace an internal electronic component. The service bulletin was issued in August 2023, one month after the serious incident, independently of the latter (see paragraph 1.6.1.3.6). At the date of publication of this report, no other similar in service report had been made to Honeywell.

The design fault identified by Honeywell confirms that demonstrations to meet specifications for equipment certification and approval are based on a certain number of accepted assumptions such as failure mode predictions (effects and probabilities of occurrence) or the reliability of equipment components (as was the case for the transistor). The limits of these assumptions mean that all the associated risks before the equipment is put into service cannot be determined, and are often identified by experience. In the case of the transponders, notifications to the equipment manufacturer by operators, via flight crews, and by air traffic controllers, as well as Eurocontrol's monitoring of the 1,030 and 1,090 MHz frequencies in Europe as network manager (see paragraph 1.9.2), facilitate the rapid and effective implementation of corrective measures to guarantee a level of safety in line with applicable certification requirements.

2.3 Systems to attract crew attention in event of a transponder failure

The examinations carried out on the transponders of the Boeing 737 during the investigation found that the partial transponder failure was detected by the transponder's internal monitoring function, which generates the signal to illuminate the **ATC FAIL** light on the ATC Control Panel located between the two crew seats. However, it cannot be affirmed that the light was indeed illuminated during the serious incident flight given that the transponders were removed from the aircraft several flights after the serious incident, and that the crew reported that they had not seen the **ATC FAIL** light illuminated.

Whether or not the light was illuminated, the crew (like others before them, see paragraphs 1.17.8.4.3 and 1.18.5) were unaware of the partial transponder failure. If the transponder failure had been total, the aeroplane’s TCAS would also have detected it through its internal monitoring function. The **ATC FAIL** light would have illuminated, the TCAS FAIL message would have been displayed on the navigation display, and the display of the traffic in the vicinity of the aeroplane would have been lost. The combination of these warning systems would have increased the probability of the crew detecting and managing the abnormal situation. In the case of the serious incident to EC-NGC, the partial transponder failure may only have been shown by the illumination of the **ATC FAIL** light.

Furthermore, before being transferred to another sector after recovering radar contact, the crew of flight LAV4651 were informed that radar contact had been lost for some time. They did not understand the exchanges in French between the PCR of the ACC/south-west sector and the crew of flight AFR21YB concerning the loss of separation and the loss of radar contact with the 737. The crew then continued to their destination. The crew did not report the transponder failure in the TLB at the end of the flight. This may be explained by the fact that the crew had not seen if the ATC FAIL light was illuminated in flight, and that the ground checks of the TCAS and associated transponder before the following flight (transponder 1, not the one used on the serious incident flight) did not reveal anything. The PCR provided limited information to the crew of flight LAV4651 about the magnitude of the past situation which may also have limited their awareness of the risk and consequences associated with the transponder failure during the flight.

Current certification specifications for flight crew alerting systems (CS 25.1322, see 1.17.1.3) require perception by at least two different senses, based on a combination of aural, visual or tactile alerts. Visual elements to attract the attention should be in the pilots’ primary field of view. Based on these specifications, and if it is considered that the **ATC FAIL** light illuminated during the flight, the lack of detection of the partial transponder failure can be explained by:

- the position of this light, between the two crew seats, and therefore outside the primary field of view of the two pilots, which requires a head movement and a voluntary action to envisage detection of the **ATC FAIL** light;
- the **ATC FAIL** light not being associated with another signal.

The installation of the TRA 100B transponder on the Boeing 737 was not considered a major modification requiring an evolution of the certification basis for these aeroplanes, taking into account new requirements such as those relating to crew alerting systems.

The FAA circular (Boeing's aircraft certification authority), which aims to guide type certificate holders in the certification process for TCAS II and Mode S transponder installations on board aircraft (see paragraph 1.17.1.2), recommends in particular, that alerts in the event of a transponder failure should be in the pilot's primary field of view (see 1.17.1.3) and associated with the aircraft's primary caution and warning system. These provisions correspond to AMC and concern only “new installations”, for aircraft not already equipped with Mode S transponders or TCAS II or of new design.

At the date of publication of the report, the installation of a new type of transponder did not constitute a modification subject to compliance with the certification specifications applicable at the date of the request for this modification, or coming into force subsequently if the design organization so wishes (see paragraph 1.17.1.2), in particular those relating to flight crew alerting systems (CS 25.1322, see paragraph 1.17.1.3). The FAA circular also indicated that compliance with new requirements when installing new types of transponders, particularly those relating to flight crew alerting systems, can be complex due to the limitations of the alert systems already installed on aircraft, possible functions to be added, and economic considerations.

The European certification specifications for the installation and certification of transponders (CS-ACNS, see paragraph 1.17.1.2) are applicable to new aircraft and to those undergoing modifications which require the application of these specifications. They do not apply to the installation of new types of transponder. They require that the non-operation or failure of a transponder be indicated, without delay and without the need for crew intervention. There are no other details on how to alert a crew in the event of a transponder not operating or failing.

The serious incident on 21 July 2023, like others (see paragraphs 1.17.8.4.3 and 1.18.5), illustrates the risk of a mid-air collision or a collision with the ground due to a transponder malfunction transmitting erroneous information. This risk is currently being assessed by EASA in the scope of the safety issues relating to air navigation of the European Plan for Aviation Safety (EPAS) (see paragraph 1.9.5).

Requirements relating to systems for alerting crews in the event of a transponder failure are the subject of a safety recommendation (see paragraph 5.1).

2.4 Management of loss of radar contact by air traffic controllers

2.4.1 Context when radar contact was lost

Several messages and symbols relating to updates of radar track information for flight LAV4651 (see paragraph 1.17.3.7) and intended to attract the attention of air traffic controllers, were displayed on the label for this flight due to the absence of replies from the aeroplane's transponder to interrogations issued by ground radar stations.

These alerts were not perceived by the pair of controllers in charge of the sector in which the aeroplane was flying. Similarly, the track marker and the “Flights without track” window, characteristic of a loss of radar contact (see paragraphs 1.17.3.6 and 1.17.3.7) were not perceived at first. All of these alerts appeared on the controllers' screens for a period of four to five minutes during which no messages were transmitted on the radio frequency and no mouse movements were recorded in the positions of the two controllers.

This absence of messages and mouse movements is characteristic of a low workload, confirmed by the two air traffic controllers of the sector and by the low traffic in the sector. This period of a low workload came after several busy sequences for the PCR since he started his shift at 04:30.

The period of a low workload probably had the effect of reducing the pair's level of vigilance and degrading their monitoring task, including the scan of their sector. Both controllers confirmed this and stated that they had been talking during this period of a low workload. However, as there was no recording of the aural environment at the air traffic controllers' workstations, it was not possible to accurately assess the pair's activity during this period of a low workload. This lack of recording also meant that it was not possible to identify any indicators of behaviour that could affect human activity, such as fatigue: the PCR had gotten up early after approximately 4.5 to 5 hours of sleep, after a period of six days of rest (a situation that can contribute to falling asleep late and making an early wake-up difficult). He had also started his shift with periods of heavy traffic.

The DGAC has updated an order (see paragraph 1.9.6) which stipulates that the DSNA must equip its units with systems for recording background communication and the aural environment from February 2026, in accordance with ATS.OR.460 of Regulation (EU) 2017/373.

2.4.2 Taking into account flight LAV4651 alerts

When the PCR received a message from a crew after a period of inactivity lasting more than four minutes, neither of the two position controllers had detected the ageing mechanism of the LAV4651 track or the subsequent loss of the track. The track marker associated with LAV4651 was, however, immediately deleted by the PCR in a reflex single mouse click as soon as he had sector management actions to perform. The PCR indicated that he had forgotten about flight LAV4651, characteristic of the undesired event “disappearance of the flight from the controllers' mental picture” identified in the ERATO electronic environment safety file (and similar to the problematic situation of “loss of awareness of a flight concerning the sector” in the 4-FLIGHT safety file). The PCO also deleted the track marker a few moments later. The PCR then lifted the Mach constraint transmitted to flight EFW3HY (see paragraph 1.1.2) which he had previously imposed in order to separate it from flight LAV4651 in the horizontal profile. This action tends to confirm that the PCR had forgotten about LAV4651 during a low workload period with a reduced level of vigilance. This action provided the PCR with an additional means of detecting the loss of radar contact with flight LAV4651, by prompting him to question the reasons for the Mach constraint displayed and the singling out of the label for the flight in question.

Neither controller attempted to analyse or verify, based on the information available on the screen, whether the track marker was associated with a flight on the frequency. Similarly, each controller deleted the track marker without prior coordination. The “Flights without track” window was seen by the PCR, who immediately moved it to one side of the screen without taking into account the information about LAV4651 that it contained. This window, which also appeared fifteen minutes after the transponder failure on the screens of the pair of controllers of the RL3 sector of ACC/south-west was also moved by these controllers. The PCO for this sector considered that the flight was late, and neither the PCR nor the PCO sought to coordinate with the QXI sector of ACC/west to find out more.

2.5 Ergonomics and certification specifications for air navigation

The serious incident, similar transponder failure events (see paragraph 1.17.8.4.3) and Eurocontrol studies (see paragraphs 1.9.4 and 1.9.5) bear witness to the risk of controllers not perceiving or taking into account warning systems relating to track ageing. This risk was identified in the safety analyses carried out during the implementation of electronic environments at the DSNA (EEE and 4-FLIGHT). It should also be noted that for more than four minutes the pair of controllers for the QXI sector of ACC/west did not detect or react to the display of the symbol relating to the CPDLC link transfer problem and the display of the "special flights" window (see paragraph 1.17.3.7).

The display of track markers for flights that do not concern the sector or for reasons that do not present a real threat, is principally due to the ERATO electronic environment display mechanism, the materialization of certain traffic flows as well as the zoom functionalities on the control positions. The frequency of the display of the track markers explains why there was no double-check or a visual scan, as specified by the work method to interpret the information presented to air traffic controllers.

Systematically associating the display of a track marker with a known situation and of no real threat tends to alter the meaning and reduce the relevance of the tasks that are supposed to be implemented. In other words, the overall recognition of frequent and known situations can lead to certain habits that result in responses or actions that differ from established expectations (e.g. work methods) and from what is taught in training. Generally speaking, the habit of deleting track markers without taking into account other available information stems from the possible misinterpretation of alerts which, due to the frequency of their occurrence, are perceived as nuisance alerts or false alerts. These habits also bring to light a latent risk of normalizing deviations in processing alerts. Thus, the management of a rarer and more critical situation but giving rise to the same display (display of track marker due to a transponder failure) can be more difficult. The deletion of track markers is also facilitated by the simplicity of the process (a simple mouse click), without having to confirm the deletion or coordinate with the other controller.

The controllers had, however, received theoretical and practical training on transponder failures a few months before the serious incident (see paragraphs 1.5.3 and 1.17.5.5). The theoretical training covered the actions to be taken in the event of a transponder failure, assuming that the failure had been identified beforehand. The low frequency of exposure to these trainings, as well as to feedback, such as that transmitted to air traffic controllers at ACC/west after the similar occurrence in June 2023 (see paragraph 1.17.8.4.3), tend to show the limits of their effectiveness.

Systems for alerting air traffic controllers are the subject of a safety recommendation (see paragraph 5.2).

2.6 DSNA SMS

2.6.1 Identification and assessment of risk

As part of the implementation of its SMS, the DSNA established procedures to identify safety risks related to its activities, such as conducting safety studies with respect to changes to functional systems and analysing safety events.

The failure of an air traffic controller to detect, perceive, or take into account an alert system related to a flight's non-conformity is a risk that was specifically listed in the safety study prior to the commissioning of the ERATO electronic environment. As this study mentions, deleting a track marker on the screen can erase a flight from the controller's memory. This risk is further confirmed by the analysis of the three safety events reported by the DSNA (see paragraph 1.17.8.4.3).

The DSNA has not implemented sufficient means to assess risks comprehensively and reliably. In particular, the limited and insufficient knowledge of the frequency of risk situations, such as the deletion of track markers by a pair of controllers without prior analysis of the situation, without considering the information available to them, and without coordination between the PCR and the PCO, prevents the DSNA, within the framework of its SMS, from proactively assessing the associated risks and proposing appropriate response strategies.

This assessment relies primarily on the reporting of events by operational staff. This notification or reporting is mandatory for safety events listed in European regulations (see paragraph 1.17.8.4.1). However, the obligation sometimes depends on the air traffic controller's judgement of the risk level. Generally speaking, the reporting method alone is insufficient to detect potential deviations or differences in the application of work methods or operational procedures. For example, it does not allow for the quantification of all cases of mishandling or failure to detect warning systems, such as track markers and “Flights without track” windows, in the daily use of the ERATO electronic environment. It should be noted that the three safety events reported by the DSNA resulted in a loss of radar track for more than fifteen minutes.

Various methods and activities other than event reporting can be implemented to facilitate the identification and assessment of risks. The DSNA has undertaken, particularly based on a BEA safety recommendation in 2024 (see paragraph 1.17.8.5.2), to identify the needs and objectives of the assessment of the controllers' actual work in the control position and to define the resources and organization necessary for the DSNA to implement this on a sustainable basis within the framework of the SMS.

2.6.2 Mitigation and reduction of risk, assessment of effectiveness

During the safety studies it conducted with respect to the functional system, the DSNA defined Risk Reduction Measures (RRM) for identified risk situations. DSNA procedures stipulate that the effectiveness of the RRM is evaluated during a phase after the implementation of the change, often of the order of 6 to 12 months. Points of vigilance (or monitoring criteria, see paragraph 1.17.8.3.3) are defined and monitored based on event reports from operational staff. These points of vigilance do not appear to systematically cover all identified RRM, as demonstrated by those identified by the DSNA in the EEE safety study.

The reported safety events were initially analysed by the local DSNA services. These analyses may lead to local measures. Only events whose potential consequences ("air navigation malfunction") are considered serious ("very significant") are analysed at the national level by the DSNA (see paragraph 1.17.8.4). These events are reviewed in a national meeting that may take place several months after the event. Actions assigned to local or national DSNA entities are then decided upon and followed up in a steering committee meeting held twice a year. This mode of operation does not appear to guarantee effective and continuous progress and monitoring of the measures taken by the DSNA, whether it be those resulting from the analyses of events or the RRM defined in the safety studies. The DSNA decided in June 2025 to establish a steering committee responsible for monitoring the various actions to improve DSNA safety.

Furthermore, except when the DSNA decides to conduct a national analysis of the event, the DSNA indicates that the ITES is a body specifically designed to evaluate the effectiveness of existing RRM. However, the reports do not establish an explicit link with these RRM. As the DSNA emphasized in one of these reports, it seems difficult to link the safety studies to the events, given the scenarios initially envisioned and what actually occurs.

The safety events involving the inappropriate handling of track markers and the “Flights without track” windows, known to the DSNA, and the resulting safety measures, are not mentioned in the ITES report, which raises questions about the overall consideration of the risks. In the absence of means to track the frequency of cases of incorrect handling or failure to detect alert systems (see paragraph 2.6.1) and given that the DSNA no longer plans any changes to the ERATO electronic environment which is to be replaced, the consideration given to the associated risks curbs all the more, the measures taken following feedback, or training on the application of work methods. Moreover, the effectiveness of these measures does not appear to be questioned.

2.6.3 Risk map

The DSNA had not developed a national risk representation model on which a comprehensive risk management process could be based. In 2010, the DSNA produced a basic risk map that defines a concise list of "undesired occurrences" and "ultimate occurrences." It does not mention the various risks identified through the SMS processes, nor the associated prevention or mitigation measures. Furthermore, it is not updated based on feedback and is not used to support event analysis or risk studies prior to change. This lack of a national overview prevents the DSNA from assessing and questioning the effectiveness of existing risk mitigation measures. It also prevents a coherent and comprehensive analysis of risks at national level.

The DSNA’s overall management of safety risks is the subject of a safety recommendation (see paragraph 5.3).

2.7 Compulsory position reporting

The regulations stipulate that crews report their position when passing compulsory position reporting points. The crew of flight LAV4651 failed to do this when passing the BALAN reporting point, which meant that the PCR did not notice the loss of the flight's radar blip on his screen after deleting the track marker displayed because of the transponder failure. A call from the crew when passing BALAN would have meant, with the probable recovery of the radar track on the screen, that the crew would have been asked to contact the frequency of the next sector, in this case the RL3 sector of ACC/south-west, in which the aeroplane flew without radar or radio contact before the loss of separation with flight AFR21YB and radio contact was made on the distress frequency.

This situation, combined with the statements from airline pilots, seems to show that the safety barrier that could be provided by compulsory position reporting points has become obsolete. However, according to a study conducted by Eurocontrol in 2014 (see paragraph 1.9.5), position reporting is an effective means of detecting transponder malfunctions.

The use of on-board navigation systems in cruise that do not include the official symbols of waypoints shown on charts, as well as increased traffic that could lead to frequency saturation, may have naturally led to crews no longer systematically reporting their position at compulsory position reporting points.

Compulsory position reporting is the subject of a safety recommendation (see paragraph 5.4).

3. CONCLUSIONS

3.1 Findings

- The transponder on the Boeing 737-809 operated by Albastar and registered EC-NGC, flight LAV4651, failed in cruise flight; this was not detected by the crew.
- The transponder failure meant that the aeroplane was no longer being tracked and the radar track was no longer being correlated; this was not detected by the air traffic controllers in charge of the control sector in which flight LAV4651 was flying.
- The **ATC FAIL** light on the ATC Control Panel, a system designed to alert Boeing 737-809 crews in the event of a transponder malfunction, is not located in the pilots' primary field of view. This system complied with all the certification requirements applicable to the Boeing 737-809 at the time of the aeroplane’s design.
- The track markers displayed on the screens of the control positions for the sector in which flight LAV4651 was operating at the time of the transponder malfunction were deleted by the position air traffic controllers, without coordination and without analysing the other information available to them on their interfaces.
- The two air traffic controllers for the sector in which flight LAV4651 was operating at the time of the transponder failure lost awareness of the presence of this flight within their control sector and no longer provided air traffic services.
- The track markers displayed on the controllers' screens can be deleted without an in-depth analysis of the situation, out of habit, due to the identical and more frequent display of track markers for situations where the criticality level is often low.
- The crew of flight LAV4651 continued on its flight plan route after passing the compulsory position reporting point that had been transmitted by the air traffic controller when he instructed the crew to fly directly to this point.
- The crew of flight LAV4651 entered the airspace of another ACC without radio contact with the air traffic controllers in the associated control sector.
- The TCAS of flight LAV4651 was able, despite the malfunction of the aeroplane’s transponder, to issue traffic and resolution advisories, but without any possibility of coordination with the TCAS systems of nearby aircraft.
- The crew of flight LAV4651 saw the presence of nearby traffic on their navigation displays.
- The transponder and TCAS of the Embraer 190 operated by Hop! and registered F-HBLD, flight AFR21YB, as for any other aircraft that may have been nearby, could not receive information from the transponder of the Boeing 737 and were therefore unable to detect it or issue traffic or resolution advisories.
- The crew of the Embraer 190 saw flight LAV4651 pass in front of them at the same flight level without their TCAS displaying it on the screens.
- The minimum separation between the two aeroplanes flying at the same flight level was 2.6 NM, compared to the minimum required separation of 5 NM.
- Military air traffic controllers in the Cinq-Mars-La Pile CDC visually detected on their screens via the primary radar, that the transponder code of the Boeing 737-809 was missing as it approached a temporary restricted area.
- After numerous telephone exchanges between ACC/west, ACC/south-west and Cinq-Mars-La Pile CDC, radio and then radar contact was re-established.
- The lack of aural environment recordings at the air traffic controllers' workstations meant that it was not possible to fully and accurately analyse their activities before and after the loss of radar contact.

- As the Boeing 737 continued its flights, it was not possible to obtain the cockpit audio recording, and thus a complete and accurate analysis of the crew's activity before and after the transponder malfunction.
- The cause of the transponder failure was known to the manufacturer Honeywell, which issued a service bulletin, independently of the serious incident, to correct the failure that occurred during this flight.
- The analysis and monitoring of safety events in the scope of the DSNA's SMS did not explicitly correlate in-service events, known since at least 2017, with undesired events, identified in the safety files produced for the implementation of the ERATO and 4-FLIGHT electronic environment.
- The DSNA had not developed a national risk representation model on which a comprehensive risk management process could be based.

3.2 Contributing factors

While cruising at FL 350, the transponder on the Boeing 737-809 operated by Albastar, flight LAV4651, experienced a failure, which meant that both nearby aircraft were not able to detect it and that its correlated radar track was no longer being tracked and no longer being displayed. The air traffic controllers in ACC/west in charge of the sector in which the aeroplane was flying did not perceive the loss of radar contact, which was indicated by various warning systems. These included a track marker, which they deleted without first analysing the information available to them. This action resulted in a loss of awareness of the flight in the control sector for which they were responsible. The crew, for their part, did not detect the transponder failure and continued on their flight plan route without reporting their position by radio at the compulsory reporting point. The crew entered the ACC/south-west airspace without radio or radar contact. A few minutes later, the aeroplane crossed paths with an Embraer 190, at a distance of 2.6 NM and at the same flight level. The crew of this aeroplane saw the Boeing 737 pass in front of them, with no TCAS information displayed. The crew of the Boeing 737, for their part, saw a white diamond on their screens advising of the presence of the Embraer 190 and indicating that there was no risk of collision.

Radio and radar contact with flight LAV4651 was re-established by means of the Embraer 190 crew, visual detection without a targeted search by military controllers in Cinq-Marc-La Pile CDC, and numerous telephone exchanges between ACC/south-west, ACC/west and the CDC.

Beyond these findings, the loss of separation between the two aeroplanes during cruise flight can be explained by a set of measures intended to reduce the risk of errors, which did not function as expected and did not ensure flight safety.

The following factors may have contributed to the two aeroplanes following conflicting flight paths in RVSM airspace without radar contact:

- insufficient margins taken into account when designing the transponder model, with respect to the heat dissipation requirements of a transponder component;

- a system to alert the crew and inform them of a transponder malfunction or failure, which relies solely on an amber indicator light located outside the primary field of view of both pilots, requiring a deliberate movement of the head in order to see that it has illuminated;
- insufficient certification specifications relating to indications of non-functioning or failure of transponders and in force at the time of the certification of the Boeing 737-800;
- the display of identical alerts (“track markers”) for different levels of criticality to attract the attention of air traffic controllers;
- the routine which had set in based on the frequency of “track markers” related to non-critical situations, which may lead air traffic controllers to delete them without a comprehensive analysis of the information available on their screens;
- the handling of safety events by the DSNA, which did not identify all the threats and risk situations with a view to establishing technical and operational mitigation measures;
- the limitations of the compulsory position reporting points provided for in the regulatory texts.

4. MEASURES TAKEN

4.1 DSNA

Aware of the difficulties in monitoring its various safety improvement initiatives, including all actions taken within the framework of safety event analysis, the DSNA has indicated that it established a Steering Committee dedicated to this monitoring in June 2025, scheduled to meet twice a year.

The management of statements of requirements transmitted by operational centres to the DTI is the subject of much discussion in order to reform the current process, which is outdated and considered ineffective by the DSNA. The DSNA thus plans to improve the management of the process at the national level and the decision-making, validation, and follow-up stages of the implementation of the statements of requirements. There are also plans to conduct continuous monitoring of safety events in relation to the relevant statements of requirements, which, in other words, will allow for the evaluation of the relevance and effectiveness of the actions implemented following a statement of requirements.

4.2 HONEYWELL

Similar transponder failures to those on the transponder equipping the Boeing 737-809 operated by Albastar had been reported to Honeywell by several operators prior to the incident on 21 July 2023. The analysis and examinations conducted by Honeywell led to the publication of a service bulletin requesting the replacement of an internal electronic component. The service bulletin was published in August 2023, one month after the serious incident, independently of the incident. At the date of publication of this report, no other similar in service report had been made to Honeywell.

5. SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations shall report to the safety investigation authority which issued them, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

5.1 Certification Specifications for Airborne Communications, Navigation and Surveillance (CS-ACNS)

The investigation was not able to determine whether the light to alert the crew to the transponder failure had illuminated during flight LAV4651. However, examinations found that it had illuminated several times before the transponder was replaced four days after the serious incident flight. Several occurrences (see paragraphs 1.17.8.4.3 and 1.18.5) also tend to show that crews do not necessarily detect a transponder failure in flight. The risk of a mid-air collision in the event of a transponder failure not being detected by a crew is increased due to the presence of aircraft with different certification criteria flying in the same airspace.

With the exception of new types of transport aeroplane with a maximum take-off mass greater than 5,700 kg or at the request of designers in the event of modifications to an aircraft, current certification specifications do not require pilots to be alerted via at least two different channels in the event of a transponder failure. A FAA circular recommends that the transponder failure be indicated in yellow/amber in the pilots' primary field of view and that these alerts be associated with the aircraft's master caution and warning system. These recommendations only apply to aircraft that are not yet equipped with transponders or that do not yet have a type certificate. For its part, EASA, in CS-ACNS, requires that the non-operational status or failure of the transponder system be indicated without undue delay and without the need for flight crew action (specification CS-ACNS.D.ELS.030).

Consequently, the BEA recommends that:

- *whereas the risk of a collision in the event of a transponder malfunction;*
- *whereas the risk of the crew not detecting a transponder malfunction;*
- *whereas the certification specifications relating to indications of the non-operational status or failure of transponders and in force at the time of the certification of the Boeing 737-809 are insufficient;*
- *whereas aircraft with different certification criteria operate in the same airspaces;*
- *whereas the certification specifications relating to crew alerting systems on transport aeroplanes with a maximum take-off mass greater than 5,700 kg (CS 25.1322) require that the flight crew be made aware of the malfunction through at least two different senses;*
- *whereas the absence of transposition to other categories of aircraft of the requirements relating to systems to attract the attention of crews for transport aeroplanes (CS 25.1322);*

- *whereas the FAA circular[72] to guide holders of type certificates during the certification processes of TCAS II systems and mode S transponders on board aircraft recommends that the malfunction of a transponder or a TCAS shall, in order to comply with requirements relating to flight crew alerting systems, not only be indicated in yellow/amber in the pilots' primary field of view, but shall also be interfaced with the aircraft's master caution and warning system;*

EASA detail, in the certification specifications CS-ACNS, the alert systems required in the cockpit to facilitate the pilots' detection of a transponder malfunction whatever the aircraft certification criteria (CS 25 and CS 23 for example). [Recommendation FRAN-2025-009]

5.2 Systems for attracting air traffic controllers' attention

The ERATO electronic environment in place at ACC/west and ACC/south-west displays identical alerts for different levels of criticality. The information available to controllers on their control position interfaces has to be analysed in order to identify the cause and reasons for the display of these alerts.

With 4-FLIGHT, the systems used for the loss of radar contact are different. Furthermore, there are no detailed specifications for the man-machine interfaces of the ATM/ANS systems. However, studies have been conducted with respect to the design of these systems with the aim of improving the detection and integration of these alerts by air traffic controllers. The European Safety Plan (EPAS) and studies conducted by Eurocontrol have also identified that the essential elements for ensuring that the air traffic controller detects a transponder malfunction and handles it in an effective and timely manner, are based on mechanisms such as procedures and appropriate ergonomics.

Consequently, the BEA recommends that:

- *whereas the Eurocontrol study indicates that the elements for ensuring that the air traffic controller detects a transponder malfunction and handles it in an effective and timely manner, are based on mechanisms such as procedures and appropriate ergonomics;*
- *whereas in Europe, the specifications and acceptable means of compliance with respect to the ATM/ANS man-machine interface are not sufficiently detailed, probably due to their recent implementation;*
- *whereas the risk of an error when identical systems are used to attract the air traffic controller's attention for situations with different levels of criticality;*
- *whereas the influence of the traffic management activities, the characteristics of the alert systems or the workload for example, on the overall activity of the air traffic controllers;*
- *whereas the balance to be found between the ability to attract the air traffic controller's attention and the importance of the ongoing activity;*

EASA, in the scope of action RMT.0744 of the European Plan for Aviation Safety (EPAS), develop detailed specifications for ATM/ANS ground equipment in order to improve the alerting systems regarding the loss of a radar track, facilitate the detection of these losses and thus allow controllers to take the appropriate actions.
[Recommendation FRAN-2025-010]

[72] Circular 20-151C

5.3 DSNA’s overall management of safety risks

For a safety management system to be effective, it must be based on a comprehensive and harmonized approach that is both proactive and reactive, involving all components of the organisation, whether technical or operational. The safety risk management processes should enable a precise and comprehensive assessment of identified risks, an essential condition for defining appropriate risk reduction measures. Mechanisms should also be developed to reliably analyse and monitor the effectiveness of these measures, in order to guarantee the improvement of the SMS and an acceptable level of security.

The implementation of a risk representation model supports this comprehensive and harmonized approach. The investigation showed that the procedures put in place by the DSNA to manage the risks associated with its activities can be improved (see paragraph 2.6.3). Some procedures are currently being given consideration within the DSNA (on-the-job observations, development of a national risk representation model for example).

Consequently, the BEA recommends that:

- *whereas the lack of use and updating of the risk map established in 2010, which only defines "undesired" and "ultimate" events;*
- *whereas the absence of a model representing all the risks and associated prevention measures in the DSNA's SMS;*
- *whereas the identification and assessment of certain risks rely on events being reported by operational staff, including air traffic controllers;*
- *whereas the resources implemented by the DSNA to reliably and comprehensively assess the frequency and severity of risks are insufficient;*
- *whereas the links established between the analysis of safety events and the risk reduction measures (RRM) of safety studies are inadequate;*
- *whereas only the events whose potential consequences ("air navigation malfunction") are considered serious are analysed at national level;*
- *whereas the management of the progress and monitoring of the actions decided on in the various bodies processing safety events does not seem to be effective and continuous;*

the DSNA develop a risk representation model as a tool to support a more comprehensive approach to safety management, enabling reciprocal feedback from reactive and proactive approaches in order to identify and analyse threats at the interface between operational and technical components. [Recommendation FRAN-2025-011]

5.4 Compulsory reporting points

The crew of flight LAV4651 had received instructions to take a direct route to a compulsory reporting point. They did not contact the sector’s air traffic controller when passing this point and continued their route according to the flight plan, as this is regularly done. For his part, the sector controller forgot that he had this flight to manage after deleting the marker indicating the loss of radar contact following the failure of the transponder. In the absence of radar contact, the air traffic controllers of the subsequent sector were not aware of the aeroplane entering their sector.

The position reporting point could have constituted a means of recovery for the crew and the controller, with them becoming aware of the transponder failure and the loss of radar contact. This means did not, therefore, function as intended, and it would appear, according to statements collected from some airline pilots and air traffic controllers, that radio contact at compulsory reporting points is mainly made when air traffic controllers have explicitly requested it. Furthermore, the navigation displays on board aircraft do not use the defined symbology and therefore do not allow crews to differentiate between compulsory reporting points and others without consulting other charts. Eurocontrol has also shown that position reporting, particularly during transfers from one sector to another, is an effective means of identifying a loss of radar contact.

Consequently, the BEA recommends that:

- *whereas the symbology of navigation displays on board aircraft does not allow crews to explicitly identity the type of the various waypoints and in particular the compulsory position reporting points;*
- *whereas the radio contacts at compulsory position reporting points do not seem to be systematic;*
- *whereas the increase in traffic necessarily leads to greater use of radio messages on the frequency;*
- *whereas the use of navigation systems facilitates the more and more flexible use of the airspace;*

EASA assess the actual use of compulsory reporting points in European airspace in accordance with existing regulatory provisions and expectations, with the aim not only of promoting the results of this assessment to air operators and ANSP, but also of encouraging these organisations to take action based on the examination of these results.
[Recommendation FRAN-2025-012]

The BEA investigations are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.