BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

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SAFETY INVESTIGATION REPORT

Incident to the AIRBUS A350-900 registered **F-HTYO** operated by Air France on 28 May 2023 en route from Osaka airport (Japan)

Source: Air France

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SAFETY INVESTIGATIONS

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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
A/THR	Auto Thrust
ACARS	Aircraft Communication Addressing and Reporting System
ADIRS	Air Data Inertial Reference System
ADIRU	Air Data Inertial Reference Unit
ADR	Air Data Reference
AESS	Aircraft Environment Surveillance System
AESU	Aircraft Environment Surveillance Unit
AFI	Aircraft Fault Isolation
AMC	Acceptable Means of Compliance
AMM	Aircraft Maintenance Manual
AOA	Angle Of Attack
AP	Autopilot
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATPL	Airlines Transport Pilot Licence
BKUP	BacKUP
BSCS	Braking and Steering Control System
CACRC	Commercial Aircraft Composite Repair Committee
CAP	Radome nose
CAPT	Captain
CAS	Computed Air Speed
Cb	Cumulonimbus
EASA	European Union Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitoring
EFB	Electronic Flight Bag
EFIS	Electronic Flight Instruments System
EU	European Union

Abbreviations	Meanings
F/CTL law	Flight control law
F/O	First Officer
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Techniques Manual
FD	Flight Director
FDR	Flight Data Recorder
FL	Flight Level
FMA	Flight Mode Annunciator
FOD	Foreign Object Damage
FORDEC	Facts, Options, Risks and benefits, Decision, Execution, Control
FSTD	Flight Simulation Training Device
Ft	Feet
FWC	Flight Warning Computer
GM	Guidance Materials
HUD	Head Up Display
IAS	Indicated Air Speed
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
inHG	Inch of mercury
IR	Inertial Reference
ISIS	Integrated Standby Instrument System
JTSB	Japan Transport Safety Board
kt	Knot
LMP	Line Maintenance Procedure
MCC	Maintenance Control Centre
MECA	Mechanical area of radome
MFP	Multi Function Probe
MMR	Multi-Mode Receiver
MPD	Maintenance Planning Document
MSN	Manufacturer Serial Number

Abbreviations	Meanings
NAIADS	New Air and Inertia Automatic Data Switching
OAT	Outside Air Temperature
OEB	Operations Engineering Bulletin
OIS OPS	Onboard Information System - Operations
PF	Pilot Flying
PFD	Primary Flight Display
PFR	Post Flight Report
PM	Pilot Monitoring
PR	Pilot report
PRIM	PRIMary Flight Control and Guidance Computer
QAR	Quick Access Recorder
QNH	Altimeter setting for altitude above sea level
RE	Radio area (radome)
RTU	Radar Transceiver Unit
SFD	Standby Flight Display
SND	Standby Navigation Display
SPD	SPeeD
TR	Type Rating
TRI	Type Rating Instructor
TSM	Trouble Shooting Manual
UAS	UnreliAble Speed
UTC	Universal Time Coordinated
UV	Ultraviolet

SYNOPSIS

Time	Around 03:17[1]
Operator	Air France
Type of flight	Commercial air transport of passengers
Persons onboard	Captain, 3 co-pilots[2], 10 cabin crew members, 309 passengers
Consequences and damage	Radome and weather radar antenna damaged, airspeed indicator probes affected

Failure of weather radar in climb, turn-around, damage to radome, airspeed indicator probes affected and overweight landing

On 28 May 2023, the crew of the Airbus A350 registered F-HTYO, operated by Air France, were carrying out flight AF291 between Kansai international airport (Osaka-Japan) and Paris-Charles de Gaulle (France).

During the climb, the occurrence of weather radar faults (WXR fault) led the crew to perform an in-flight turn-around. While flying through FL 300 in descent, the radome collapsed on itself.

The airflow disturbances caused by the substantial damage to the radome impaired the pressure measurements of the probes located at the front of the aeroplane and resulted in discrepancies in the airspeed indications. These discrepancies changed throughout the flight depending on the aeroplane's angle of attack, and especially during the approach upon extension of the slats and the flaps; when the aeroplane was configured to CONF 1, the pilots observed fluctuations in the airspeed indications on the PFD lasting several tens of seconds and decided to disconnect the autopilot (AP) and the autothrust (A/THR).

The crew performed an overweight landing without any incident.

As a result of the investigation, Airbus updated the maintenance tasks associated with the inspection of the radome and the handling of weather radar faults as well as Airbus A350 operational documents (FCOM and FCTM).

Air France implemented measures to draw the attention of:

- pilots to the operation of the New Air and Inertia Automatic Data Switching (NAIADS) system;
- maintenance technicians to the risks of damage to the composite structure of radomes and the need to strictly apply maintenance procedures.

[1] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC).
[2] In Air France, a co-pilot is designated by the term First Officer (FO).

ORGANISATION OF THE INVESTIGATION

On 28 May 2023, Air France informed the BEA of this occurrence. The BEA then asked the Japanese safety investigation authority (JTSB) if the latter was opening a safety investigation. As the occurrence did not constitute a serious incident or an accident within the meaning of ICAO Annex 13, the JTSB decided not to open an investigation.

After receiving additional information supplied by Air France and Airbus, the BEA decided to open a safety investigation.

1. FACTUAL INFORMATION

1.1 History of the flight

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

On 28 May 2023, the Airbus A350 registered F-HTYO was carrying out flight AF291 between Kansai international airport (Osaka-Japan) and Paris-Charles de Gaulle. Fourteen crew members and three hundred and nine passengers were on board. The flight crew comprised a captain (CAPT) and three co-pilots[3].

The flight crew stated that the pilots of the previous flight (flight from Paris-Charles de Gaulle to Osaka made the day before) told them, prior to departure, of the occurrence of weather radar faults. They specified that when taking charge of the aeroplane at Osaka, the maintenance team reported having tested both radar systems, that both systems were operational and that the aeroplane was returned to service.

At 02:14, the crew took off from runway 06R. The captain was PF and co-pilot A was PM. The two other co-pilots were in the cockpit.

At 02:22, the aeroplane flew through 11,600 ft climbing towards FL 290 and a fault occurred on radar system 2 (see **Figure 2**, point 1). The MASTER CAUTION[4] alert was activated along with the message SURV WXR 2 FAULT[5] displayed on the ECAM. In the minutes that followed, the crew alternately selected radar system 1 and radar system 2. They observed that neither system was operating nominally (intermittent operation). The crew changed the operating mode of the radar (OFF/Manual/Auto) but this did not correct the situation. The MASTER CAUTION alert was activated a number of times along with the fault messages SURV WXR 1 FAULT or SURV WXR 2 FAULT displayed on the ECAM.

The crew considered both systems to be inoperative. They anticipated the application of the SURV WXR 1+2 FAULT procedure, which refers to the SURV TOTAL LOSS OF WXR procedure when a WXR 1+2 fault is confirmed. They contacted Air France operations by ACARS at 02:30. They informed them of the radar faults and requested weather forecasts for the remainder of the route to Paris. The crew were cleared to climb to FL 350 by the controller.

At 02:51, the aeroplane was at FL 350 and the SURV WXR 1+2 FAULT message was displayed on the ECAM (see **Figure 1** and **Figure 2**, point 2). The application of this procedure led the crew to perform the SURV TOTAL LOSS OF WXR procedure and to carry out a FORDEC. Informed by Air France operations of the presence of cumulonimbus along the route, and having more than six flight hours to Paris, the crew decided to turn back to Osaka (see **Figure 2**, point 3). The captain became PM to focus on the radio exchanges with the controllers and Air France operations. Co-pilot B replaced co-pilot A[6] and became PF up to landing.

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[3] Duty times exceeding the flight time limitations set by the regulation are carried out by augmented or doubled crews. The three co-pilots will be designated co-pilot A, B and C hereinafter.

[4] The alert light is amber. It can be switched off by pressing the associated button.

[5] A detailed description of the weather radar and associated faults is given in paragraph 1.6.4.2.

[6] Copilot B needed to a make a landing in the next three days in order to adhere to the quota of landings required by the regulations.

Figure 1: photo of the ECAM taken by the crew at 03:05

At 03:17, the aeroplane was flying at 320 kt (CAS) in order to reach FL 300 (ALT* mode engaged). The crew heard a thud followed by a very loud aerodynamic noise (point 4). The PF announced that he was deactivating the A/THR as he observed fluctuating engine speeds.

The crew initially considered that they were encountering loss of cabin pressure but understood that this was not the case as the altitude in the cabin remained constant. Then, observing that PFD 1 displayed an aeroplane altitude 300 ft below that displayed on PFD 2, they considered that the aeroplane may have lost a section of its radome or a probe. The engine speeds restabilised and the PF reactivated the A/THR (30 seconds after its deactivation).

At 03:18, the crew compared the speeds and observed that the indications on PFD 1 and PFD 2 were the same but that one speed source was rejected. They read out the INFO message MULTIPLE AIR DATA REJECTED BY PRIMs associated with the NAV AIR DATA REDUNDANCY LOST ECAM alert.

The crew contacted the controller to confirm the return to Osaka and requested descent clearance. The controller cleared them to descend to FL 280. The crew declared PAN-PAN, informed the controller of the occurrence of a speed problem and requested clearance to descend below FL 280. They received clearance to descend to FL 200. At 03:21, the flight controls switched to ALTERNATE law, then reverted to NORMAL law at 03:25 before returning to ALTERNATE law thirty seconds later.

Between 03:21 and 03:25, the crew extended the air brakes. In contact with the controller, they prepared the return route, listened to the ATIS, and contacted the cabin crew members to enable the latter to prepare the cabin.

In the following 10 min, the crew reviewed the ECAM messages. The main messages were as follows:

- ALTN LAW: PROT LOST
- MULTIPLE AIR DATA REJECTED BY PRIMs
- ISIS SPD UNRELIABLE

The inoperative systems displayed were as follows:

- F/CTL PROT
- RNP AR
- AUTO BRK
- ROW/ROP
- GA SOFT
- AUTOLAND

The crew considered that they had lost a section of the aeroplane's nose. They questioned whether the technician had securely locked the radome after performing maintenance. Overweight for landing (more than 258.2 t at that time for a maximum landing weight of 207 t), they decided to descend as soon as possible to consume a maximum amount of fuel and reduce the speed (250 kt- GREEN DOT[7] + 5 kt).

From 03:40, the aeroplane was stable at FL 150 and the CAS was 240 kt. The crew observed that the speeds were unstable (the speed displayed on PFD 1 fluctuated around the GREEN DOT). They referred to and applied the **NAV UNRELIABLE AIR SPEED INDICATION** procedure, and then declared a MAY DAY (point 5). The crew left the A/THR, AP and FD activated in accordance with the procedure.

At 03:50, the crew reviewed all of the ECAM messages and noted that the aeroplane's flight control law had reverted to NORMAL law.

From 04:00, the aeroplane was in level flight at FL 150 and the speed was 240 kt. The aerodynamic noise and vibrations increased. The PF felt a greater level of vibration in the rudder pedals. Suspecting that the damage was becoming worse, the crew considered diverting to Tokyo. After carrying out a new FORDEC, they decided to continue to Osaka. The PF reported that the aeroplane appeared to have a slightly unstable dynamic performance. This perceived instability and concern regarding a more turbulent atmosphere during descent led the crew to anticipate the aeroplane's configuration (extension of slats, flaps and landing gear) to assess the performance of the aeroplane and to avoid a surprise on final.

At 04:17, the aeroplane was stable at 12,000 ft QNH with a speed of 230 kt. The crew conducted the arrival briefing. The crew evoked in particular threats associated with both the overweight situation (253 t at that time) and unreliable air speeds (UAS). They applied the **MISC OVERWEIGHT LDG** procedure. They informed the controller of their wish to make a long downwind leg for runway 24, 30 NM south of the airport.

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[7] The "GREEN DOT" speed (displayed on the PFD as a green circle) applies to an aircraft in a clean configuration. It represents the speed at which the lift-to-drag ratio is best, where aerodynamic efficiency is maximized.

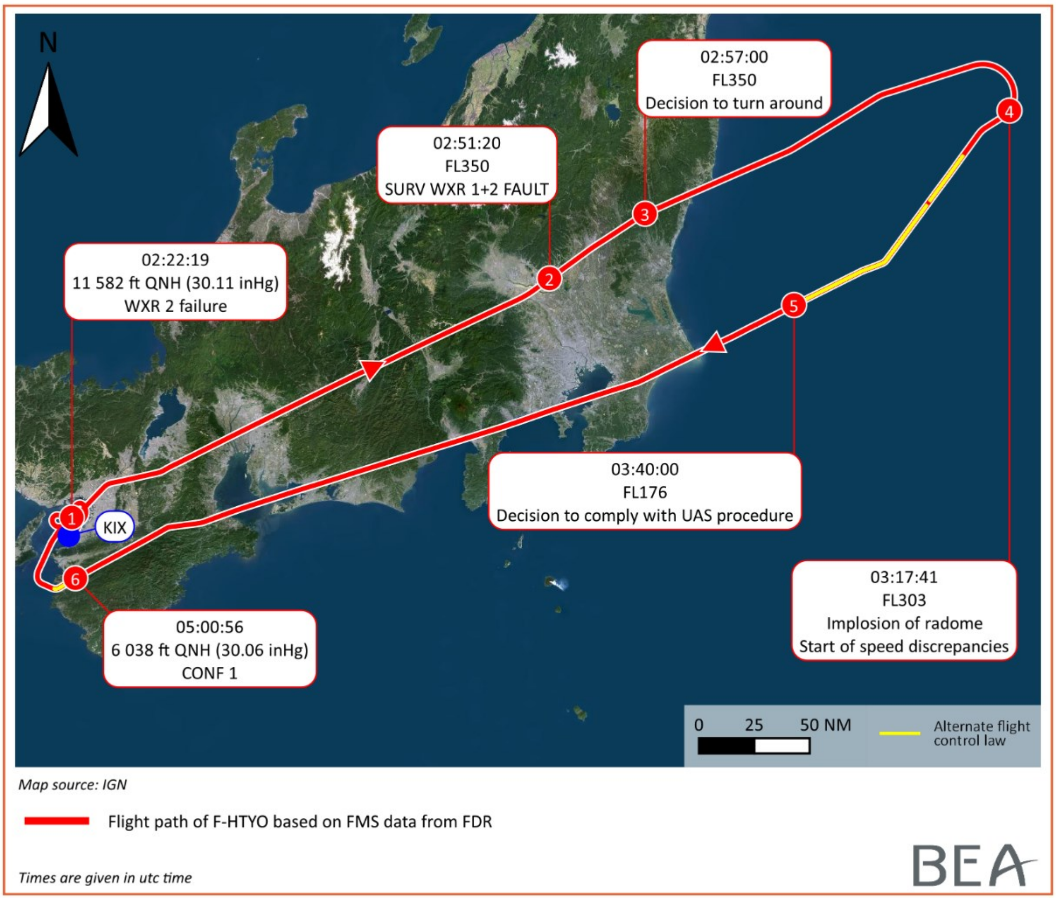


Figure 2: complete flight path

At 05:01, the aeroplane was stable at 6,000 ft at 224 kt. The crew selected CONF 1 (see **Figure 2** and **Figure 3**, point 6), the leading edge slats were deployed. They reported that the situation had not changed and selected a speed of 200 kt.

At 05:02, the aeroplane's flight control law switched to ALTERNATE law for 1 min 45 sec before reverting to NORMAL law.

When the aeroplane reached a speed of 203 kt, the flaps extended and the crew observed sudden drops and marked differences between the speeds displayed on the PFD (see **Figure 3**, point 7). Surprised by this situation, they indicated that they had just lost the radome and that the suddenness of the variations was completely abnormal. The crew set the AIR DATA selector to "F/O on BKUP SPD", disconnected the A/THR, AP and FD, and decided to remain in manual mode until landing (point 8).

From that moment, the PF flew the aeroplane using the HUD and co-pilot C checked the consistency of the displays with the pitch/thrust table available in the performance section of the FCOM. The crew noted that the "APPROACH ON A SLOPE OF MINUS 3 DEGREES" table stopped at 210 t and had to extrapolate the values for the planned weight of 248 t for the landing. The crew were then cleared by the controller to descend to 5,000 ft and selected CONF 2 (point 9).

At 05:06, the crew reported that they had returned to a situation that seemed to be stable. The PF stated that he was flying the aeroplane with the HUD and left the PM to monitor the engine N1 values as the crew were aware that the N1 value needed to be at least equal to 40% for the BKUP SPD to be reliable.

Still on a long downwind leg, the crew continued their descent, stabilised the altitude at 4,000 ft and selected CONF 3 (point 10). They continued the descent, turned right, extended the landing gear (point 11) at 2,000 ft, intercepted the ILS *localizer* and *glide* for runway 24R, then selected CONF FULL (point 12). At 05:24, the crew landed on runway 24R (point 13).

The observations made on the radome found that it was still in place, complete, and substantially damaged (see **Figure 4**).

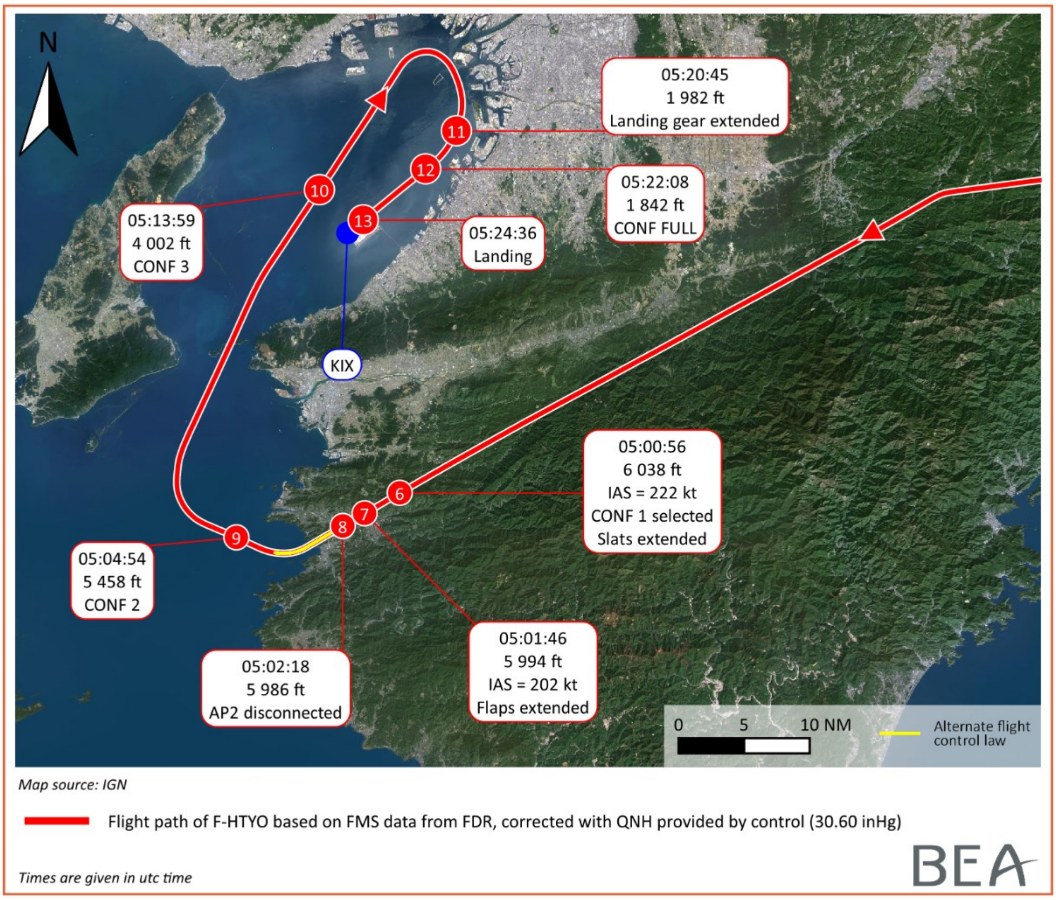


Figure 3: flight path - arrival

Figure 4: damage to the radome (Source: Air France)

1.2 Persons on board

	Injuries		
	Fatal	Serious	Minor/None
Crew members	-	-	14
Passengers	-	-	309

1.3 Damage to aircraft

The radome and the weather radar were damaged (see paragraph 1.16).

1.4 Other damage

Not applicable.

1.5 Flight crew information

1.5.1 Captain

Male, aged 60, French nationality.

Licence, rating, training and checks

ATPL(A) licence issued on 24 February 2005.
First Type Rating on A330 obtained on 12 March 2022.
First Type Rating on A350 obtained on 12 March 2023.
TR on A350 valid until 31 March 2024.

Class 1 medical fitness certificate valid until 23 July 2023.

Experience

Total experience: 14,099 flight hours including 5,411 hours as captain.
On A350: 98 flight hours, all of which as captain.
In the previous three months: 50 hours.

Professional experience

Military training, fighter pilot, had flown in particular on the Mirage 2000, and joined Air France on 22 May 2001.
Employed as co-pilot on the A320 from 2001 to 2010 then on the Boeing 777 from 2010 to 2017.
Employed as captain on the A320 from 2017 to 2022, then on the A330 since 11 May 2022 and on the A350 since 13 March 2023. The captain held ratings for both the A330 and the A350.

1.5.2 Co-pilot PF outbound (co-pilot A)

Male, aged 55, French nationality.

Licence, rating, training and checks

ATPL(A) licence issued on 04 August 2003.
First Type Rating on A330 obtained on 27 March 2015.
First Type Rating on A350 obtained on 03 December 2019.
TR on A350 valid until 30 April 2024.
Class 1 medical fitness certificate valid until 22 February 2024.

Experience

Total experience: 13,519 flight hours including 3,380 hours as captain.
On A350: 1,226 flight hours as co-pilot.
In the previous three months: 143 hours.

Professional experience

Military training, fighter pilot, had flown in particular on the Mirage 2000, and joined Air France on 13 February 2008.
Employed as co-pilot on the A320 from 2008 to 2015, on the A340 from 2016 to 2019, on the A330 since 2015 and on the A350 since 04 December 2019. The co-pilot held ratings for both the A330 and the A350 on the date of the occurrence.

1.5.3 Co-pilot PF inbound (co-pilot B)

Male, aged 55, French nationality.

Licence, rating, training and checks

ATPL(A) licence issued on 06 February 2015.
First Type Rating on A330 obtained on 01 May 2017.
First Type Rating on A350 obtained on 04 August 2020.
TR on A350 valid until 31 August 2023.
Class 1 medical fitness certificate valid until 28 February 2024.

Experience

Total experience: 10,066 flight hours including 2,599 hours as captain.
On A350: 1,231 flight hours as co-pilot.
In the previous three months: 193 hours.

Professional experience

Military training, fighter pilot, had flown in particular on the Mirage 2000, and joined Air France on 31 January 2009.
Employed as co-pilot on the A320 from 2009 to 2017, on the A340 from 2017 to 2020, on the A330 from 2018 and on the A350 since 05 August 2020. The co-pilot held ratings for both the A330 and the A350 on the date of the occurrence.

1.5.4 Relief co-pilot (co-pilot C)

Male, aged 54, Belgian nationality.

Licence, rating, training and checks

ATPL(A) licence issued on 17 May 2004.
First Type Rating on A350 obtained on 14 February 2020.
TR on A350 valid until 30 April 2024.
TRI on A330/A350 restricted FSTD valid until 30 June 2025.
Class 1 medical fitness certificate valid until 15 October 2023.

Experience

Total experience: 14,549 flight hours, 3,450 hours of which as captain.
On A350: 1,087 flight hours as co-pilot.
In the previous three months: 141 hours.

Professional experience

Airline pilot training at Sabena followed by captain training, line trainer at Ryanair on the B737, joined Air France on 04 October 2008.
Employed as co-pilot on the A320 from 2008 to 2017, on the A340 from 2018 to 2020, on the A330 since 2017 and on the A350 since 15 February 2020. The co-pilot held ratings for both the A330 and the A350 on the date of the occurrence.

1.6 Aircraft information

1.6.1 Airframe

Manufacturer	AIRBUS
Type	A350 – 900
Serial number (MSN)	546
Registration	F-HTYO
Entry into service	17 March 2022

1.6.2 Logbook / CRM

See paragraph 1.16.

1.6.3 Weight and balance

The maximum landing weight of the A350 is 207 t. When the radar faults occurred, the aeroplane weighed around 260 t, and during the landing, around 248 t. F-HTYO does not have the in-flight fuel jettison option.

In exceptional circumstances (return to the departure airport or diversion), landing over the maximum weight is permitted where the crew apply the **MISC OVERWEIGHT LDG** procedure (see Appendix I – "Procedures").

1.6.4 Equipment and/or systems

1.6.4.1 Description of the radome

The radome (for radar dome) is an aerodynamic fairing[8] that contains the weather radar antenna (WXR antenna) and the MMR (Multi-Mode Receiver) antennae. It protects these antennae from damage from air flow, rain, hail, lightning or bird strikes. The radome has radio transparency in terms of signals emitted and received by the different antennae.

The Airbus A350 radome (see **Figure 5**) has a sandwich structure comprising composite glass fibre and honeycomb material. It is divided into three different areas of differing properties and characteristics: the mechanical area (MECA), the radio area (RE) and the nose area (CAP). The periphery of the radome is a monolithic structure (glass fibre composite only, no honeycomb), with eight locking latches positioned around it.

Five lightning rods are attached to the inner skin of the radome with lightning pins and studs. The upper tip of the lightning rod is connected to a lightning rod strip that ensures electrical continuity with the aircraft structure. The electrical discharge current passes through these lightning rods to the aircraft's fuselage.

Two drainage tubes allow water collected in the two upper locking latches to evacuate.

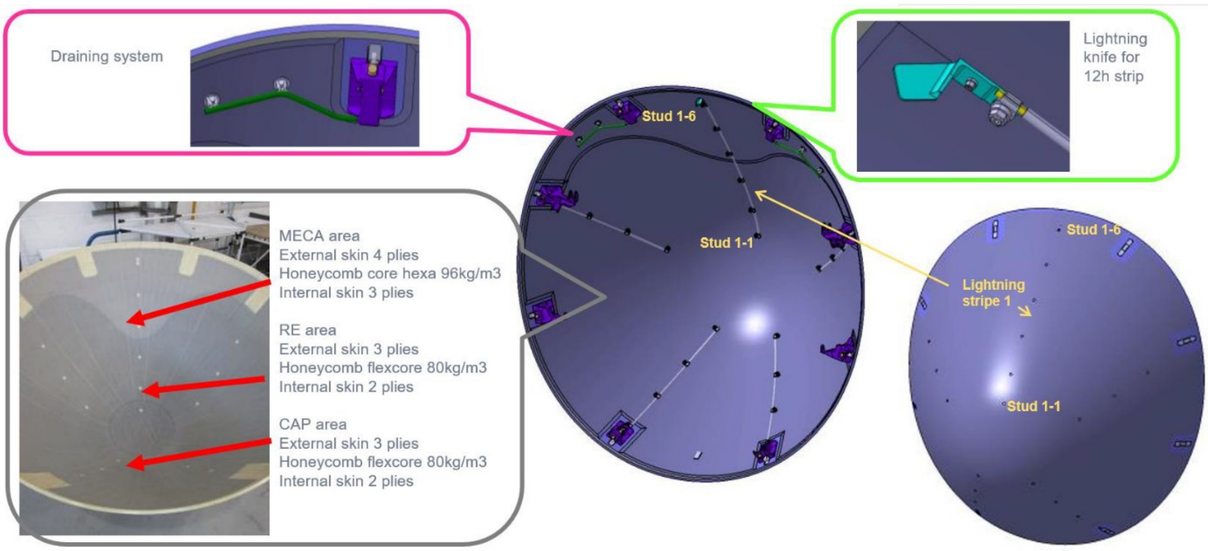


Figure 5: description of the radome (Source: Airbus)

[8] The radome dimensions are as follows: length: 1.795 m, width: 0.93 m, height: 1.960 m.

Different protection layers are applied to the radome:

- to the inner surface, a sealing varnish;
- to the outer surface:
    - a primer coat,
    - antistatic paint,
    - anti-erosion paint,
    - a final coat of paint in line with the livery paint reference.

The thicknesses are chosen to ensure compatibility with the radome's radio performance. All metallic parts are electrically grounded to the aeroplane and ensure electrical continuity with the aeroplane's fuselage.

1.6.4.2 Description of the weather radar antenna

The Airbus A350 is equipped with an AESS (Aircraft Environment Surveillance System). The role of this system is to alert the crew when it detects any hazardous conditions, notably atmospheric disturbance (clouds, storms, etc.) and areas of turbulence.

To perform its functions, the AESS comprises the following components:

- two Aircraft Environment Surveillance Units (AESU 1 and AESU 2);
- two Radar Transceiver Units (RTU 1 and RTU 2);
- a Weather Radar antenna (WXR, see **Figure 6**);
- a WXR antenna drive-unit;
- an AESS control panel;
- four S/TCAS mode antennae.

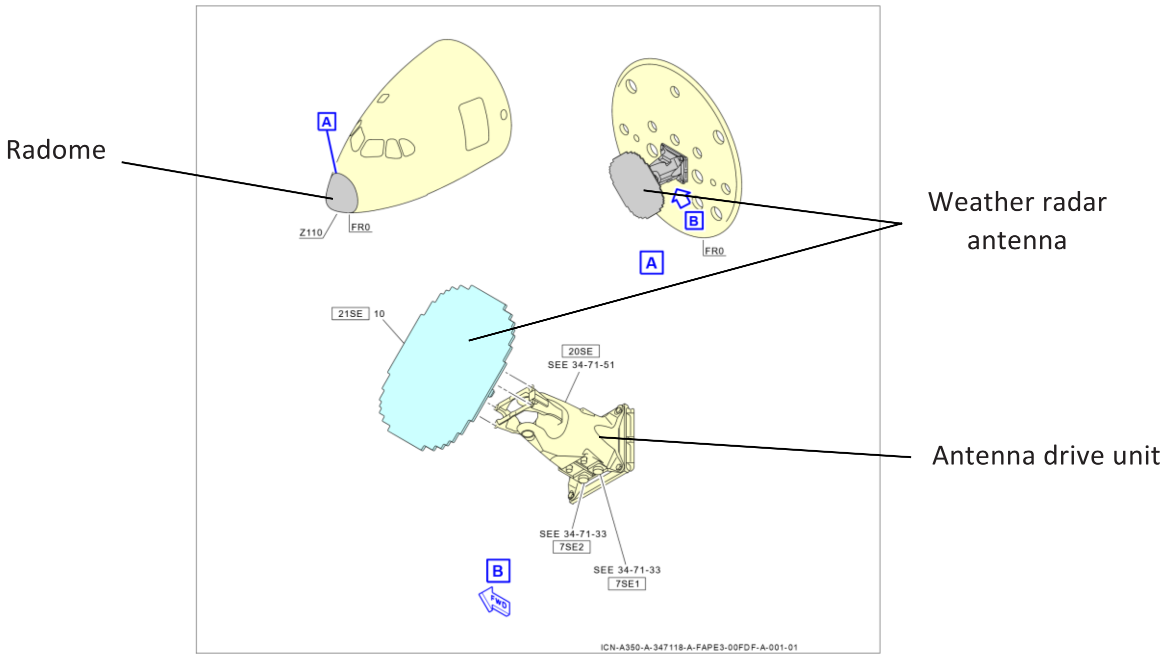


Figure ICN-A350-A-347118-A-FAPE3-00FDF-A-001-01 (SHEET 1) - ANTENNA INSTL-WEATHER RADAR ON A/C MSN ALL

Figure 6: diagram of weather antenna
(Source: Airbus Line Maintenance Procedures for the A350)

The radar antenna drive-unit (see **Figure 6**) mechanically moves the antenna plate to the commanded tilt and azimuth positions. The signals captured by the radar plate are then sent to AESU 1 (or 2) and RTU 1 (or 2), which calculate and send weather data to the DU (Display Units) and the CDS (Control and Display Systems) to display visual alerts to the crew.

In the cockpit, the WXR function uses audio and visual alerts to warn the crew when it detects hazardous weather disturbances and areas of turbulence. The crew can select either AESU 1 or AESU 2 providing the surveillance function using the WXR SYS 1(2) buttons located on the surveillance panel (SURV Panel, **Figure 7**). Therefore, if the SYS 1 (or SYS 2) button is active, surveillance system 1 (or 2) will provide the WXR function and will send data to DU 1 and DU 2 that may be configured differently.

Figure 7: WXR SYS 1(2) buttons on the SURV Panel

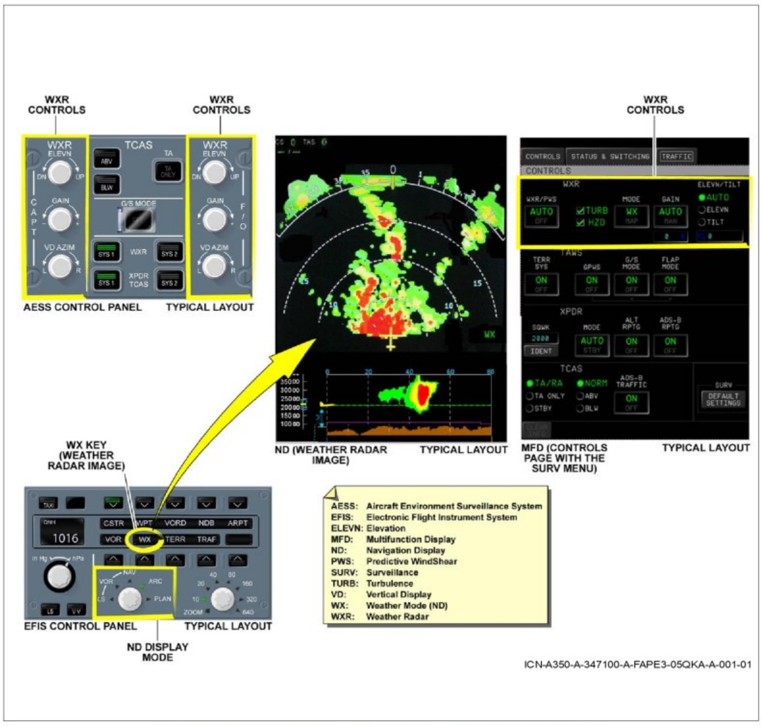


Figure ICN-A350-A-347100-A-FAPE3-05QKA-A-001-01 (SHEET 1) - AESS - WXR/PWS Function
ON A/C MSN ALL

Figure 8: WXR data displays in the cockpit
(Source: Airbus Line Maintenance Procedures for the A350)

SURV WXR 1(2) FAULT, SURV WXR 1+2 FAULT, SURV TOTAL LOSS OF WXR fault

These fault messages are displayed on the ECAM and associated with an audio alert (single chime) as well as the activation of the Master Caution light. If only one of the two systems (SURV WXR 1(2) FAULT) has a fault, the procedure asks the crew to switch to the other system.

If both systems have a fault (SURV WXR 1 +2 FAULT), the procedure requires the crew to check whether one of the functions (TURB or PWS) is still operational and to switch to the system which has been identified as having a valid functionality. If none of the functions is available on either system, the procedure asks the crew to apply the SURV TOTAL LOSS OF WXR procedure (see Appendix I). Depending on the weather conditions and the flight time to destination, the crew may be forced to abort the scheduled flight and land at a suitable airport.

1.6.4.3 New Air and Inertia Automatic Data Switching (NAIADS) system

The Airbus A350 is equipped with a NAIADS (New Air and Inertia Automatic Data Switching) system. This system is designed to:

- automatically supply optimum airspeed data to the PFD and to the flight control laws;
- supply the backup speed and altitude (BKUP), independently of the ADR and the Pitot technology;
- keep the autopilot and flight envelope protection available in the event of the nullity of different air data.

The surveillance consists in comparing each source (among the three ADRs, the ISIS and the BKUP) to a reference value calculated from sources deemed to be valid, and to invalidate the sources presenting a deviation. A rejected source can be reused if it is deemed to be normal again by the PRIM (Primary Flight Control and Guidance Computers), both for display and for flight control law calculations[9]. The speed discrepancy thresholds used for this comparison vary depending on the context.

The three ADR sources come from the ADIRS (Air Data and Inertial Reference System) (**Figure 9**). This system comprises three identical and independent ADIRU (Air Data and Inertial Reference Unit) that supply flight data to the aeroplane's different systems.

Each ADIRU comprises an ADR and an IR (Air Data Reference and Inertial Reference). Both of these sources respectively supply air data and inertial data.

Each ADR is connected to:

- an MFP (Multi Function Probe) supplying the angle of attack, the total temperature and the speed;
- two static probes, located on either side of the fuselage, supplying the local static pressure;
- one OAT (Outside Air Temperature) probe supplying the static temperature.

A fifth AOA probe is used to improve the surveillance of the other probes and notably enhances availability of the flight control laws.

[9] See paragraph 1.6.5.2.1

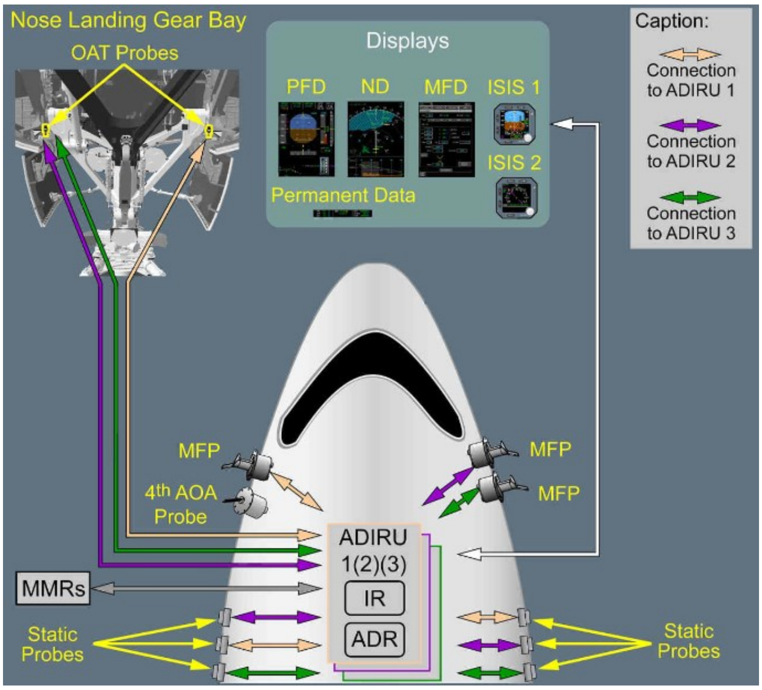


Figure 9: architecture of the ADIRS
(Source: FCOM, DSC-34-NAV-20-10-20, ADIRS-SYSTEM DESCRIPTION-ARCHITECTURE)

The "standby" instruments are composed of two ISIS (Integrated Standby Instrument Systems). One of these is used for the SFD (Standby Flight Display) and the other is used for the SND (Standby Navigation Display).

The two ISIS are connected to three probes, independent of the ADIRS probes: one "standby" Pitot probe and two "standby" static probes (see **Figure 10**).

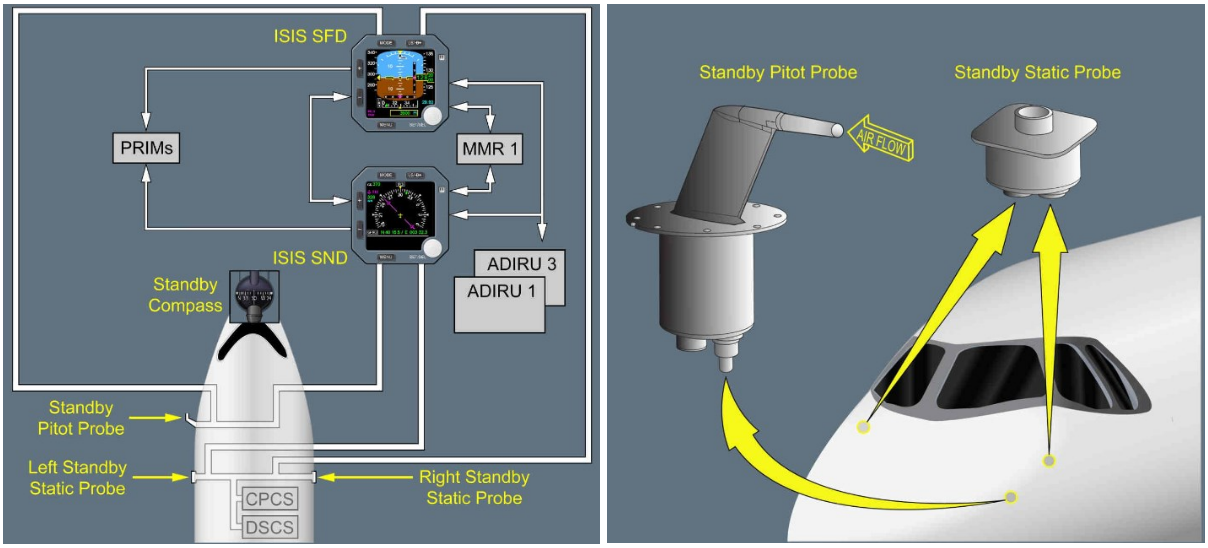


Figure 10: architecture of the "standby" instruments and position of the ISIS probes
(Source: FCOM, DSC-34-NAV-30-20, STANDBY INSTRUMENTS-ARCHITECTURE)

Lastly, the BKUP source is generated, independently of the Pitot technology, using angle of attack and weight data, or static pressure probes located in the engines.

The reconfiguration of the display of the data from these five sources is automatic (see **Figure 11**).

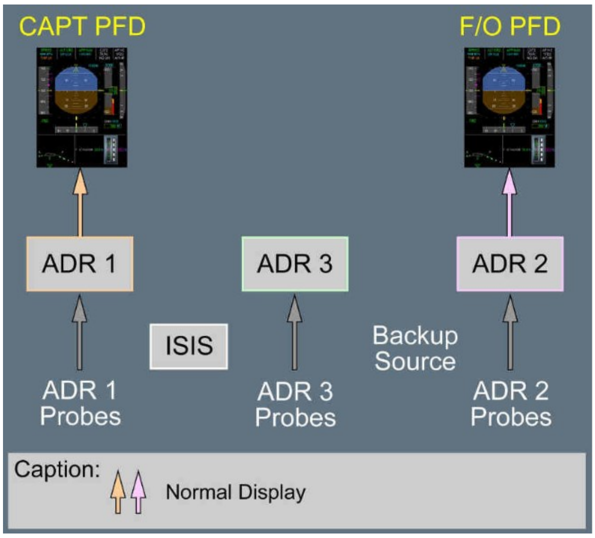


Figure 11: automatic reconfiguration of the display of speed and altitude data (Source: FCOM, DSC-34-NAV-20-10-30, ADIRS-SYSTEM DESCRIPTION-ADR)

While at least three sources are available and validated, normal law is available. When only two sources are available and validated, the flight control law switches to ALTERNATE[10]. Protection remains available, but may be less effective than in NORMAL law depending on the faults that occur. Protection is nevertheless indicated as lost on the PFD (e.g. amber cross). The AP and A/THR are available.

When the three ADR sources and the ISIS are lost and only the BKUP is available, the flight control law switches to direct law. The protections, AP and A/THR are lost. The BKUP speed is then automatically displayed on the two PFD and is calculated by the PRIM based on different data depending on the Mach number:

- angle of attack and weight data (“BKUP AOA”) at low Mach number;
- static pressure data from the engines (“BKUP engine”) at high Mach number.

In Table 1, the green boxes indicate a source that is available and validated by PRIM surveillance. The red boxes indicate a source that is unavailable and rejected by PRIM surveillance.

[10] This case is not listed in the faults leading to a reconfiguration of the flight control law in section DSC-27-10-40 of the A350 FCOM.

Only some combination examples are shown.

Source					PFD display		F/CTL law	AP A/THR Protections
ADR 1	ADR 2	ADR 3	ISIS	BKUP (PRIM)	Captain	Co-pilot		
					IAS1	IAS2	NORMAL	Available
					IAS3	IAS2		
					IAS1	IAS3		
					IAS3	IAS3		
					IAS1	IAS1		
					IAS1	IAS1	ALTERNATE	
					ISIS CAS	ISIS CAS		
					BKUP SPD	BKUP SPD	DIRECT	Unavailable

Table 1 : source automatic selection logic, flight law and automatic systems availability (examples of combinations)

When the crew detect that an air data indication is no longer reliable or consider the automatic system to be faulty, they can manually reconfigure the data display. The NAV UNRELIABLE AIR SPEED INDICATION procedure is then carried out and the AIR DATA selector can used for the manual reconfiguration (see **Figure 12**).

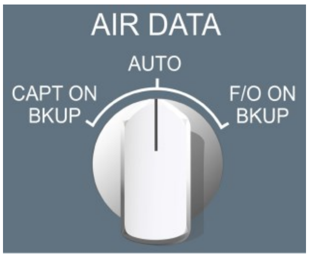


Figure 12: AIR DATA selector positions

When the AIR DATA selector is set to CAPT ON BKUP (or F/O ON BKUP) by the crew, the system displays on the captain's PFD (or F/O), the "BKUP engine" speed if at least one ADR is active and whatever the Mach number. "BKUP engine" reliability is assured by an N1 engine speed greater than or equal to 40%.

If the three ADRs are switched off, the BKUP SPD calculation logic described above ("BKUP AOA"' or "BKUP engine" depending on the Mach number) will be monitored and the displayed speed will then be more reliable. Thus, in the event of an Unreliable Air Speed (UAS) indication, and if the crew chose to manually switch to BKUP SPD, the procedure asks for the three ADRs to be switched off in order to ensure reliability of the BKUP.

It is worth mentioning that the AIR DATA selector only controls displayed data. It does not control data used by the AP and the FD. It has no impact on the flight control law or the parameters used for automatic guidance.

Thus, if the AIR DATA selector is set to CAPT ON BKUP (or F/O ON BKUP) and AP 1 (or AP 2) is activated, the air data displayed on the captain's PFD (or F/O) is not necessarily the same as that used by the engaged AP. Moreover, if both FD are engaged, FD 1 (or FD 2) does not display data and the message "-FD2 (or 1FD-)" appears on the FMA.

The crew are alerted to this situation by the NAV CAPT PFD ON BKUP (or NAV F/O PFD ON BKUP) alert for which the procedure states not to use the engaged AP.

1.6.5 Limitations Operational documentation (FCOM and FCTM)

1.6.5.1 Foreword[11]

AIRBUS "GOLDEN RULES"

The AIRBUS "Golden Rules" indicate that when the situation does not unfold as planned, the pilot must take over the controls in accordance with the following four recommendations:

Figure 13: "Golden Rules" (Source: Airbus)

When an abnormal situation is detected by the crew, their priority is to hold a safe path before performing any "READ & DO" action.

When the crew apply a "READ & DO", ECAM, QRH or OEB[12] procedure, they must:

- read and apply the ECAM/QRH/OEB[13] actions;
- adhere to the distribution of specified tasks;
- carefully monitor the parameters and displays associated with the abnormal situation.

In the event of an abnormal or emergency situation, different types of procedure are available:

- some situations require the application of an OEB procedure;
- procedures detected by the ECAM - ECAM Sensed procedures - are automatically triggered when an abnormal performance of the systems monitored by the FWC[14] is detected;
- procedures not detected by the ECAM - ECAM Not-Sensed procedures - can be manually activated by the crew in response to an abnormal event detected by the crew;
- not-sensed QRH procedures are applied by the crew in response to an abnormal event detected by the crew.

The aforementioned procedures are "READ & DO" type procedures. The PM reads and performs the actions specified in the adapted ECAM/QRH/OEB procedure. Nevertheless, in some cases, the crew do not have time to refer to the ECAM/QRH/FCOM procedures to hold a safe path.

As such, the crew must know and strictly perform "MEMORY ITEMS".

---

[11] Source: FCTM A350, "Airbus Operational Philosophy/Management of Abnormal Operations".

[12] OEB: Operations Engineering Bulletin. These are temporary procedures published for flight crews. An OEB is applicable until a permanent corrective solution is implemented.

[13] The crew can decide to read in full a procedure before applying it. In this case, it is stated that the procedure is read, applied and executed in strict sequence.

[14] Flight Warning Computer.

In the event of an abnormal or emergency situation, the crew must apply procedures in the following order:

- MEMORY ITEMS;
- OEB;
- Sensed ECAM;
- Not- Sensed ECAM;
- QRH.

The procedures applied by the crew are available in Appendix I - FCOM procedures:

- total loss of WXR;
- unreliable air speed indication MEMO ITEM;
- unreliable air speed indication Not-sensed procedure;
- handling of the aircraft in the case of severe damage;
- overweight landing.

1.6.5.2 Information on the New Air and Inertia Automatic Data Switching (NAIADS) system

1.6.5.2.1 AIRBUS FCOM (used by Air France)

Three information levels L1, L2 and L3 are available in the FCOM. When the pilot selects level L1, only the most important information is visible. When he selects levels L2 or L3, more detailed information is visible with hyperlinks, if applicable, to other parts of the FCOM.

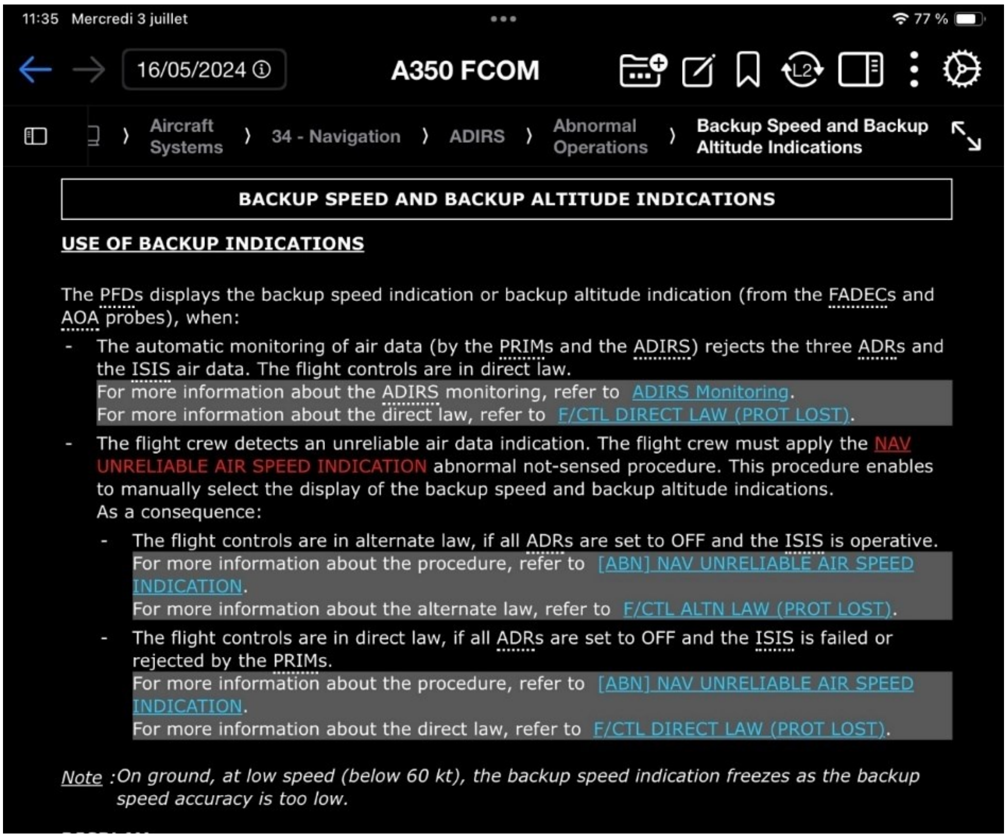
The information relating to the air data and inertia systems can be found in the "Aircraft systems/34 Navigation/ADIRS/system description/ADR" part.

In this part, the "*ADR AIR DATA SOURCE AND DISPLAY RECONFIGURATION*" section provides basic information such as "*For airspeed and altitude, the CDS can also use a backup source of air data based on AOA probes and engine parameters.*"

For example, it is indicated:

- "for more information about the backup airspeed and altitude indications, refer to Backup speed and Backup Altitude indications";
- "for more information about the ADIRS monitoring that enables the automatic reconfiguration, refer to ADIRS Monitoring";
- "for more information about the Backup manual reconfiguration, refer to Backup Speed and Backup Altitude Indications".

Moreover, the FCOM "*Aircraft Systems/34 NAVIGATION: ADIRS/ABNORMAL OPERATIONS*" part provides information about the use of Backup indications. In the *"BACKUP SPEED AND BACK UP ALTITUDE INDICATIONS"* section, the references in blue only appear for levels L2 and L3.



BACKUP SPEED AND BACKUP ALTITUDE INDICATIONS

USE OF BACKUP INDICATIONS

The PFDs displays the backup speed indication or backup altitude indication (from the FADECs and AOA probes), when:

- The automatic monitoring of air data (by the PRIMs and the ADIRS) rejects the three ADRs and the ISIS air data. The flight controls are in direct law.
  For more information about the ADIRS monitoring, refer to ADIRS Monitoring.
  For more information about the direct law, refer to F/CTL DIRECT LAW (PROT LOST).
- The flight crew detects an unreliable air data indication. The flight crew must apply the NAV UNRELIABLE AIR SPEED INDICATION abnormal not-sensed procedure. This procedure enables to manually select the display of the backup speed and backup altitude indications.
  As a consequence:
  - The flight controls are in alternate law, if all ADRs are set to OFF and the ISIS is operative.
    For more information about the procedure, refer to [ABN] NAV UNRELIABLE AIR SPEED INDICATION.
    For more information about the alternate law, refer to F/CTL ALTN LAW (PROT LOST).
  - The flight controls are in direct law, if all ADRs are set to OFF and the ISIS is failed or rejected by the PRIMs.
    For more information about the procedure, refer to [ABN] NAV UNRELIABLE AIR SPEED INDICATION.
    For more information about the direct law, refer to F/CTL DIRECT LAW (PROT LOST).

Note :On ground, at low speed (below 60 kt), the backup speed indication freezes as the backup speed accuracy is too low.

Figure 14: excerpts from AIRBUS A350 FCOM

The "ADIRS MONITORING" section shows all the ECAM messages that can be generated in the event of an anomaly detected by the ADIRU, the PRIM and the FADEC.

L1 - The PRIM s

L2 If the PRIM s reject one or more sources of air data or inertial reference data, the ECAM triggers:

- One or more of the following alerts:
  - AUTO FLT A/THR OFF (*Refer to procedure*)
  - AUTO FLT AP OFF (*Refer to procedure*)
  - F/CTL DIRECT LAW (PROT LOST) (*Refer to procedure*)
  - NAV AIR DATA REDUNDANCY LOST (*Refer to procedure*)
  - NAV AOA DISAGREE (*Refer to procedure*)
  - NAV ISIS ALT(ATT)(SPD) UNRELIABLE (*Refer to procedure*)
  - NAV ISIS ALT(SPD) RECOVERED (*Refer to procedure*)
  - SURV REACTIVE W/S DET FAULT (*Refer to procedure*).

L3
- One or more of the following dispatch messages:
  - NAV ADR 1(2)(3) REJECTED BY PRIMs (*Refer to MEL/ME-DM-NAV NAV ADR 1(2)(3) REJECTED BY PRIMs*)
  - NAV AOA 4 PROBE (*Refer to MEL/ME-DM-NAV NAV AOA 4 PROBE*)
  - NAV IR 1(2)(3) REJECTED BY PRIMs (*Refer to MEL/ME-DM-NAV NAV IR 1(2)(3) REJECTED BY PRIMs*)
  - NAV ISIS INERT DATA REJECTED BY PRIMs (*Refer to MEL/ME-DM-NAV NAV ISIS INERT DATA REJECTED BY PRIMs*)
  - NAV ISIS AIR DATA REJECTED BY PRIMs (*Refer to MEL/ME-DM-NAV NAV ISIS AIR DATA REJECTED BY PRIMs*)

L1 The CDS receives:
- Air data and inertial data from four sources: the ADIRS and the ISIS
- The backup air data from the backup sources: the FADEC s or the AOA Probes
- Confirmation that this data is accurate from the PRIM s.

When a source is rejected or inoperative, the CDS automatically reconfigures the PFD display. It reconfigures as below:
- In the case of failure that affects up to three air data and inertial data sources, the PFD display uses the remaining sources
- In the case of failure of all air data sources, the PFD display uses the backup air data source.

L2 For more information about the backup speed and altitude indications, *Refer to DSC-34-NAV-20-30 Backup Speed and Backup Altitude Indications*.

It also specifies:

L1 The PRIM s send information about the rejection to the CDS for display reconfiguration.

L3 The PRIM s monitor the air and inertial data: when one source diverges from the median value, above a certain threshold, the PRIMs automatically reject this source, and the PRIM s continue to operate with the remaining sources. Based on this monitoring, the CDS automatically reconfigures the data sources. It ensures the display of consistent values on both PFD s.

The PRIM s continue to monitor the rejected air data source. If the PRIM s confirm that a rejected air data source is back to normal (compared to two other valid sources), the automatic reconfiguration of the PFD display may allow to reuse this air data source.

L1 The PRIM s use the ADIRU s for the flight control laws.

L2 For the flight control laws, the PRIM s cannot reuse a rejected air or inertial data source even if this source is back to normal. In case of rejection of all ADR s or IR s, the PRIM s reconfigure the flight control law to alternate law. For more information, *Refer to DSC-27-10-40 Alternate Law*.

Figure 15: excerpts from FCOM A350 DSC-34-NAV-20-10-50, ADIRS- SYSTEM DESCRIPTION-ADIRS MONITORING (Source: Airbus)

This section specifies that a rejected source may be subsequently displayed on the PFD when it is deemed to be valid once again.

With regard to the flight control laws, this section specifies that a source that has been rejected, but has become valid again, is no longer used by the flight controls laws.

However, unlike the Airbus A330, on the Airbus A350, a rejected source *can* be reused by the flight control laws when it is deemed to be valid again. For example, if three of the five sources of air or inertia data are rejected, the flight control law switches to ALTERNATE. If one of these three sources becomes valid again, and three sources are valid, the flight control law reverts to NORMAL law. This indication of flight control law irreversibility in the FCOM was incorrect.

The part of the A350 FCOM, "*DSC-27-10-40 Aircraft Systems-Flight controls system-Reconfiguration control laws*", mentions switching to ALTERNATE law if ADR 1, 2 and 3 are rejected. This table only lists straight faults or losses of computers or equipment. Therefore, the case encountered in the occurrence involving F-HTYO (switching to ALTERNATE mode when the two available sources are an ADR and ISIS or BKUP) is not shown.

The FCOM ADIRS MONITORING paragraph also mentions the impact on the level of the flight command law in the event that all ADR or IR are rejected, but does not cite the case encountered during the occurrence.

AIRFRANCE A350 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS 27 - FLIGHT CONTROLS FLIGHT CONTROL SYSTEM - RECONFIGURATION CONTROL LAWS

This degradation of the flight control laws is referred to as reconfiguration.

There are two reconfiguration levels:
- Alternate law (*Refer to DSC-27-10-40 Alternate Law*)
- Direct law (*Refer to DSC-27-10-40 Direct Law*).

F/CTL Law	Ops impact	Failure Leading to Reconfiguration
ALTERNATE LAW	Max Speed: Depending on the position of flaps/slats	F/CTL SLAT SYS 1+2 FAULT
		F/CTL FLAP SYS 1+2 FAULT
		F/CTL INR FLAPS FAULT
		F/CTL SLATS LOCKED
		F/CTL FLAPS LOCKED
	Max Speed: 310 kt	F/CTL L(R) INR(OUTR) AILERON FAULT (if two ailerons are failed)
		NAV RA SYS A+B+C FAULT (during the approach phase)[(1)]
		F/CTL RUDDER FAULT
		F/CTL L(R) ELEVATOR FAULT
		F/CTL PART SPLRS FAULT (if more than three pairs of roll spoilers are failed)
		F/CTL MOST SPLRS FAULT
		F/CTL STABILIZER FAULT
		NAV ADR 1+2+3 FAULT
		HYD G+Y SYS PRESS LO
		ENG ALL ENGINES FAILURE
		ELEC EMER CONFIG

Figure 16: excerpt from the A350 FCOM "DSC-27-10-40 Aircraft systems-Flight controls system-Reconfiguration control laws" (Source: Air France)

Airbus specified that it has deliberately chosen to list only straight faults or losses of computers or equipment in this table.

The impact of source rejection by the PRIM on the flight control law level is explained in the paragraph, "ADIRS MONITORING".

The FCTM explanations do not provide additional information about the NAIADS system in relation to the FCOM.

1.6.6 Location of the pitch-thrust table (Pitch N1 tables)

In the event of the deactivation of all the automatic systems or ADR, the pilot must display the pitch and thrust values available in the tables (Pitch N1 tables) that take into account the aeroplane's weight and configuration.

In the case of the incident, the crew specified that when they deactivated the automatic systems, they experienced difficulties rapidly and easily accessing these tables in the Airbus documentation. They added that they regretted that these were not directly available in the **NAV UNRELIABLE AIR SPEED INDICATION** procedure as was the case for the Airbus A330. Airbus specified that it was a deliberate decision not to make the tables directly accessible in this procedure as the design of the Airbus A350 made their use highly improbable.

The Pitch-N1 tables can be accessed in three ways:

- In the **NAV UNRELIABLE AIR SPEED INDICATION** *not sensed* procedure, for levels L2 and L3 only. Airbus states that "*If the air data is not available on any sides, refer to INTRODUCTION*." This hyperlink is a cross-reference to the introduction page for the Pitch-N1 tables "PERFORMANCE" section. The pilot must then scroll through the pages to access the table sought for depending on the flight phase.

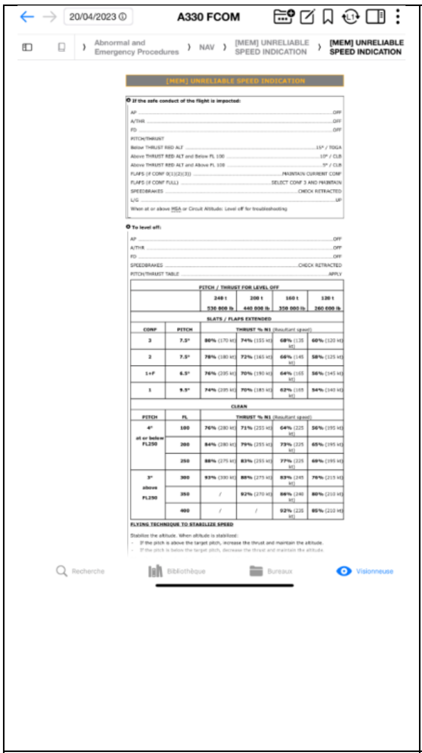
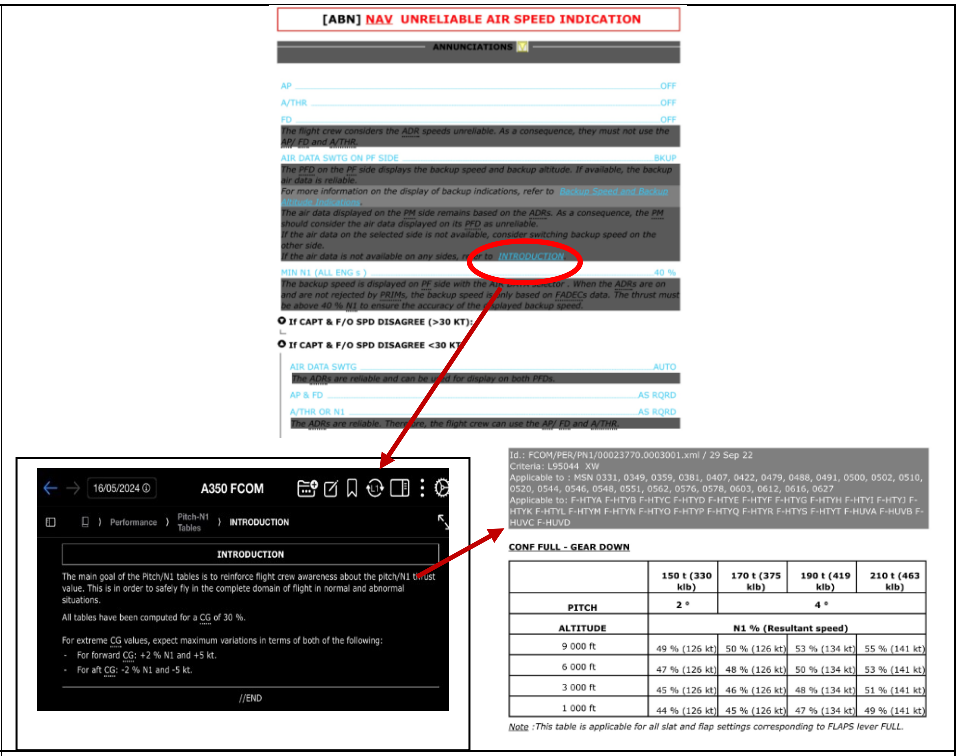
	
A330 UAS procedure	A350 UAS procedure

Figure 17: excerpts from the A330 and A350 FCOM (Source: Airbus)

- In the FCOM "PERFORMANCE" section, by clicking directly on the "PITCH/THRUST TABLES" shortcut in the EFB, in the "Quick Access" part of the OIS OPS Library. Aeroplanes delivered by Airbus have this configuration and the operator is free to modify it.

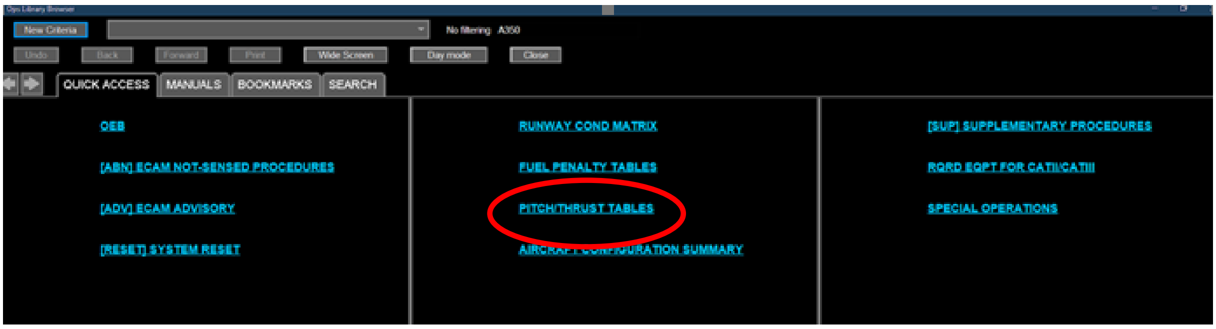


Figure 18: screenshot of the EFB as delivered by Airbus to operators

At the time of the incident, Air France reported to the BEA that their A350 EFB had been reconfigured and that the Quick Access no longer contained the shortcut to the pitch/thrust tables.

In the case of the incident, when the crew deactivated all the automatic systems and applied the pitch/thrust values, the aircraft weighed 248 t and was in FULL-GEAR DOWN configuration. The available pitch/thrust table specified no values for a weight over 210 t.

AIRFRANCE A350 FLIGHT CREW OPERATING MANUAL	PERFORMANCE PITCH-N1 TABLES

Ident.: PER-PN1-003-00023770.0003001 / 29 SEP 22

Applicable to: F-HTYA, F-HTYB, F-HTYC, F-HTYD, F-HTYE, F-HTYF, F-HTYG, F-HTYH, F-HTYI, F-HTYJ, F-HTYK, F-HTYL, F-HTYM, F-HTYN, F-HTYO, F-HTYP, F-HTYQ, F-HTYR, F-HTYS, F-HTYT, F-HUVA

CONF FULL - GEAR DOWN

	150 t (330 klb)	170 t (375 klb)	190 t (419 klb)	210 t (463 klb)
PITCH	2 °	4 °		
ALTITUDE	N1 % (Resultant speed)			
9 000 ft	49 % (126 kt)	50 % (126 kt)	53 % (134 kt)	55 % (141 kt)
6 000 ft	47 % (126 kt)	48 % (126 kt)	50 % (134 kt)	53 % (141 kt)
3 000 ft	45 % (126 kt)	46 % (126 kt)	48 % (134 kt)	51 % (141 kt)
1 000 ft	44 % (126 kt)	45 % (126 kt)	47 % (134 kt)	49 % (141 kt)

Note: *This table is applicable for all slat and flap settings corresponding to FLAPS lever FULL.*

Figure 19: excerpt from the Air France FCOM identical to the AIRBUS FCOM

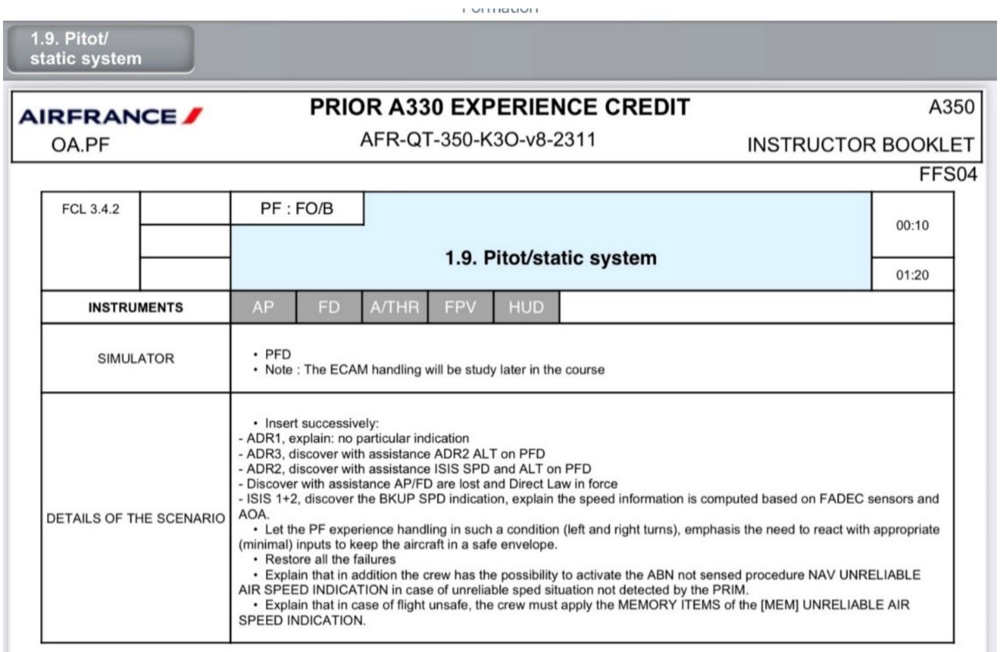
1.6.7 Pilot training

The four pilots initially held ratings for the A330 before obtaining their ratings for the A350 and had completed training in the differences between the two aeroplanes (CTR A350).

Theoretical CTR A350 training is delivered via e-learning, in particular ATA 34 (navigation), and is subject to a MCQ test.

Practical training takes place in a simulator and in line training. Six simulator sessions are scheduled.

The FFS 04 session gradually introduces the pilot to the reconfigurations according to the successive failures of the three ADRs, of the ISIS 1+2, then the switch to BKUP SPD. The failures are straight faults and the exercise is carried out in demonstration mode. The demonstration is only given once.



1.9. Pitot/ static system

AIRFRANCE OA.PF	PRIOR A330 EXPERIENCE CREDIT AFR-QT-350-K3O-v8-2311	A350 INSTRUCTOR BOOKLET

FFS04

FCL 3.4.2	PF : FO/B **1.9. Pitot/static system**	00:10 01:20
INSTRUMENTS	AP FD A/THR FPV HUD	
SIMULATOR	• PFD • Note : The ECAM handling will be study later in the course	
DETAILS OF THE SCENARIO	• Insert successively: - ADR1, explain: no particular indication - ADR3, discover with assistance ADR2 ALT on PFD - ADR2, discover with assistance ISIS SPD and ALT on PFD - Discover with assistance AP/FD are lost and Direct Law in force - ISIS 1+2, discover the BKUP SPD indication, explain the speed information is computed based on FADEC sensors and AOA. • Let the PF experience handling in such a condition (left and right turns), emphasis the need to react with appropriate (minimal) inputs to keep the aircraft in a safe envelope. • Restore all the failures • Explain that in addition the crew has the possibility to activate the ABN not sensed procedure NAV UNRELIABLE AIR SPEED INDICATION in case of unreliable sped situation not detected by the PRIM. • Explain that in case of flight unsafe, the crew must apply the MEMORY ITEMS of the [MEM] UNRELIABLE AIR SPEED INDICATION.	

Figure 20: excerpt from the CTR A350 training programme

1.7 Meteorological information

The ATIS taken at 04:33 by the crew indicated the following information: runway 24R in operation, wind from 250° of 15 kt, several cumulus clouds at 2,000 ft, temperature of 23 °C and QNH 30.05 inHg.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

Osaka-Kansai international airport has two runways 06L/24R (length 4,000 m, width 60 m) and 06R/24L (length 3,500 m, width 60 m).

1.11 Flight recorders

In accordance with the regulations in force, the aeroplane was equipped with two flight recorders (FDR and CVR). These recorders were read out at the BEA. The FDR (Flight Data Recorder) contained over 77 hours of data, including the occurrence flight (last flight recorded) and five previous complete flights. The history of the complete flights available in the FDR is given below.

- Flight N-5: 24 May 2023, CDG (09:13 UTC) - LIM[15] (20:52 UTC), duration 11 h 39 mins.
- Flight N-4: 24 May 2023, LIM (23:27 UTC) - CDG (11:30 UTC, D+1), duration 12 h 03 mins.
- Flight N-3: 25 May 2023, CDG (22:11 UTC) - SCL[16] (11:59 UTC, D+1), duration 13 h 48 mins.
- Flight N-2: 26 May 2023, SCL (16:19 UTC) - CDG (05:01 UTC, D+1), duration 12 h 42 mins.
- Flight N-1: 27 May 2023, CDG (11:47 UTC) - KIX[17] (23:59 UTC), duration 12 h 12 mins.
- EVT flight: 28 May 2023, KIX (02:15 UTC) - KIX (05:24 UTC), duration 03 h 09 mins.

The CVR (Cockpit Voice Recorder) contained over 69 hours of data, including the occurrence flight.

1.12 Wreckage and impact information

Damage was confined to the radome. Details of the examinations are given in paragraph 1.16.1.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 Examinations of F-HTYO radome after the incident

The F-HTYO radome was examined at the Airbus failure analysis laboratory in Toulouse, under the supervision of the BEA.

The ultraviolet (UV) ray examination was able to detect organic residue (bird strike) at the top left of the radome nose. The area was removed and sent to the French Natural History Museum in Paris for DNA analysis of the residue. This analysis revealed that the bird strike likely involved a falcon, without it being possible to know the date and geographical location.

[15] IATA code for Jorge-Chávez International Airport (Lima, Peru).
[16] IATA code for Arturo-Merino-Benítez International Airport (Santiago, Chile).
[17] IATA code for Kansai International Airport (Osaka, Japan).

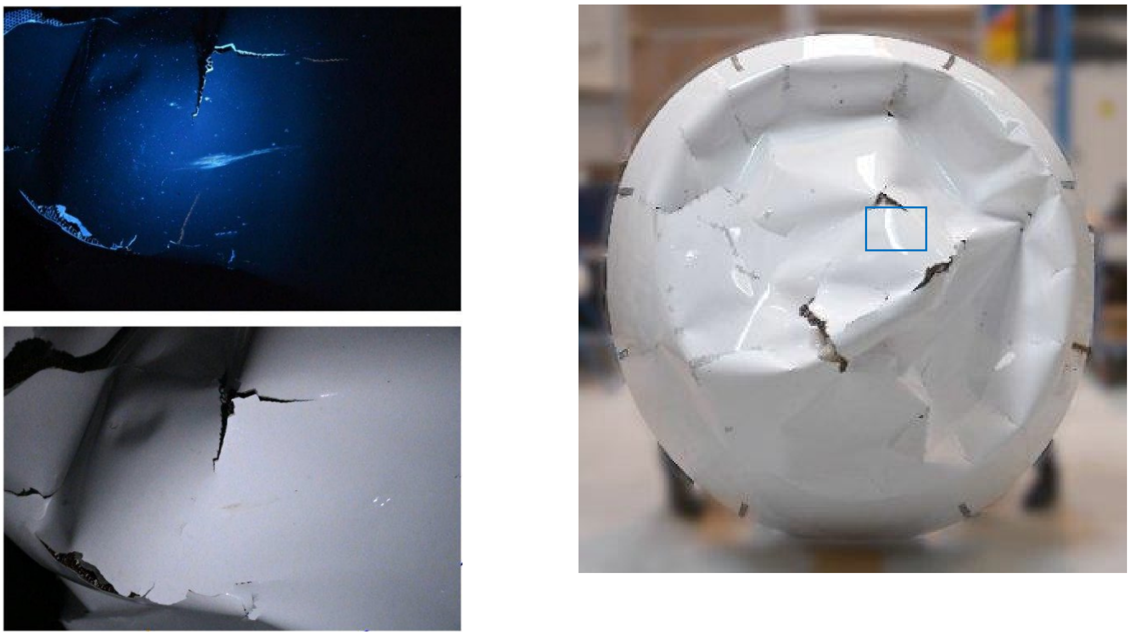


Figure 21: view of mark under UV light (top left) and in visible light (bottom left) - location on the radome (right) (Source: BEA)

The radome was destroyed by buckling. Its outer surface presented multiple cracks of which some were open and passing through the sandwich structure. The inner skin was detached from the honeycomb over approximately 80% of its surface.

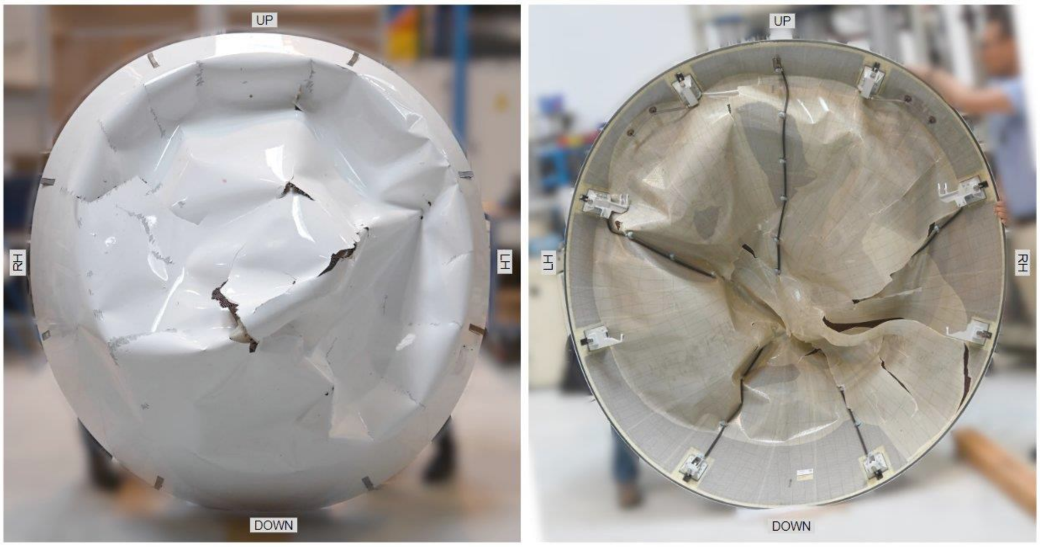


Figure 22: external view (on left) and internal view (on right) of F-HTYO radome

On the outer side, around the edge of the aforementioned organic residue, extended concentric cracks were observed in the paint. A developer powder was used to clearly highlight these.

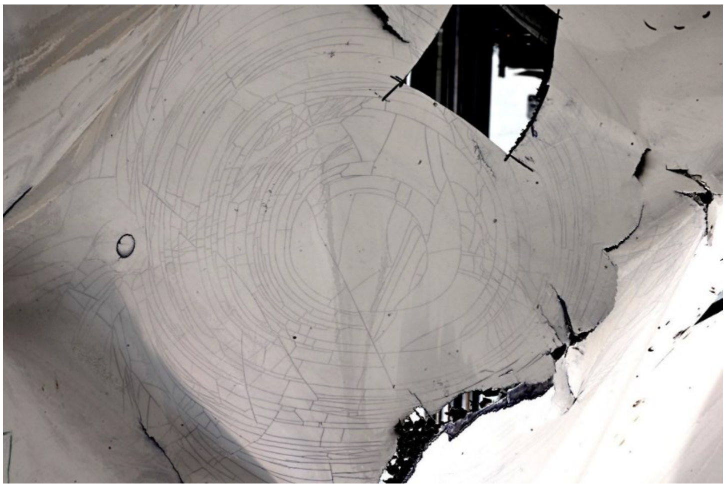


Figure 23: presence of concentric cracks in the paint (Source: BEA)

On the inner side, localised damage evidenced crushing of the honeycomb and coincided with the centre of the concentric cracks in the paint. These elements were consistent with the occurrence of an external impact in this area.

Blackish linear contact marks were observed on the inner skin of the radome. An analysis of these marks confirmed that they resulted from contact between the aluminium radar antenna and the inner skin of the radome. Nevertheless, it was not possible to establish whether these marks were made before or during the collapse of the radome.

Fractographic examinations conducted on the debonded surface of the inner skin showed that most of the peripheral area of the inner skin was detached in the radome nose towards aft edge direction.

A large middle area of the inner skin showed slightly raised resin residue. This area largely coincided with the area in which concentric cracks were observed in the paint, i.e. the suspected strike area.

No specific anomaly in the radome structure was brought to light by the various tests conducted as part of the investigation:

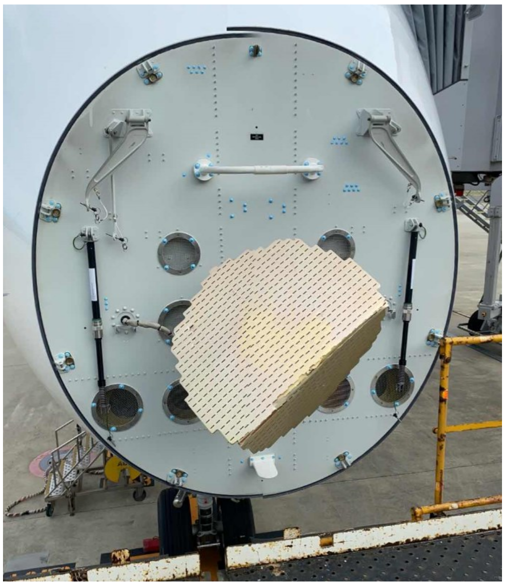
- the stripping tests conducted on the specimens sampled from the intact areas of the radome showed cohesive rupture characteristics consistent with observations made on the control specimens, evidencing the lack of an adhesion fault between the composite skins and the honeycomb;
- the morphology of the sandwich cross-section was compliant with the radome qualification specimens;
- the quality of the curing of the sandwich resin was compliant with Airbus specifications;
- the measured moisture regain on the damaged radome upon its acceptance at Airbus was at an intermediate level, below the maximum saturation level of 85% relative humidity. This was consistent with a radome that had been in service then stored in the open air before being examined.

The examination of the radome and its manufacturing monitoring documents did not bring to light any fault or deviation from Airbus specifications.

To conclude, it is very likely that the damage observed on the radome was caused by a falcon strike. It is very likely that this strike caused a debonding of the inner skin that spread radially and aftward on the radome until the latter completely collapsed. It was not possible to determine when, nor in which region of the world, the bird strike occurred.

1.16.2 Examinations of the weather radar antenna

The F-HTYO weather radar antenna was examined at the Airbus failure analysis laboratory in Toulouse, under the supervision of the BEA. It was found folded on the aeroplane, along a line running from the bottom to the upper left edge (antenna viewed from behind), oriented at approximately 30° in relation to the vertical axis.



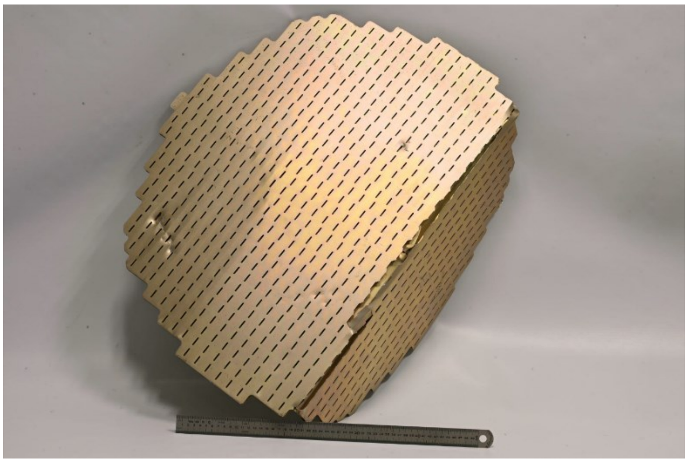


Figure 24: front face of the weather radar antenna (Source: Airbus)

The damage observed resulted from contact between the antenna and the inner side of the radome. However, it was not possible to determine with certainty whether the damage occurred before or after the radome collapsed.

1.16.3 Simulated debonding

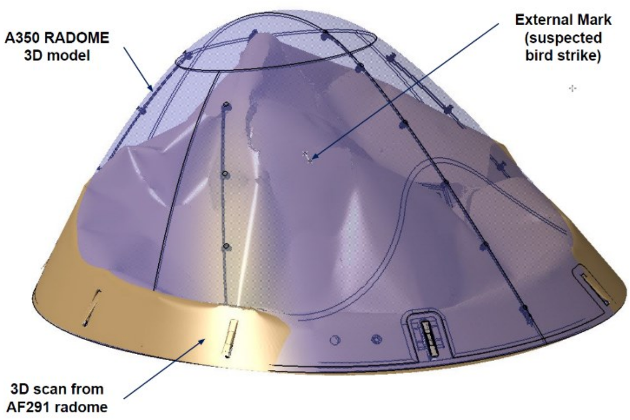
During the investigation, Airbus conducted a study to determine the minimal extent of debonding of the radome inner skin required for there to be an interaction between the latter and the weather radar antenna.

The various instances of damage observed during the examinations were located on a digital three-dimensional model. The damage was modelled as circular debonding areas, which were then projected onto the outer surface of the intact theoretical model.

Firstly, Airbus estimated that the distance between the radar antenna and the inner surface of the radome in normal condition was at least 48 mm.

Two conditions were considered: on the ground and in flight. The corresponding aerodynamic loads were applied to the radome in these two situations. In flight, it was shown that a debonding of 380 mm in diameter was required for there to be an interaction between the inner skin and the antenna. On the ground, the required debonding was 390 mm.

In both cases, the extent of the debonding was much greater than the maximum size of acceptable damage as described in the AMM, which is 250 mm in diameter. According to Airbus, a debonding of this extent is clearly visible.



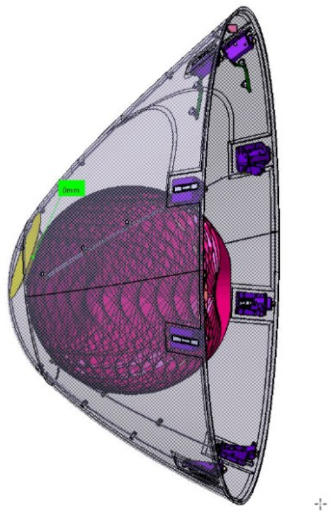


Figure 25: simulation of debonding based on observed damage (Source: Airbus)

1.16.4 Maintenance inspections of the radome

There are two radome inspection levels:

- scheduled maintenance of area, defined in the MPD (*Maintenance Planning Document*)[18]: an external inspection of the radome must be carried out every 36 months, an internal inspection must be carried out every 72 months;
- unscheduled inspections instigated by an abnormal occurrence in operation. The line maintenance documentation to be used is the "*A350 Line Maintenance Procedure*", or LMP, supplied by Airbus and used by Air France.

When an abnormal event occurs in flight, the crew must record this in the aeroplane's ATL (Aircraft Technical Log*).* This entry in the ATL triggers ground maintenance and inspection operations. According to Air France's Line Maintenance Manual, the ground technician must contact the Maintenance Coordination Centre (MCC) by telephone and then by email to provide the information reported by the crews in the ATL. The MCC technicians will then assist the ground technician by indicating the maintenance procedures to follow. These exchanges take place using the maintenance management software. Once the maintenance operations are completed, these operations are recorded in the ATL and the Air France maintenance management software. This traceability can be used to identify which maintenance task(s) from the LMP was/were applied.

The crew can also write a Pilot Report (PR). The latter is a separate way of reporting information from the ATL. For example, a PR can be written several hours after a flight. If a crew do not fill in the ATL, the aeroplane can carry out another flight without maintenance operations.

[18] Title of the maintenance task in the MPD: *A350-A-05-21-10-00001-310A-A - General Visual Inspection of the Radome Nose Cone (Internal Area)*

1.16.5 History of occurrences reported by F-HTYO crews and maintenance tasks associated with these occurrences

In the month preceding the incident flight, F-HTYO encountered a certain number of occurrences (mainly bird strikes) that may have damaged the radome. These occurrences were those reported in the ATL. Between 03 July 2022 and the incident, the aeroplane was subjected to at least five known bird strikes. In the month preceding the incident, the aeroplane experienced a bird strike and radar faults:

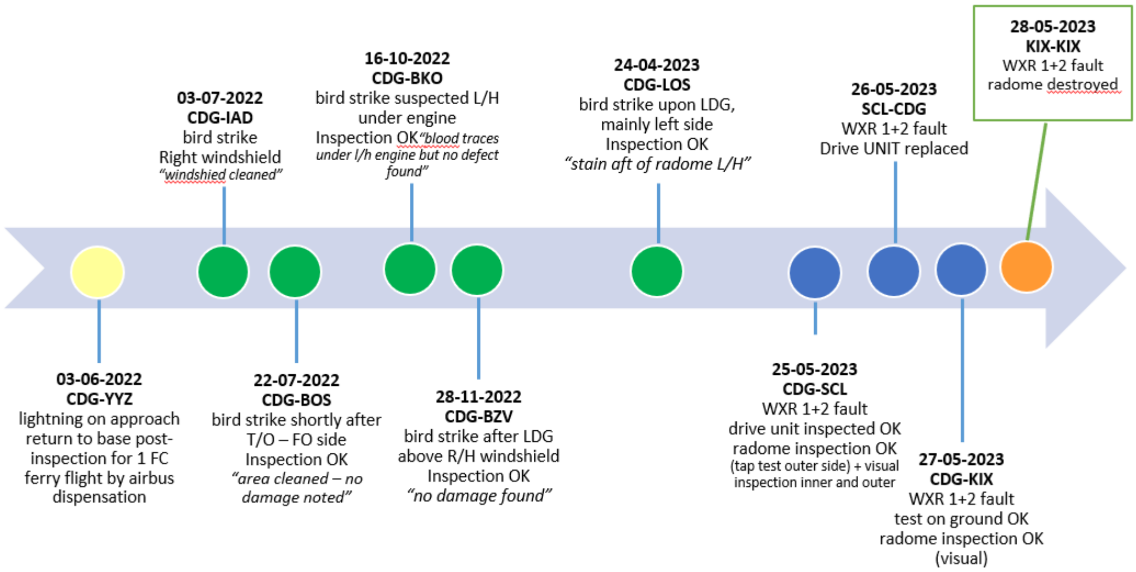


Figure 26: history of faults reported in the month preceding the incident

Bird strike on 24 April 2023

On 24 April 2023, during a flight from Paris to Lagos, a bird struck the left side of the aeroplane during landing. The ATL indicated that LMP Task "A350-A-05-51-14-00001-282A-A - Inspection of the Aircraft after a Bird Strike" was carried out.

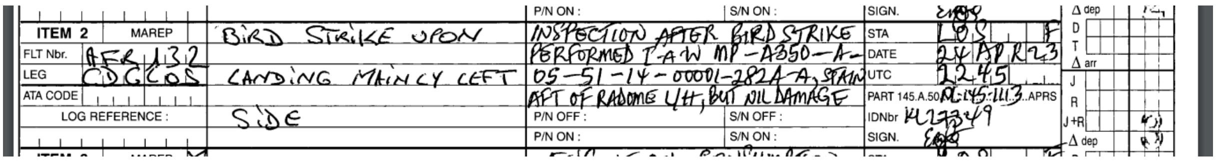


Figure 27: excerpt from the ATL of F-HTYO on 24 April 2023 following a bird strike during the Paris-Charles de Gaulle-Lagos (Nigeria) flight (Source: Air France)

This maintenance task systematically requires an external and internal visual inspection of the radome (chapters "C. General" et "F. Inspection"): *"It is mandatory to open and examine the radome. In some special conditions, the radome can have delamination without organic residue or signs of impact."*

A bird strike, wherever this occurs on the aeroplane, must be followed by an external and internal inspection of the radome. This inspection requires the use of a 6 m-high adjustable platform. The radome inspection is described as follows:

H. Inspection of the Radome

ITEM	INSP CODE	INSPECTION TASKS	PHASE1	PHASE2	INSP SIGN	REF.FIG.
A		Inspection of the radome:				
		- Externally examine the radome (skin, studs, latches, etc.) for scratches, dents, damaged paintwork and other damage. - Open the radome Ref. A350-A-53-15-73-00ZZZ-398Z-A. - Internally examine the radome for the signs of delamination and/or debonding.	X			
		If you find damage: - Do the full inspection of the radome Ref. A350-A-53-15-73-02ZZZ-398Z-A. - Examine the weather-radar antenna drive-unit and the weather-radar antenna plate for damage. - Examine the localizer antenna and the glide capture antenna. - Examine the adjacent structure (FR0) and grids for damage. - Refer to the phase 1 inspections of the NLG, the NLG bays and the NLG doors Ref. 4. R. Inspections of the NLG, the NLG Bay and the NLG Doors.		X		
B		Close the radome Ref. A350-A-53-15-73-01ZZZ-398Z-A.				

Table - INSPECTION TASKS

Figure 28: excerpt from line maintenance task “A350-A-05-51-14-00001-282A-A Inspection of the Aircraft after a Bird Strike” (Source: Air France)

If damage is observed during this visual examination, a complete inspection of the radome “A350-A-53-15-73-02001-398A-A Inspection of the radome” is required. The inspection comprises:

- External visual inspection of the radome

> (1) Do a visual inspection of the outer side of the radome:
> - Make sure that the paint is in the correct condition: no scratches, gouges, nicks, perforations or peeling
> - If the paint is damaged, make sure that the composite shell below the paint is in the correct condition: no scratches, gouges, nicks or perforations
> - Make sure that the lightning studs, the latches and the fasteners are in the correct condition: no burn spots.

- Internal visual inspection of the radome[19]

> (2) Do a visual inspection of the inner side of the radome:
> - Make sure that the draining devices are correctly attached
> - Make sure that the lightning arrestor strips are correctly attached
> - Make sure that the spheres and the lightning blade are in the correct condition
> - Make sure that the sealing varnish is in the correct condition: no scratches, gouges, nicks, perforations or peeling
> - If the sealing varnish is damaged, make sure that the composite shell below the paint is in the correct condition: no scratches, gouges, nicks or perforations.

- Tap test of the external and inner faces of the radome to identify any delamination or debonding.

The tap test is a simple non-destructive inspection method used to detect damage to composite materials by tapping the surface with a hammer or similar equipment. A damaged area will produce a muffled sound compared to an undamaged area. Although this technique has long been approved and used, it may be less reliable than other non-destructive methods (ultrasonic techniques, radiography, thermography, etc.) because it requires the technician to have a certain experience, it is the technician who determines if there is a change in sound, and it is not suitable for noisy working environments.

> (3) Do a tap test on the outer and inner sides of the radome with a TAP TEST-TOOL (98A57103013000). Make sure that there is no delamination and/or debonding. Two test procedures are available:
> - NDT inspection tap-test Ref. NDT A350-A-51-93-10-00ZZZ-35BZ-A
> - Instrumented tap test (woodpecker) Ref. NDT A350-A-51-93-10-02ZZZ-35BZ-A.

Figure 29: excerpt from line maintenance task “A350-A-53-15-73-02001-398A-A - Inspection of the Radome” (Source: Air France)

[19] Sealing varnish is a varnish that is applied to the entire inner surface to seal it.

The ATL indicates that task "*A350-A-05-51-14-00001-282A-A Inspection of the Aircraft after a Bird Strike*" was carried out and that a mark was observed behind the radome. No damage was observed. The ATL did not specify whether the inside of the radome was inspected.

Radar fault in May 2023: display on the ECAM of the SURV WXR 1(2) or 1+2 FAULT message and application of Task "A350-A-34-71-XX-3V001-421A"

If a radar system fault is displayed, the maintenance task initially requires the AESS (*Aircraft Environment Surveillance System*) test to be carried out. This test notably consists in moving the radar antenna to detect any mechanical blockage, then in identifying any fault codes saved in the CMS "AVIONICS FAULT HISTORY" memory.

ON A/C MSN ALL

TASK A350-A-34-71-XX-3V001-421A-A

"SURV TAWS FAULT", "SURV TERR SYS FAULT", "SURV TERR SYS REDUNDANCY", "SURV WXR 1+2 FAULT", "SURV PRED W/S 1+2", "SURV TCAS 1+2 FAULT", "SURV ADS-B TRAFFIC 1+2 FAULT" Alert Message (s) and/or Dispatch Message(s) Shown on the ECAM Display

1. Job Set-Up Information

A. Referenced Information.

REFERENCE	DESIGNATION
A350-A-34-71-XX-3VZZZ-429Z-A	AFI - FAULT CONFIRMATION
A350-A-34-71-XX-00ZZZ-343Z-A	MP - BITE Test of the Aircraft Environment Surveillance System (AESS) (Master AESU System-Test)

2. Fault Isolation

A. Go to the Fault Confirmation Ref. AFI A350-A-34-71-XX-3VZZZ-429Z-A.

Does one of fault codes 3471W100, 3471H101, 3471W130, 3471H131, 3471H140, 3471W300, 3471H301, 3471H302, 3471W450, 3471H451 and/or 3471W600, 3471H601 stay in view? YES (Go to Step

B.
) / NO (Go to Step
C.
)

B. Do the BITE test of the AESS (Master AESU system-test) Ref. MP A350-A-34-71-XX-00ZZZ-343Z-A.
If the test gives a fault message, do the related Fault Isolation procedure.

Go to Step
D.

C. No maintenance action is necessary.

Go to Step
D.

D. Go to the Close-up.

Go to Step
3.

3. Close-Up

A. Put the aircraft back to its initial configuration.

Figure 30: excerpt from line maintenance task "A350-A-34-71-XX-3V001-421A-A – SURV WXR 1+2 FAULT" (Source: Air France)

If none of the fault codes in the list above are identified, the maintenance task is completed and the aircraft is returned to service.

However, Airbus states that if the same fault occurs three times, additional maintenance tasks known as *Aircraft Fault Isolation* tasks must be carried out.

3.D.(3)(b)
[...] If you find three or more occurrences of the same intermittent fault symptom, although the fault is still not confirmed by the Fault Confirmation paragraph, you must do each step of the Fault Isolation paragraph until the subsequent monitoring confirms that the root cause is found and the fault is fixed. If the fault isolation step contains a fault confirmation test or requires a confirmation that the symptom is still present, consider the fault as confirmed or the fault symptom as still present and do the related corrective actions.[...]

Figure 31: excerpt from Task "A350-A-00-61-02-11001-018A-D - Aircraft Fault Isolation (AFI)" (Source: Airbus)

By applying this principle in the case of the maintenance task associated with SURV WXR 1+2 Fault messages, if this occurrence arises three times in succession, even if this fault is not confirmed during the AESS test, the complete inspection of the radome is required (according to Task "A350-A-53-15-73-02001-398A-A Inspection of the radome"). This includes a visual internal examination.

Fault on radar and its WXR antenna drive-unit – application of Task "A350-A-34-71-XX-1Q001-421A-A Fault of the WXR Antenna Drive-Unit"
If a radar system fault is displayed, the maintenance task initially requires the AESS test to be carried out.

ON A/C MSN ALL
TASK A350-A-34-71-XX-1Q001-421A-A
Fault of the WXR Antenna Drive-Unit

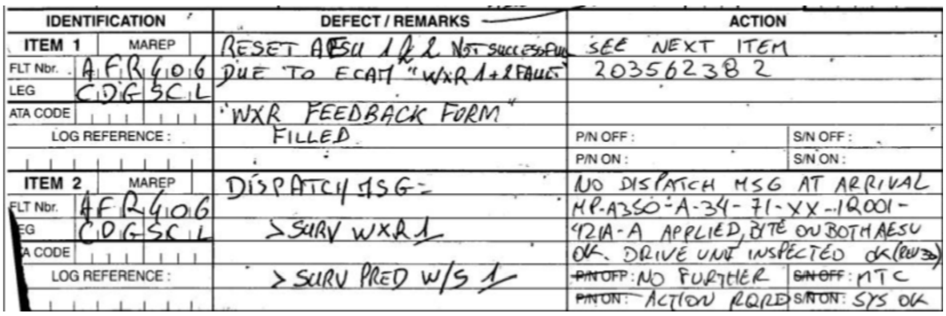
1. Job Set-Up Information

A. Referenced Information.

REFERENCE	DESIGNATION
A350-A-34-71-XX-05ZZZ-429Z-A	AFI - FAULT CONFIRMATION
A350-A-34-71-XX-00ZZZ-343Z-A	MP - BITE Test of the Aircraft Environment Surveillance System (AESS) (Master AESU System-Test)
A350-A-34-71-51-00ZZZ-520Z-A	MP - Removal of the Weather Radar (WXR) Antenna Drive-Unit
A350-A-34-71-51-00ZZZ-720Z-A	MP - Installation of the Weather Radar (WXR) Antenna Drive-Unit
A350-A-53-15-73-02ZZZ-398Z-A	MP - Inspection of the Radome
A350-A-53-15-73-00ZZZ-520Z-A	MP - Removal of the Radome
A350-A-53-15-73-00ZZZ-662Z-A	ASR - Temporary Repair for the Radome

Figure 32: excerpt from line maintenance Task "A350-A-34-71-XX-1Q001-421A-A Fault of the WXR Antenna Drive-Unit" (Source: Airbus)

On 25 May 2023, during a flight from Paris to Santiago (Chile), the first radar faults occurred. The ATL filled in by the crew at this stage indicated the display of the "WXR 1+ 2 FAULT" message on the ECAM.



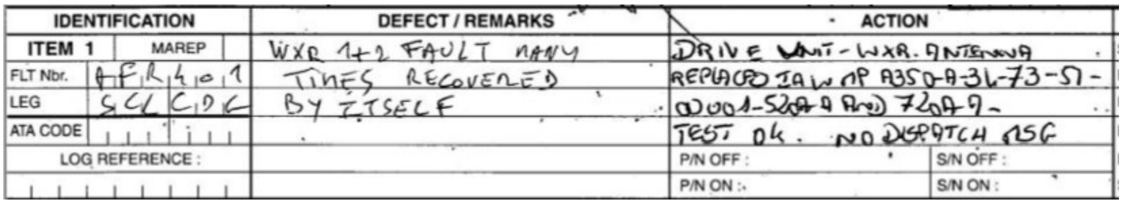
IDENTIFICATION	DEFECT / REMARKS	ACTION
ITEM 1 MAREP	RESET AESU 1 & 2 NOT SUCCESSFUL	SEE NEXT ITEM
FLT Nbr. AFR406	DUE TO ECAM "WXR 1+2 FAULT	203562382
LEG CDG SCL		
ATA CODE	"WXR FEEDBACK FORM"	
LOG REFERENCE :	FILLED	P/N OFF : S/N OFF :
		P/N ON : S/N ON :
ITEM 2 MAREP	DISPATCH MSG :	NO DISPATCH MSG AT ARRIVAL
FLT Nbr. AFR406		MP-A350-A-34-71-XX-1Q001-
LEG CDG SCL	> SURV WXR 1	421A-A APPLIED, BITE ON BOTH AESU
ATA CODE		OK. DRIVE UNIT INSPECTED OK
LOG REFERENCE :	> SURV PRED W/S 1	~~P/N OFF~~ : NO FURTHER ~~S/N OFF~~ : MTC
		~~P/N ON~~ : ACTION RQRD S/N ON : SYS OK

Figure 33: excerpt from the ATL of F-HTYO on 25 May 2023
during the Paris-Santiago (Chile) flight (Source: Air France)

The ground maintenance technician at Santiago (Chile) stated that the fault code saved in the CMS associated with the display of the WXR 1+2 Fault message on the ECAM was associated with a problem on the WXR antenna drive-unit. He applied maintenance task "*A350-A-34-71-XX-1Q001-421A-A - Fault of the WXR Antenna Drive-Unit*" associated with this fault code. The fault did not reoccur when the AESS was tested. He indicated that he carried out a Tap test on the outer surface of the radome without this being a requirement of the maintenance task, but in accordance with the instructions of the Air France MCC. He added that he carried out a visual examination of the outer and inner faces of the radome, and the radar drive-unit. No damage was observed and the aeroplane was returned to service.

The Air France MCC explained that it was working in coordination with Airbus on a study of radar operation[20] and that it was for this reason that it had issued the instruction to carry out a radome inspection in addition to the actions required by the maintenance task associated with radar problems. These additional maintenance actions were available for the ground maintenance technicians in the maintenance software used by Air France.

On 26 May 2023, during the return flight from Santiago (Chile) to Paris, new radar faults occurred with the display of intermittent "WXR 1+2 FAULT" messages on the ECAM, reported by the crew in the ATL.



IDENTIFICATION	DEFECT / REMARKS	ACTION
ITEM 1 MAREP	WXR 1+2 FAULT MANY	DRIVE UNIT - WXR. ANTENNA
FLT Nbr. AFR401	TIMES RECOVERED	REPLACED IAW MP A350-A-34-71-51-
LEG SCL CDG	BY ITSELF	00001-520A A And 720A-A -
ATA CODE		TEST OK. NO DISPATCH MSG
LOG REFERENCE :		P/N OFF : S/N OFF :
		P/N ON : S/N ON :

Figure 34: excerpt from the ATL of F-HTYO on 26 May 2023 during a flight from Santiago (Chile) to Paris (Source: Air France)

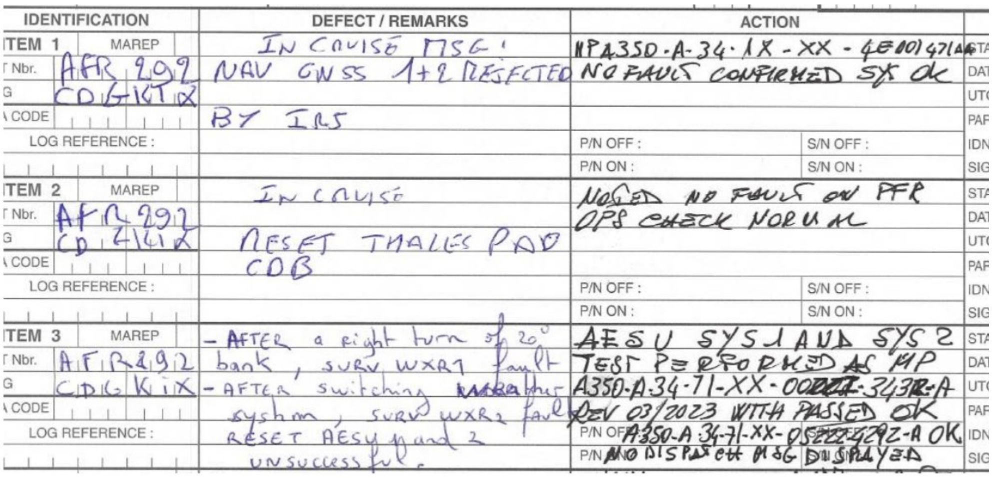
On the ground, the fault code recorded indicated a fault associated with the antenna drive-unit. This was replaced by carrying out the drive-unit removal and installation tasks:

- task "*A350-A-34-71-51-00ZZZ-520Z-A - Removal of the Weather Radar (WXR) Antenna Drive-Unit*" and
- task "*A350- A-34-71-51-00ZZZ-720Z-A - Installation of the Weather Radar (WXR) Antenna Drive-Unit*".

[20] This study was launched following feedback from crews indicating that, depending on the settings and in certain conditions, the radar was unable to detect cumulonimbus.

According to the ATL, the antenna drive-unit was replaced. The ATL did not specify that the inspection task was carried out. Nevertheless, the maintenance technician who replaced the unit stated that the outer surface was undamaged and that he did not inspect the inside of the radome.

On 27 May 2023, during an outbound flight from Paris to Osaka, the crew reported in the ATL, new radar faults with the "WXR 1+2 FAULT" messages being intermittently displayed on the ECAM.



IDENTIFICATION	DEFECT / REMARKS	ACTION
ITEM 1 MAREP AFR 292 CDG KIX CODE LOG REFERENCE :	IN CRUISE MSG : NAV GNSS 1+2 REJECTED BY IRS	MP A350-A-34-1X-XX-4E001471A NO FAULT CONFIRMED SYS OK P/N OFF : S/N OFF : P/N ON : S/N ON :
ITEM 2 MAREP AFR 292 CDG KIX CODE LOG REFERENCE :	IN CRUISE RESET THALES PAD CDB	NOTED NO FAULT ON PFR OPS CHECK NORMAL P/N OFF : S/N OFF : P/N ON : S/N ON :
ITEM 3 MAREP AFR 292 CDG KIX CODE LOG REFERENCE :	- AFTER a right turn of 20° bank, SURV WXR1 fault - AFTER switching other system, SURV WXR2 fault RESET AESU 1 and 2 unsuccessful.	AESU SYS 1 AND SYS 2 TEST PERFORMED AS MP A350-A-34-71-XX-00001-343A-A REV 03/2023 WITH PASSED OK P/N OFF A350-A-34-71-XX-05222-929Z-A OK P/N NO DISPATCH MSG DISPLAYED

Figure 35: excerpt from the ATL of F-HTYO on 27 May 2023 during the Paris-Osaka flight (Source: Air France)

The ground maintenance technician stated that he had exchanged with the Air France MCC about the WXR SYS radar faults during the flight.

The MCC had requested that the maintenance task, "*A350-A-53-15-73-02001-398A-A Inspection of the radome*", corresponding to an external and internal visual inspection of the radome be carried out.

The ground technician explained that after the arrival of the aeroplane, he performed a visual examination of the outside of the radome. He saw no signs of impact or damage and observed that all of the radome latches were correctly closed and locked. He added that when studying the maintenance file for this aeroplane (provided by the MCC), he took into consideration the replacement of the antenna drive-unit. To confirm the fault, he tested the AESS by carrying out task "*A350-A-34-71-XX-00001-343A-A BITE Test of the Aircraft Environment Surveillance System (AESS) (Master AESU System-Test)*". This test did not confirm the fault. He also performed an AESU reset by carrying out task "*A350-A-34-71-XX-00001-132A-A Reset of Aircraft Environment Surveillance Unit (AESU) 1(2)*". As there were no signs of damage on the outer surface, he did not judge it necessary to carry out all of the task and did not inspect the inner surface.

The Paris-Osaka flight on 27 May 2023 was the last flight before the occurrence and the third flight during which radar faults occurred with the "WXR 1+2 FAULT" messages. In this situation, even if the fault that occurred during the flight did not reoccur during the ground radar operation test, a visual inspection of the inner face of the radome should have been carried out.

Following the F-HTYO occurrence, Air France initiated an inspection of all radomes equipping its A350 fleet (*A350-A-53-15-73-02001-398A-A Inspection of the radome)*. The radomes on which anomalies were identified were sent to Airbus Nantes for inspection (see paragraph 1.18.2).

1.16.6 Analysis of F-HTYO PFR, FDR, CVR and maintenance (CMS) data

1.16.6.1 Analysis of saved fault codes

The analysis conducted by Airbus and Honeywell of data saved in the CMS identified a fault code in the "AVIONICS FAULT HISTORY" recordings, until now not used in the maintenance tasks.

This fault code is used to confirm the existence of a mechanical blockage of the radar antenna in its travel at the same position and with each sweep. The value of this parameter during the incident flight and the three previous flights confirmed the presence of this mechanical blockage.

However, this fault code does not indicate whether the antenna movement problem is due to radome damage (blockage) or whether there is a problem with the antenna drive-unit.

1.16.6.2 Operation of the NAIADS system during the incident flight

During the incident flight and subsequent to the collapse of the radome, thirteen automatic reconfigurations of the air data displayed on PFD 1 occurred. The display on PFD 2 was not automatically reconfigured. Manual reconfigurations were commanded by the crew using the AIR DATA selector (six switches to BKUP SPD on the captain or co-pilot side). A maximum of three sources out of the five available sources were simultaneously lost during the flight. The flight control law therefore never switched to DIRECT law and the BKUP SPD was never automatically displayed on the PFD.

The sequence of the automatic and manual air speed display reconfigurations, which took place during the flight, as well as the associated faults, is described below. A summary table is also available (see Table 2). The sequence below also includes the crew's reaction to these reconfigurations (text in *italics*). The sequence was established based on recorded FDR, CVR and PFR data and on crew statements.

The operating logic of these reconfigurations is explained in Table 1 of paragraph 1.6.4.3.

At take-off, all five air speed sources were available. The system adhered to the order of priorities and displayed IAS1 on PFD 1 and IAS2 on PFD 2.

At 03:17, the aeroplane was at 320 kt (CAS) and in the process of acquiring FL 300 (mode ALT* engaged). The air speed sources 1 and 3 were greatly affected by the change in aerodynamic flow caused by the collapse of the radome. The PRIM successively rejected ADR1 and ADR3, resulting in the display of the **NAV AIR DATA REDUNDANCY LOST** alert on the ECAM. The air speeds displayed on PFD 1 were successively IAS3 (rejection of ADR1) and IAS2 (rejection of ADR3).

ADR2 was not affected during this flight phase. The AP2 and A/THR guidance was not affected at this point. A/THR controlled an increase in nominal thrust to acquire the flight level.

At 03:21, during the descent from FL 300 to FL 200, the crew deployed the speed brakes for 21 s to reduce the aeroplane's speed. The change in angle of attack induced by this deployment affected the measurements again, especially the air data sent to the ISIS which were rejected. The **NAV ISIS SPD UNRELIABLE** alert was displayed. With three sources rejected, the flight control law switched to ALTERNATE and the **F/CTL ALTN LAW (PROT LOST)** and **NAV RNP AR CAPABILITY DOWNGRADED** alerts were displayed, followed by the **NAV AIR DATA REDUNDANCY LOST** alert.

*Crew reaction: identification of the **UNRELIABLE AIR SPEED** situation*

From 03:17, following the collapse of the radome, the crew identified the unreliable air speed situation by comparing the speeds of both PFD and that of the ISIS as well as the differences in altitude between both PFD. The origin of the disturbance (structural damage to the radome) and its consequences were also identified. All of the ECAM messages were called out. The crew started to process the ECAM messages.

*Apart from a brief deliberate disconnection of the A/THR, the pitch/thrust flight parameters were consistent, notably on PFD 2, all automatic systems were kept in operation. In this initial phase, the crew did not apply the **UNRELIABLE AIR SPEED** procedure as they did not consider they had the condition, "if the safe conduct of the flight…".*

At 03:25, while the aeroplane was stabilising at a speed of 250 kt, the ADR1 source and NORMAL law were recovered (IAS1 displayed on PFD 1). As the BSCS (Braking and Steering Control System) had rejected the three ADIRU used to control true air speed, the **BRAKES AUTO BRK FAULT** alert was displayed. Around 30 s later, the speed brakes retracted and the ADR1 source was again rejected. The flight control law reverted to ALTERNATE, the **NAV AIR DATA REDUNDANCY LOST** and **F/CTL ALTN LAW (PROT LOST)** alerts were displayed and IAS2 was displayed on PFD 1. The rejection of the speed sources by the PRIM resulted in the loss of the ROW/ROP function and therefore the display of the **SURV ROW/ROP LOST** alert. The aeroplane stabilised at FL 200.

At 03:37, the crew began descent to FL 150 and selected a target speed of 240 kt. One minute later, the target speed of 240 kt was reached and the ADR1 source was recovered (IAS1 displayed on PFD 1). The flight control law reverted to NORMAL law. IAS1 fluctuated around the green dot for several minutes. The two IAS differed by approximately 10 kt up to 04:05.

At 03:40, the **NAV RNP AR CAPABILITY LOST** alert was displayed.

At 03:42, the **ENG GA SOFT FAULT** alert associated with the control of true air speeds was displayed. FL 150 was reached.

Crew reaction: implementation of the unreliable air speed procedure

From FL 150, the fluctuations in speed increased. The captain indicated that the speed was unstable and warned the crew to be vigilant as it was dropping under the green dot. Co-pilot B answered that this was not the case on his side, then added he was keeping the AP and FD activated as safe management of the flight was not affected.

*The crew continued to read the **UNRELIABLE AIR SPEED INDICATION** procedure.*

At the same time, co-pilot B carried out the first ITEMS of the procedure, disconnected the AP, A/THR, FD, and called out use of the HUD using the BIRD and energy recovery systems.

At 03:45, the AIR DATA selector was set to CAPT ON BKUP for approximately one minute (BKUP SPD displayed on PFD 1) then repositioned on AUTO (IAS1 displayed on PFD 1).

At 03:46, the crew initiated the **NAV UNRELIABLE AIR SPEED INDICATION** procedure. At 03:48, the AIR DATA selector was set to co-pilot ON BKUP for around 20 s (BKUP SPD displayed on PFD 2). Observing a difference of less than 30 kt between the speeds displayed on PFD 1 and PFD 2, the crew reset the selector to AUTO (IAS2 displayed on PFD 2). At 03:49, AP2, the A/THR and the FD were reengaged.

Crew reaction: at 03:50, the crew were surprised to see[21] *that the aeroplane had reverted to normal flight control law.*

At 03:51, the AIR DATA selector was set to CAPT ON BKUP (BKUP SPD displayed on PFD 1) then repositioned on AUTO (IAS1 displayed on PFD 1).

At 04:04, the inertial data delivered to the ISIS was rejected and the **NAV ISIS ATT UNRELIABLE** alert was displayed. According to Airbus' analysis, this alert was triggered by the surveillance of an attitude parameter, the value of which was falsified by disruptions to ISIS air data. As this parameter was not visible to the crew, the triggering of this alert was deemed to be inappropriate. Airbus stated it was looking into a modification of this system.

At 04:09, the crew began descent to a target altitude of 12,000 ft, which they reached at 04:12.

At 04:15, the AIR DATA selector was set to CAPT ON BKUP (BKUP SPD displayed on PFD 1) for several seconds in order to compare the IAS and the BKUP SPD. This operation was repeated at 04:43, just several minutes after the aeroplane stabilised at 8,000 ft and 225 kt.

At 05:01, the aeroplane was stable at 6,000 ft and CONF 1 was selected[22]. At a speed of 224 kt, only the leading edge slats were extended. The ADR3 source was rejected and the **NAV AIR DATA REDUNDANCY LOST** alert was displayed.

At 05:02, the speed dropped below 203 kt and the flaps were deployed. With the change in angle of attack disrupting the speed measurements, IAS1 and IAS2 dropped by around 30 kt and 20 kt respectively in several seconds. AP2 and the A/THR were engaged and using the speed displayed on PFD 2, the flight level was maintained by increasing the N1 speed of the engines and decreasing the pitch. Around 20 s later, the ADR1 source was rejected (IAS2 displayed on PFD 1) and the **NAV AIR DATA REDUNDANCY LOST** alert reappeared. The flight control law once again switched to ALTERNATE and the **F/CTL ALTN LAW (PROT LOST)** and **NAV RNP AR CAPABILITY LOST** alerts were displayed.

Crew reaction: aeroplane configuration and reversion to manual mode
From 05:02, the crew became concerned when they observed the marked differences between the speeds, the pitch modifications and the increase in N1. Co-pilot C asked for BACKUP SPEED to be selected, explaining that the speeds were not reliable. The captain set the AIR DATA selector to F/O ON BKUP (BKUP SPD) displayed on PFD 2. Co-pilot C asked for the automatic systems to be disconnected and for manual piloting. Co-pilot B disconnected the AP and the A/THR, and flew using the speed vector until the end of the flight. The crew then monitored the pitch, the thrust and the angle of attack, and assessed the validity of the speeds displayed.

The captain and co-pilot C concluded that the landing would be made with the BKUP SPD as, according to them, this was the only reliable source if the thrust exceeded 40%. Co-pilot B called out the parameters displayed. The path was managed.

[21] See paragraph 1.6.5.2.1: flight control laws can be reversed on the A350 contrary to what the FCOM indicated and what the crew thought.

[22] On the A350, the selection of CONF 1 at a speed between 203 kt and 255 kt implies extension of the slats only. When the speed drops below 203 kt, and if CONF 1 is still selected, the AES (Automatic Extension System) activates extension of the flap to switch to configuration 1+F.

At 05:03, the crew had initiated the descent, the ADR3 source was valid again and IAS3 was displayed on PFD 1. The flight control law returned to NORMAL law and remained in NORMAL law until the end of the flight. A few seconds later, the NAV RNP AR CAPABILITY LOST and NAV ISIS SPD RECOVERED alerts were displayed.

At 05:05, after configuring to CONF 2, the GPWS (Ground Proximity Warning System) and TCAS (Traffic Alert and Collision Avoidance System) became inoperative due to the surveillance of the IAS by the PRIM. The SURV GPWS FAULT and SURV TCAS 1+2 FAULT alerts were displayed. The ADR2 source was then rejected and the NAV AIR DATA REDUNDANCY LOST alert was displayed.

At 05:14, when the aeroplane stabilised at 4,000 ft, the crew selected CONF 3 (flaps and leading edge slats). The ADR2 source was recovered and IAS2 was displayed on PFD 1. The NAV RNP AR CAPABILITY LOST alert was displayed. The air data delivered to the ISIS was then rejected and the NAV AIR DATA REDUNDANCY LOST and NAV ISIS SPD UNRELIABLE alerts were displayed.

At 05:15, the ADR1 source was recovered (IAS1 displayed on PFD 1) for two minutes and rejected at around 05:17 (NAV AIR DATA REDUNDANCY LOST alert).

At 05:18, the NAV RNP AR CAPABILITY LOST and NAV ISIS SPD RECOVERED alerts were displayed.

At 05:20, when flying through 2,000 ft, the air data delivered to the ISIS was rejected twice (sequence of alerts: NAV ISIS SPD UNRELIABLE, NAV ISIS SPD RECOVERED, NAV AIR DATA REDUNDANCY LOST, NAV ISIS SPD UNRELIABLE, NAV RNP AR CAPABILITY LOST). The ADR1 source was recovered (IAS1 displayed on PFD 1).

At 05:21, once the landing gear were extended and locked, the autobrake function was recovered.

At 05:22, the crew selected CONF FULL.

At 05:24, three seconds after the main landing gear touched down and four seconds before the nose gear touched down, the ADR1 source was rejected (NAV AIR DATA REDUNDANCY LOST alert) and IAS2 was displayed on PFD 1.

<table>
<tr><th>Time (UTC)</th><th>Capt EFIS CAS</th><th>Co-pilot EFIS CAS</th><th>Flight control law</th></tr>
<tr><td rowspan="2">02:15</td><td colspan="3">Take-off</td></tr>
<tr><td>ADR1</td><td>ADR2</td><td>Normal</td></tr>
<tr><td>03:17:41</td><td colspan="3">Collapse of radome</td></tr>
<tr><td>03:17:42</td><td>ADR3</td><td rowspan="11">ADR2</td><td rowspan="2"></td></tr>
<tr><td>03:17:48</td><td rowspan="2">ADR2</td></tr>
<tr><td>03:21:26</td><td rowspan="2">Alternate</td></tr>
<tr><td>03:25:04</td><td rowspan="2">ADR1</td></tr>
<tr><td>03:25:14</td><td rowspan="2">Normal</td></tr>
<tr><td>03:25:42</td><td rowspan="2">ADR2</td></tr>
<tr><td>03:25:43</td><td rowspan="2">Alternate</td></tr>
<tr><td>03:38:39</td><td rowspan="2">ADR1</td></tr>
<tr><td>03:38:49</td><td rowspan="3">Normal</td></tr>
<tr><td>03:45:09</td><td>BKUP</td></tr>
<tr><td>03:46:01</td><td>ADR1</td></tr>
<tr><td>03:46:54</td><td colspan="3">UAS activation</td></tr>
<tr><td rowspan="2">03:48:57</td><td colspan="3">UAS application</td></tr>
<tr><td rowspan="2">ADR1</td><td>BKUP</td><td rowspan="9"></td></tr>
<tr><td>03:49:16</td><td rowspan="7">ADR2</td></tr>
<tr><td>03:51:53</td><td>BKUP</td></tr>
<tr><td>03:52:35</td><td>ADR1</td></tr>
<tr><td>04:15:38</td><td>BKUP</td></tr>
<tr><td>04:15:47</td><td>ADR1</td></tr>
<tr><td>04:43:17</td><td>BKUP</td></tr>
<tr><td>04:43:20</td><td>ADR1</td></tr>
<tr><td>05:02:10</td><td rowspan="2">ADR2</td><td rowspan="10">BKUP</td></tr>
<tr><td>05:02:11</td><td rowspan="2">Alternate</td></tr>
<tr><td>05:03:46</td><td rowspan="2">ADR3</td></tr>
<tr><td>05:03:56</td><td rowspan="7">Normal</td></tr>
<tr><td>05:05:03</td><td>ISIS</td></tr>
<tr><td>05:14:49</td><td>ADR2</td></tr>
<tr><td>05:15:22</td><td>ADR1</td></tr>
<tr><td>05:17:39</td><td>ADR2</td></tr>
<tr><td>05:20:28</td><td>ADR1</td></tr>
<tr><td>05:24:39</td><td>ADR2</td></tr>
<tr><td>05:24:43</td><td colspan="3">Landing</td></tr>
</table>

Table 2: summary of reconfigurations of display of air speed sources and the flight control law (Source: BEA)

1.16.7 Crew behaviour

The BEA decided to look at the crew's behaviour using the Air France competency reference frame which is similar to the EASA reference frame. Of the five "non-technical" competencies: communication (COM), leadership and teamwork (LTE), situational awareness (COS), workload management (GES) and decision-making (DEC), the competencies detailed in this chapter (LTE, DEC, GES) are those that appeared to be the most relevant.

1.16.7.1 Leadership and teamwork

The competency of leadership is described in the airline's reference document[23] as the capacity of a pilot to establish a climate of trust conducive to teamwork, working together to reach a common objective. The behavioural markers associated with this competency are as follows:

- provide support;
- encourage the expression of opinions and doubts;
- stay calm and remain factual when managing disputes, and suggest solutions;
- justify your position and be self-confident;
- take responsibility and recognise your mistakes.

The playback of the CVR and the interviews were used to determine the leadership competencies of the four pilots. This competency was deployed differently depending on the position of each pilot in the crew.

From the start of the radar malfunction, the captain gave assurance, being proactive by indicating that they were experiencing an intermittent fault situation, and that he therefore thought there was a radar fault. He asked all of the co-pilots for their opinions, generally by asking open questions.

The captain encouraged the co-pilots to express their opinions and doubts, not only when the crew decided to continue to Osaka, but also during application of the procedures.

Co-pilot B took the initiative to ask for assistance (to be "monitored") when the captain stated that he needed to focus on the call to the CCO.

The co-pilots proved to be assertive and did not hesitate to voice their disagreement with other crew members, notably on two occasions:

- When the captain initially wanted to keep the BKUP SPD selector on his side as this configuration enabled him to have access to two reliable speed data (PFD 2 and BKUP SPD on PFD 1) and to monitor the speed more effectively. Co-pilot A responded that the checklist specified leaving the selector on AUTO. As such, the captain concluded that, although he thought his suggestion was logical, co-pilot A was right.
- When abeam Tokyo, the crew reviewed the appropriateness of continuing to Osaka, the captain, co-pilot A and co-pilot C were all in favour of this option. Co-pilot B, who was more concerned due to the vibrations he felt, stated that he would prefer to land quickly. The captain suggested testing the flight controls and the anticipated configuration of the aeroplane, with sufficient altitude to enable control of the aeroplane to be regained in the event of difficulties. This reassured co-pilot B, who agreed with the decision to continue to Osaka.

[23] Supplement to the pilot competencies document (May 2021)

1.16.7.2 Decision-making

The competency of decision-making is described in the airline's reference document[24] as the capacity of pilot to identify risks and opportunities, to solve problems and to make decisions. The behavioural markers associated with this competency are as follows:

- take into account the available time and the possibility of a FORDEC[25];
- gather, interpret and validate information essential to the situation;
- draw up a list of options;
- assess the risks and benefits of each option;
- decide on a plan of action, in consultation;
- implement the crew's strategy;
- revalidate the decision based on changes in the context.

Following the radar malfunction, the flight abortion principle was guided by the ECAM. The captain indicated that they must now manage the fault and proposed carrying out a FORDEC. The crew assessed together and in a structured way the initial decision to return to Osaka, in consultation with the CCO.

When the context evolved (increase in aerodynamic noise and vibrations during descent), the crew gathered and reviewed the facts. The captain asked the other crew members if they objectively observed a deterioration, which he did not believe to be the case. Co-pilot B stated that his preference was to cut short the flight despite there being no conclusive element.

The options and associated risks were clearly identified. The crew then determined that the flight time saved between Narita and Osaka (alternative airports) was approximately 15 minutes, and in the absence of any apparent degradation, they decided to save resources and to continue with their initial plan to return to Osaka.

1.16.7.3 Workload management

The competency of workload management is described in the airline's reference document[26] as the capacity of a pilot to ensure the prioritisation and distribution of tasks based on the resources available. The behavioural markers associated with this competency are as follows:

- prioritise and organise tasks and make sure they are taken into account;
- recognise and manage interruptions in tasks;
- identify and use the resources available;
- evaluate the time required and manage the time available.

The A350 procedures are designed to be managed by two pilots. During the occurrence, due to the duration of the flight, the crew numbered four pilots who were, moreover, highly experienced.

From the start of climb, the crew's resources were focused on diagnosing the radar fault, making the decision to return, and executing this return via contact with the ATC, the CCO and the CCP. Co-pilot B then replaced co-pilot A in the right seat. He became PF and the captain became PM. The collapse of the radome occurred when the aeroplane was in descent, close to reaching FL 300 on the return heading to Osaka.

[24] Supplement to the pilot competencies document (May 2021)

[25] Acronym for decision-making (Facts, Options, Risks, Decision, Execution, Control)

[26] Supplement to the pilot competencies document (May 2021).

The crew then had to manage the aeroplane's energy and configuration, the flight path, with the approval of Japanese air traffic control, ensure communication with the CCO and the CCP, and prepare to carry out the "unreliable air speed" and "overweight landing" procedures.

The CVR recording showed that the captain immediately distributed tasks between the pilots in a clear manner, and used all resources available (three co-pilots, ATC, CCO). Co-pilot B (PF) was responsible for piloting and the flight path. The captain (PM) monitored his actions and managed communications with ATC.

The captain set "the pace" of the flight, both accelerating and slowing down certain processes, particularly during the descent or when there was an unplanned break in the **UNRELIABLE AIR SPEED** procedure.

The captain and co-pilot C provided systematic support to co-pilot B (PF), confirming and monitoring flight parameters. Co-pilot C covered for the captain when he was communicating with ATC, the CCP and the CCO. He monitored co-pilot B's actions as a PM would have done.

Co-pilot C, sat in the service seat between the two pilots, adjusted to the operational needs at the time. When a procedure was carried out, co-pilot C first read this out loud from his iPad, then monitored its execution. He discussed the procedures with the captain in the event of doubt.

Co-pilot A monitored changes in the situation despite having no microphone on his headset and intervened when he deemed this necessary. Having more mobility, he was asked to perform certain checks in the cabin.

1.17 Organisational and management information

Not applicable.

1.18 Additional information

1.18.1 Statement

The statement below was taken during an interview with the entire crew shortly after their return from Osaka.

The crew stated that when they arrived at the aeroplane, the maintenance technician was in the cockpit. No platform was present near the radome and the crew did not know if the radome had been inspected.

The crew could not remember hearing the noise of a bird strike during climb.

Co-pilot B (PF) stated that when the radome collapsed, he saw the green arcs showing the thrust trend increase suddenly before decreasing again. This behaviour of the indicators led to his decision to deactivate the A/THR. The crew initially thought there was a pressurisation problem because, during the loss-of-pressure exercise in the simulator, the noise was identical to the noise they heard in the aeroplane.

The crew stated that they knew of the existence of a system that reconfigures speed sources, but did not have detailed knowledge. As there was no indication confirming a pressurization problem, they then understood that the three ADR sources were simultaneously impacted by the damage to the radome.

The crew explained that they felt a sharp and sudden nose-up movement when changing to configuration 1. According to them, this impression could have been associated with the dilatation of the HUD.

The speeds displayed then suddenly dropped by 40 kt on PFD 1 and 20 kt on PFD 2. The crew then decided to switch to manual mode. They stated that they then definitively lost confidence in the ADR speeds displayed by the CDS, and that they only trusted the BKUP SPD.

The crew explained that on the A350, unlike on the A330, access to the “pitch/thrust” parameters table did not appear in the “Unreliable air speed” procedure and that you had to look for the parameter values in the “Performance” section of the FCOM (see paragraph 1.6.6).

The crew added that they did not know if the system was working nominally or otherwise and that they would have been reassured by a display indicating whether the reconfiguration calculations were in progress.

They found it useful that the table in the “A350 Systems*”* document, which explained the logic of reconfigurations by the system, was presented in the FCOM.

The crew added that they only noticed the switch to alternate law once during the flight.

Statement from captain - PM at the time of the occurrence
The captain, who already held the A330 rating, had recently completed his A350 CTR at Airbus. The theoretical part of the training on the systems was followed by four simulator sessions.

The CTR at Airbus was followed by standardization training at Air France: a simulator session before the flights and a simulator session during his line training. UAS training in the simulator covers ADR faults to switch to backup speed (BKUP SPD). He added that the Line Flying Under Supervision (LIFUS) training had consisted of two rotations.

He stated that being new to the A350, he preferred to read a procedure in full before applying it in order to understand all the consequences, in particular during the “Unreliable air speed” procedure that covers, if the case arises, cutting off the three ADRs.

Statement from co-pilot A
Co-pilot A had completed his A350 CTR at Airbus in 2019. He was one of the first pilots at the operator to hold a rating for this aeroplane.

After the decision to turn back to Osaka and handing his seat to co-pilot B, co-pilot A was then in the “*4th man*” position. He found this position difficult to manage, especially as he was stood behind the captain’s seat, with a headset that had no microphone and on which he was unable to adjust the volume. He was forced to raise his voice to speak. He thought that if he had had a microphone, he would have been more involved. In addition, his view of the cockpit was fragmented and he could not see the HUDs. He considered making himself useful to the crew, who were busy managing the flight, notably by offering them water as he knew that hydration levels can impact performance.

He thought that on the A350, the alternate law offers better protection against stall than on the A330.

Statement from co-pilot B - PF at the time of the occurrence

Already holding the A330 rating, co-pilot B had completed his A350 CTR at AF. He stated that the A330 and the A350 had certain differences, in particular in terms of the scan pattern.

During the occurrence, the speeds fluctuated and he considered that the fault was difficult to identify.

In the FCOM, he had read that it was possible for speed reconfigurations to occur. He specified that he did not know how the system worked and did not know how long the reconfigurations took. He thought that the crews needed to be better trained on this subject.
During the application of the "*Unreliable air speed*" procedure, he had not felt that there were any piloting difficulties and the flight was stable. He indicated that the crew were therefore able to take time reading the procedure before applying it.

He was aware of the risk of dispersion in a four-pilot crew.

In some heavy workload phases, he chose to break his flying strategy down into "*milestones"*. He did not hesitate to impose a reorganisation in the cockpit when the captain was unavailable to monitor, asking co-pilot C to do so.

He added that the crew updated the FORDEC and questioned the decision in light of the new facts.

He noted the importance of assessing the aeroplane's manoeuvring capabilities in the event of structural damage.

Statement from co-pilot C, in relief position at the time of the occurrence

During the occurrence flight, he had an overview as he was sat in the service seat between the two pilots.

He highlighted that the documentation available to the pilots does not specify that a rejected ADR can be recovered by the system.

1.18.2 Inspection of other Air France A350 radomes following the occurrence

Following the F-HTYO occurrence, Air France requested a full inspection of all radomes equipping its A350 fleet ((*A350-A-53-15-73-02001-398A-A Inspection of the radome*). Damage was observed on three radomes that were sent to Airbus Nantes for further examinations.

Of these three radomes, one had out-of-tolerance damage (based on the criteria defined in the Airbus maintenance documentation), characteristic of a hail strike. It also showed signs of lightning strike. On the second, the inner skin had debonded over a surface area 70 mm x 55 mm, i.e. within the acceptable limits enabling a repair. This debonding was characteristic of FOD (Foreign Object Damage). Lastly, the third radome had several small debondings characteristic of a hail strike as well as a more substantial debonding characteristic of FOD. The extent of the debonding was within the acceptable damage limits (diameter of 250 mm) and was compatible with a repair. Signs of lightning strike were also observed.

1.18.3 Similar cases of radome damage

1.18.3.1 Damage to the Airbus A350 radome

During the investigation, Airbus informed the BEA of an in-service occurrence on 10 June 2022 to the A350 B-324X (MSN 489) operated by China Eastern. This aeroplane had substantial damage to the radome. This damage was nonetheless less substantial than on F-HTYO. With this occurrence being the closest in nature to that of F-HTYO, the BEA contacted the Chinese civil aviation authority to obtain more information. The BEA wanted to compare the performance of the avionics systems on these two flights, and in particular the management of air data reconfigurations. The QAR (Quick Access Recorder) data for flight MU7710 was sent to the BEA by the Chinese investigation authority.

The crew of flight MU7710 (Madrid - Shanghai) reported the appearance of the SURV WXR 1+2 FAULT alert after reaching FL 200. As the reinitialization of AESS 1 and AESS 2 was unsuccessful, and after analysing the meteorological conditions, the crew decided to turn back to Madrid. The fault codes recorded in the CMS confirmed the existence of a mechanical blockage of the radar antenna. The radome, the drive-unit, the antenna, the RTU, the AESU and the Control Panel were sent to Airbus for inspection. The crew of the previous flight had reported a bird strike during the flare upon landing in Madrid. No damage was identified during the visual inspection by maintenance (the visual inspection of the inner face of the radome was not, however, confirmed by the operator) and the aeroplane was returned to service.

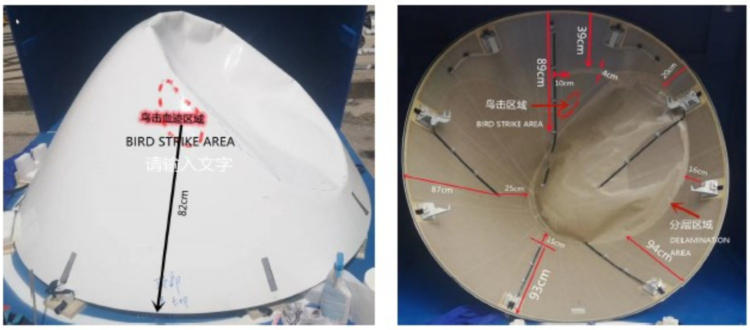


Figure 36: photographs of the B-324X radome after flight MU7710 (Source: Airbus)

1.18.3.1.1 Analysis of flight MU7710 QAR data

The B-324X QAR parameters indicated the occurrence of a radar fault when flying through FL 150, in climb to cruise altitude. This fault, occurring simultaneously on both the captain and co-pilot sides for approximately 1 min 30 s after a right turn (20° roll), was followed by a number of master cautions, and remained present until the end of the flight.

Around seven minutes after the WXR fault, the ADR2 speed measurement began to differ gradually from the ADR1 and ADR3 measurements. It was rejected by the PRIM around 10 minutes later when flying through FL 324. IAS3 was then displayed on PFD 2. Upon acquiring the cruise level (FL 340), the maximum discrepancy of around 7 kt was reached between ADR2 and the other two ADR. The situation remained in this configuration until the start of descent, at which point the ADR2 source started to gradually get closer to the other ADR. When flying through FL 293, ADR2 was recovered by the PRIM and IAS2 was displayed on PFD 2.

The extension of the drag surfaces (CONF 1, 2, 3, FULL) did not seem to cause any notable modification of the speed measurements.

1.18.3.1.2 Comparison between flight MU7710 and flight AF291

During flight MU7710, there was only one source rejection (i.e. two automatic display reconfigurations: rejection and recovery of ADR2), on the co-pilot's side. No automatic reconfiguration took place on the captain's side and the crew did not resort to manual reconfiguration (AIR DATA selector on AUTO for the duration of the flight).

Moreover, the difference in speeds was very gradual on B-324X and only concerned one speed source, while the differences were sometimes very marked on F-HTYO and concerned four speed sources.

Lastly, the disrupted speed measurement seems to have been associated with flight altitude/atmospheric pressure on B-324X. The difference in speed was at its greatest and constant during cruise, whereas it appeared and disappeared in climb and descent respectively.

The management of air data reconfigurations during flight MU7710 was therefore not similar to the F-HTYO occurrence, which comprised numerous and dynamic reconfigurations. One of the reasons may be the difference in nature of the radome distortion (very localised distortion on B-324X).

1.18.3.2 Bird strike on an Airbus A318

During the investigation, the BEA was informed of the occurrence of a bird strike on an Air France A318 carrying out a scheduled flight from Marseille-Paris Orly. The on-ground personnel observed a blood stain on the left of the radome in addition to traces of blood and feathers in the right engine. The ground mechanic cleaned the blood off the radome before carrying out a tap test on its outer surface. No damage was observed. As the occurrence was FOD, the flight safety coordinator advised the technicians to open the radome. When they opened the radome, a white mark was observed, exceeding the acceptable damage limits.

The radome was removed and sent for repair.

Figure 37: bird strike and debonding of the inner skin of an A318 radome (Source: Air France)

1.18.4 Occurrences reported to the BEA by EASA

EASA reported to the BEA occurrences during which the failure to detect damage to composite structures resulted in incidents or accidents. These different occurrences concerned other manufacturers. They show that the difficulty in identifying damage and the lack of strict application of maintenance procedures on composite structures concern the entire aviation industry. For example:

- Serious incident to the Fokker 100 registered D-AGPH on 01 July 2001

Summary: while the aeroplane was climbing to FL 70, the crew heard a muffled noise which came from the lower part of the nose. The crew turned around and landed without any particular incident.

Figure 38: excerpt from the final report on the serious incident to D-AGPH

In its final report, the Polish Investigation Authority (SCAAI) stated that the gradual reduction in strength of the composite structure may have been the cause of the serious incident. Several bird strikes, which occurred prior to the occurrence flight, may have contributed to this gradual weakening that was not detected during maintenance inspections.

- Incident to the Boeing B747 registered N470EV on 19 May 1996

Summary: during the flight, while flying over the Pacific ocean, the composite coating of the upper panel of the right inboard wing trailing edge separated. The damage to the aeroplane was minor and the crew was uninjured.

The examinations showed that trailing edge portions of the composite right inboard wing panel had separated and damaged the fore and mid right inboard flaps. Maintenance records revealed that cracking was detected in the forward outboard corner during the last C check. The crack was repaired, inspected, and repainted. The previous C check also found debonding and delamination in the right wing panel.

Boeing has received a total of 245 operator reports involving debonding of this panel, which has separated from the aircraft in flight in 95 instances. The wing flaps are susceptible to secondary damage as a result of the panel separations. A service bulletin with five revisions has been issued. Operators have been directed to replace the inspection with an ultrasound inspection of the panels to improve the likelihood of detecting debonding below the panel surface. Prior to this incident, the operator had chosen to retain the Tap test method rather than adopt the ultrasonic inspection.

1.18.5 Maintenance technician training

1.18.5.1 EASA regulation pertaining to the maintenance of composite structures.

The personnel responsible for maintaining aircraft are qualified in compliance with the provisions of Annex III (Part 66) of EU regulation No 1321/2014[27].

In the case of aircraft of the same category as the Airbus A350 (group 1 aircraft), maintenance operations on the structure and the issuance of a return to service authorisation certificate are carried out by a maintenance technician who holds a category B1.1 licence and a type rating specific to the aircraft.

Training is not mandatory to obtain a B1.1 license; successfully passing an exam is sufficient. However, training courses are available from Part-147 accredited organizations. EASA has published Acceptable Means of Compliance (AMC) and Guidance Materials (GM) for Part-66 to define a Part-66 maintenance technician training syllabus (Appendix I - Basic Knowledge Requirements) comprising 13 modules. Some of these modules deal with composite structures:
• Module 6 "Materials and Hardware" (characteristics, properties, damage detection, etc.);
• Module 7 "Maintenance Practices" (inspection and repair techniques, etc.).

The training to obtain the type rating comprises a chapter entitled "Composite Structure Awareness", which provides the following information:

- description of composite material characteristics;
- list of different possible damage:
  - environmental damage (hail, lightning, bird strike, etc.),
  - damage associated with human activity around the aeroplane (maintenance and handling),
  - description of the different damage (delamination, debonding, etc.);
- description of the methods and techniques to be used to assess the damage and apply adequate TSM.

Airbus and Air France both offer specialist composite structure training. There is no regulatory requirement for a maintenance technician who holds a Part 66 B1.1 licence to attend this training. This training is principally given to maintenance technicians who work at the main operator bases and who are responsible for major repairs (identified and out-of-tolerance) of composite structures. Airbus training notably includes training specific to the repair of radomes but this is only dispensed to technicians working in repair shops. Air France added that, frequently at stopover airports, the maintenance teams responsible for conducting any inspections and repairs do not include personnel who have completed this specialist training.

1.18.5.2 Aircraft Composite Repair Committee

The Commercial Aircraft Composite Repair Committee (CACRC) was established by SAE International[28] *"to promote repair and modification standardization and to provide guidance to composite and bonded structure maintenance providers, airlines, regulators, material suppliers and OEMs."*

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[27] Commission Regulation of 26 November 2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organisations and personnel involved in these tasks (Version in force on the day of the incident).

[28] SAE International is a global association that brings together technical experts in order to promote and develop techniques in the aeronautical and automobile sectors.

This committee is made up of authorities (EASA and FAA), aircraft manufacturers (Airbus, Boeing, Embraer, etc.), equipment manufacturers and operators. It comprises seven working groups who develop and publish documents in the form of information (AIR-*Aerospace Information*), recommendations (ARP-*Aerospace recommended practice*) and specifications (AMS-*Aerospace Materiel specification*).

The different members of the "Repair techniques" and "Training" groups have published the following documents:

- AIR5719 *Teaching points for a class on "Critical issues in composite maintenance, repair and overhaul";*
- AIR4938 *Composite and bonded structure technician/specialist training*;
- AIR6825 *Identification and Assessment of damage to composite aircraft structures training document*.

Other documents are being developed, for example "Reporting of damage" AIR7509 and "Composite NDT/NDI guidance documents » ARP7532 and ARP5089A

1.19 Useful or effective investigation techniques

Not applicable.

2. ANALYSIS

2.1 Introduction

The collapse of the F-HTYO radome during initial climb resulted from the debonding of its inner wall. This debonding was probably caused by a bird strike. F-HTYO was struck by a bird on its left side during a flight the month before. The analysis of the DNA in the samples taken from the radome identified the bird to be a falcon but it was not possible to determine the date and geographical location of the strike.

During several flights preceding the occurrence, weather radar faults occurred. Maintenance actions performed did not identify the damage inside the radome.

During the incident flight, on the appearance of radar faults, the crew decided to perform an in-flight turn-around by applying the procedure associated with these faults. During descent, when flying through FL 300, the radome collapse disrupted the aerodynamic flow, which considerably impaired the pressure measurements of the probes located at the front of the aircraft and for the duration of the flight, gave rise to:

- multiple ECAM messages;
- deviations in the indicated air speeds displayed on the PFD. These deviations were even significant when selecting CONF 1;
- three temporary switches to ALTERNATE law. Outside of these three periods, the aeroplane was in NORMAL law.

The sequence of automatic and manual air speed display reconfigurations, which took place during the flight, as well as the associated faults, is described in paragraph 1.16.6.2**.**

The fluctuations in the indicated air speed surprised the crew, who decided to deactivate all of the automatic systems (namely, the AP, FD and A/THR) despite these still being available. The analysis of the incident showed that the crew did not have detailed knowledge of the New Air and Inertia Automatic Data Switching (NAIADS) system. The absence of information regarding this specific in-flight context in the Airbus documentation and in crew training contributed to the lack of knowledge of this system's operation.

In the two referenced occurrences (F-HTYO and B-324X, see paragraph 1.18.3.1), the NAIADS system equipping the Airbus A350 enabled the flight control systems and the PFD to have the optimum data available. The flight envelope protection and automatic systems (AP, FD and A/THR) remained available for the duration of the flight.

The overweight landing, on a long runway, was uneventful. However, the absence in the FCOM, of pitch/thrust values in CONF FULL for a weight of 248 t forced the crew to perform extrapolation calculations, which increased the already-high workload.

The analysis focuses on:

- the lack of detection of the damage inside the radome during the maintenance inspections;
- the crew's management of this situation, in particular the application of the **UNRELIABLE AIR SPEED** procedure in a high workload context;
- crew behaviour.

2.2 Lack of detection of damage to a radome during maintenance

On 24 April 2023, one month before the incident, the ATL document indicates that the aeroplane suffered a bird strike on its left side during the landing at Lagos (Nigeria). The associated maintenance task requires a mandatory and systematic visual inspection of the outer and inner surfaces of the radome, regardless of where the aeroplane was struck, even in the absence of visible signs or organic residue. The ATL indicated that this task was applied and specified that a mark was observed on the rear of the radome, without any damage being observed.

Between 25 and 27 May, three flights were made during which weather radar faults occurred. According to the analysis conducted by Airbus and Honeywell (the radar manufacturer), these faults resulted from the mechanical blockage of the radar antenna. The investigation revealed that these blockages were probably caused by a debonding of the radome inner wall.

When there is a radar fault, the first action of the maintenance task consists in confirming the fault by moving the antenna when the aircraft is on the ground. If this fault is confirmed, a visual inspection of the radome inner wall must be performed.

However, during the maintenance inspections performed after each of the three flights preceding the occurrence flight, the radar fault was not confirmed on the ground.

The investigation showed that:

- in flight, a debonding of at least 380 mm in diameter is required for contact to occur between the radome inner skin and the antenna;
- on the ground, the required debonding is 390 mm due to the differences in aerodynamic conditions between both situations.

It therefore appears that the first item of this maintenance task does not always guarantee detection on the ground, of a debonding of the radome inner wall despite this being sufficient enough in flight to interact with the radar antenna.

According to Airbus, a debonding of this size would nevertheless be detectable if a visual inspection was performed. In both cases, the extent of the debonding exceeded the threshold limit of acceptable damage of 250 mm in diameter, as described in the AMM.

History of maintenance operations on F-HTYO in the days preceding the incident

- After the flight on 25 May (CDG-SCL flight), the technician reported having visually inspected the radome inner face without observing any damage.
- After the flight on 26 May (SCL-CDG flight), the radar antenna was replaced. No visual examination of the radome inner face was conducted.
- On 27 May, the day before the incident flight (CDG-KIX flight), after the third consecutive flight during which radar faults occurred, the Air France maintenance centre requested a visual inspection of the inner surface of the radome. This was not performed by the maintenance technician who carried out a visual inspection of the outer surface and tested the radar antenna which had been replaced the day before.

According to the Airbus maintenance documentation (*Fault Isolation*), in the case of repetitive radar faults, an inspection of the radome inner and outer surfaces is required:

- either if the radar antenna fault is confirmed on the ground by a system test;
- or after three successive faults unconfirmed on the ground.

With this being the third consecutive flight during which radar faults appeared, without these being confirmed on the ground, an internal radome inspection should have been carried out.

Composite structure inspection issues

EASA, Airbus and Air France informed the BEA of cases of composite structure damage that went undetected, were incorrectly assessed, or were not reported during maintenance inspections. It was frequently mentioned that after a bird strike, the maintenance technicians cleaned and performed a Tap test on the outer surface of the radome. In the absence of any anomaly observed, the aeroplane was returned to service. However, the maintenance task associated with the inspection of the aeroplane after a bird strike requires a systematic visual inspection of the outer and inner surfaces of the radome.

Maintenance technicians may have little or no specific training or limited knowledge of composites. This lack of knowledge can influence their decisions and actions when reporting or performing maintenance in relation to an occurrence giving rise to damage to a composite structure.

2.3 Management of the UNRELIABLE AIR SPEED procedure

The analysis of the occurrence showed that, up until setting the aeroplane to CONFIG 1 at around 6,000 ft, the crew applied the **UNRELIABLE AIR SPEED** procedure and kept the automatic systems activated most of the time.

During the transition to CONF 1, when the speeds considerably fluctuated, co-pilot C indicated to the captain to switch to BKUP SPD. The captain set the AIR DATA selector to F/O ON BKUP (BKUP SPD displayed on PFD 2), and co-pilot B definitively disengaged the automatic systems and conducted the approach and landing in manual mode.

This action was performed in a surprise situation, and the **UNRELIABLE AIR SPEED** procedure was not fully complied with. Strictly speaking, switching to and maintaining BKUP SPD is only specified if the difference between the airspeeds on PFD 1 and 2 exceeds 30 kt and must be followed by all three ADRs being cut off. Nevertheless, this action did not compromise the flight's safety.

In manual mode and with speeds considered to be unreliable, the crew encountered difficulties in rapidly accessing the pitch/thrust tables.

Unlike on the Airbus A330, on which the crew had logged a lot of flight hours, the **UNRELIABLE AIR SPEED** procedure does not include these tables directly. It simply contains a hyperlink to the introductory paragraph of the PERFORMANCE chapter of the aircraft’s FCOM. The crew then needs to scroll through the pages to find the tables. Airbus proposes quick access to these tables in the EFB “QUICK ACCESS” section. Air France had deleted this shortcut that was therefore no longer available.

Given the conditions of the day and the four-pilot crew, manual piloting of the aeroplane remained compatible with the available resources.

The investigation showed that it would have been possible to make the approach with the automatic systems engaged, as the NAIADS system was functional. In less favourable conditions, the strategy of keeping the automatic systems is still to be privileged as it preserves the crew's resources.

The following elements, based on the statements and the CVR recording, explain the crew's decision.

- **Loss of confidence in the system and automatic systems following aircraft behaviour and speed fluctuations perceived to be abnormal during the configuration change (CONF 1)**

Although the captain anticipated the extension of the slats and flaps, the crew were surprised by the considerable fluctuations in the speeds displayed on the PFD. The crew then considered that all of the speeds associated with the probes in the vicinity of the radome were adversely affected. The decision to pilot in manual mode was practically immediate. From this time, the crew considered the only reliable speed source to be the BKUP SPD, whose sensors are in the engines and are reliable for an engine N1 speed of more than 40%. With landing imminent, the PF controlling the flight path did not reactivate the automatic systems.

- **Knowledge of Air and Inertia Automatic Data Switching (NAIADS) system**

The crew stated that they were aware of a system that could reconfigure speed sources but that they did not know the details. The investigation showed that the FCOM and FCTM documents did not provide the crew with adequate knowledge of the system's operation in a situation such as that of the occurrence (major disruptions to the aerodynamic flow that could result in a system reconfiguration delay).

This system is complex and its description in the FCOM may be difficult to comprehend in full as it requires users to browse between several hyperlinks. It is also necessary to select more detailed FCOM levels (L2 and L3) to obtain more accurate information. It is likely that the fragmented and dense nature of the information describing this system does not bring to the fore information of more use to the pilots.

The investigation also identified an error in the FCOM: the latter indicates that a rejected source of air or inertial data cannot be used by the flight control laws if it becomes available again. This is not correct on the Airbus A350.

- **Simulator training far removed from the occurrence conditions**

In a simulator, during the demonstration of the system, faults are straight and definitive. Trainees observe the system reconfigure itself as the ADR and ISIS sources disappear, until only the BKUP SPD is in operation. The sequence of reconfigurations depends on the rhythm of the faults programmed by the instructor.

During the occurrence, the radome collapse created such high aerodynamic fluctuations around the probes that the system made multiple reconfigurations and displayed several ECAM messages:

- **NAV AIR DATA REDUNDANCY LOST.**
- MULTIPLE AIR DATA REJECTED BY PRIMs
- ISIS SPD UNRELIABLE
- NAV ISIS SPD RECOVERED

The crew explained that they did not know whether the system was functioning nominally or not and that they would have been reassured by a display indicating that reconfiguration calculations were in progress. This statement seems to indicate that they were unaware that these messages indicate that reconfigurations are underway.

Thus, the planned simulator exercise only informed the crew of the operation of the NAIADS system, within the framework of straight faults, and as a consequence, in a context far removed from operational conditions and without the same level of stress.

Impact of dual A330/A350 rating

Due to the technological advances between the A330 and the A350, in particular the NAIADS system, the **UNRELIABLE AIR SPEED** procedure is different on both aeroplanes.

- On the A330, the "unreliable air speed" procedure imposes a definitive reversion to manual piloting with pitch/thrust tables. The BKUP SPD does not exist and landing is made with CONF 3.
- On the A350, in the case of the incident, it was possible to keep the automatic systems activated after completing the procedure. The landing could be made with FULL configuration.

All of the pilots held a dual A330/A350 rating. The captain had only flown eight legs in total on the A350 since he completed his simulator training, six of which in the last three months.

2.4 Crew behaviour

During the occurrence flight, the crew had to manage a complex situation. The radome collapsed when the workload was already high due to the implementation of operational changes: change of route, in coordination with Japanese air traffic control, change of PF, communication with the CCO and the CCP, initiation of descent in anticipation of a landing with an overweight of 40 t.

When the radome collapsed, the crew initially had to manage stress levels associated with the sudden occurrence of structural damage close to the cockpit, which generated noise and vibrations. They had to simultaneously manage the energy and flight path of the aeroplane and apply procedures in a situation that remained dynamic up to landing.

In this context, the analysis of the CVR and parameters indicated that the crew successfully managed a considerable workload. The presence and commitment of three experienced co-pilots on board, whose roles were clearly established by the captain, enabled high safety margins to be maintained.

3. CONCLUSIONS

3.1 Findings

- It is very likely that the damage observed on the radome was caused by a bird strike. It is very likely that this strike caused a debonding of the inner skin that spread radially and aftward on the radome until the latter completely collapsed.
- One month before the incident flight, the aeroplane was struck by a bird, the maintenance task triggered by this strike did not identify any damage and the aeroplane was returned to service.
- Three days before the incident flight, the repeated occurrence of weather radar faults indicated the presence of a debonding of the inner wall of the radome that was already substantial enough to prevent movement of the radar antenna and therefore generate these faults.
- During the performance of the maintenance tasks triggered by these radar faults, the damage on the inner surface of the radome was not identified and the aeroplane was returned to service.
- The non-detection of the damage on the inner surface despite being of a considerable size indicates that the visual inspections of the inner face of the radome were not adequately performed and/or that the required maintenance task (radar fault) was not adapted.
- The maintenance technicians who worked on the aeroplane on the ground held a B1.1 licence and the type rating.
- During the incident flight, the radome collapse generated a number of ECAM messages, temporary switches to ALTERNATE law and multiple variations in displayed speeds.
- The New Air and Inertia Automatic Data Switching (NAIADS) system equipping the Airbus A350 kept the flight envelope protection and automatic systems (AP, FD and ATHR) available for the duration of the flight.
- The crew did not have an in-depth knowledge of how the NAIADS system works. Surprised by the variations in speed displayed when the aeroplane was configured to CONF 1 on approach, they decided to deactivate all the automatic systems until landing despite the latter still being operational.

3.2 Contributing factors

The following factors may have contributed to the non-detection of the damage on the inner wall of the radome during maintenance operations in connection with the flights preceding the incident flight:

- Probable insufficient awareness and training of maintenance technicians in the risks caused by a bird, hail, lightning or other FOD strike on a composite structure. This lack of knowledge can result in the technicians failing to apply all of the manufacturer's maintenance tasks. Thus, in the event of a bird strike, it would seem that, in many cases, if technicians do not observe damage on the outer surface of the radome, they do not inspect the inner face despite this being a requirement of the maintenance task.
- A maintenance task pertaining to a radar fault that does not guarantee the systematic detection of damage to the inner wall of the radome; the deformation of the composite structure may differ in flight and on the ground and impair the operation of the other systems, especially the weather radar, in different ways.

The following factors may have contributed to the crew's insufficient knowledge of the operation of the NAIADS equipping the Airbus A350:

- The drafting and organisation of information pertaining to the NAIADS in the manufacturer's documentation (FCOM and FCTM) that probably do not enable pilots to have a clear understanding of the functioning of this system.
- Limited simulator training, not closely related to the operational conditions in which this type of fault can occur.

4. SAFETY MEASURES TAKEN SINCE THE OCCURRENCE

4.1 Maintenance-related measures implemented

4.1.1 Airbus – Update of maintenance procedures with respect to inspection of the radome and bird and hail strikes

In light of the facts established during the F-HTYO investigation and of the in-service experience, Airbus conducted a review of the organisation of the information available in the maintenance tasks associated with inspections after FOD (bird or hail strike).

This review led Airbus to update its maintenance procedures at the beginning of 2024 to highlight the systematic and mandatory character of inspections of the inner surface of the radome in all main sections of the procedures. These reminders should allow maintenance technicians not to forget this mandatory inspection that previously only figured in the "Introduction" and "General information" paragraphs of these procedures, paragraphs that may not be systematically read by maintenance technicians.

4.1.2 Airbus - Update of Fault Isolation Manual with respect to radar faults

During the investigation, Airbus determined that the first item of the maintenance task to be applied in the event of a radar fault did not always guarantee detection on the ground, of a debonding of the radome inner wall despite this being sufficient in flight to hinder movement of the radar antenna and cause the occurrence of its fault.

To improve detection of internal debonding occurrences not identified during inspections performed following a FOD (bird or hail) strike, Airbus modified the maintenance task in question. From now on, a thorough visual inspection, to include an internal visual inspection, of the radome is systematically required if the history of faults recorded (CMS) indicates a mechanical blockage of the antenna. This procedure has been in force since April 2024.

2. Fault Isolation

A. Go to the Fault Confirmation Ref. AFI A350-A-34-71-XX-05ZZZ-429Z-A.

Is there confirmation of the fault? YES (Go to Step
C.
) / NO (Go to Step
B.
)

B. On the maintenance terminal, get access to the "AVIONICS FAULT HISTORY" page Ref. MP A350-A-45-45-XX-0BZZZ-132Z-A.
On the "AVIONICS FAULT HISTORY" page, do a check of the complementary data of FC 3471F008.

Are the first four digits of complementary data 0FB4? YES (Go to Step
C.
) / NO (Go to Step
E.
)

C. Do a detailed inspection of the radome (5001MW) Ref. MP A350-A-53-15-73-02ZZZ-398Z-A.
If you find damage:
- Repair the radome (5001MW) Ref. ASR A350-A-53-15-73-00ZZZ-662Z-A, or
- Replace the RADOME-NOSE (5001MW) Ref. MP A350-A-53-15-73-00ZZZ-520Z-A and Ref. MP A350-A-53-15-73-00ZZZ-720Z-A.

Do the BITE test of the AESS (master AESU system-test) Ref. MP A350-A-34-71-XX-00ZZZ-343Z-A.
If the test gives a fault message, do the related Fault Isolation procedure.

Does the fault continue? YES (Go to Step
D.
) / NO (Go to Step
E.
)

D. Replace the DRIVE UNIT-WXR ANTENNA (20SE) Ref. MP A350-A-34-71-51-00ZZZ-520Z-A and Ref. MP A350-A-34-71-51-00ZZZ-720Z-A.
Go to the Fault Confirmation Ref. AFI A350-A-34-71-XX-05ZZZ-429Z-A.

Go to Step
E.

Figure 39: excerpt from the updated "A350-A-34-71-XX-3V001-421A-A – SURV WXR 1+2 FAULT" line maintenance task (Source: Airbus)

4.1.3 Airbus - communication and publications

In March 2024, during the flight safety conference[29] that Airbus organises each year, the manufacturer and Air France co-presented a summary of the F-HTYO incident.

In April 2024, Airbus published an article entitled "Bird or Hail strikes on the radome" in the *Safety First* magazine. This article reminds flight crews and maintenance personnel of recommendations in order to ensure the detection, reporting and correct management of a bird or hail strike. It also explains why it is important to always check the outer and inner surfaces of a radome following a strike, specifying that a debonding on the radome inner side can prevent free movement of the weather radar antenna and trigger fault alerts to the crew. The images used to illustrate this chapter are those associated with an Airbus A320 for which the WXR ANT fault is displayed. This is not the case on an Airbus A350.

In May 2024, Airbus published In-Service Information ISI 53.15.00026. This information provides an overall description of changes to the A350 radome and the interchangeability options, periodic checks and procedures in the event of abnormal occurrences. The chapter on unscheduled inspections, triggered by an abnormal occurrence such as a bird strike, also highlights that it is mandatory to open and inspect the radome:

[29] Airbus organises an annual conference on flight safety for operators. The aim of this conference is to share pertinent information on safety and lessons learned from in-service experience with those responsible for flight safety at operators.

6.1 BIRD STRIKE:
Inspection of the Aircraft after Bird strike Task A350-A-05-51-14-00001-282A-A

Ref SUBTASK 055114-60000780001
Radome mandatory inspection:
IT IS MANDATORY TO OPEN AND EXAMINE THE RADOME. In some special conditions the Radome can have delamination without organic residue or signs of impact.

Figure 40: excerpt from In-Service Information ISI 53.15. 00026

4.2 Update of Airbus operational documentation (FCOM and FCTM)

4.2.1 Update of the FCTM UNRELIABLE AIR SPEED INDICATION procedure

The investigation showed that the NAIADS system enabled the AP/FD/ATHR automatic systems to remain available for the duration of the flight.

In the case of a radome with substantial damage, aerodynamic disturbances can result in multiple fluctuations of the speeds displayed on the PFD that can be detected by the crew, who, surprised by these fluctuations, may deactivate the automatic systems. These fluctuations can occur when the aeroplane's pitch varies or when the aeroplane's configuration is changed. Consequently, the crew must only assess the reliability of data sources when the path and the configuration of the aeroplane are stable.

To inform the crews and make them aware of these potential situations, Airbus updated the FCTM **UNRELIABLE AIR SPEED INDICATION** procedure in April 2024 by adding a paragraph entitled "SPECIFIC CASE OF RADOME COLLAPSE".

AIR FRANCE A350 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES NAV

WHEN TO APPLY THE UNRELIABLE AIR SPEED INDICATION PROCEDURE

The flight crew should consider applying this procedure when they suspect an erroneous speed or altitude indication (not detected by the aircraft systems).

For more information on the ADIRS monitoring, *Refer to FCOM/DSC-34-NAV-20-10-50 ADIRS Monitoring*.

SPECIFIC CASE OF RADOME COLLAPSE

In the case of a radome collapse, the systems reconfigurations may induce air parameters deviations, and temporary air speed fluctuations that the flight crew can detect. These effects may happen when the aircraft attitude varies, or when the aircraft configuration is changed due to a modification of the airflow around the probes.
As a result, the flight crew should only assess the reliability of the air data sources when the aircraft trajectory and configurations are stable.

The flight crew can suspect an erroneous speed or altitude indication, in any of the following cases:

1. Fluctuating or unexpected variations in the indicated airspeed or altitude
2. Abnormal correlation between the basic flight parameters (i.e. pitch, thrust, airspeed, altitude and vertical speed indications).

   For example, an erroneous speed or altitude indication can be suspected when one of the following applies:
   - The altitude does not increase, although there is a significant nose-up pitch and high thrust
   - The IAS increases, although there is a significant nose-up pitch
   - The IAS decreases, although there is a significant nose-down pitch
   - The IAS decreases, although there is a nose-down pitch and the aircraft descends.
3. An abnormal behavior of the AP/FD and/or the A/THR
4. The STALL warning triggers and this is in contradiction with the indicated airspeeds. In this case, the flight crew should rely on the STALL warning. Erroneous airspeed data does not affect the STALL warning, because the STALL warning is based on the Angle Of Attack (AOA)
5. The OVERSPEED warning triggers and this is in contradiction with the indicated airspeeds. Depending on the situation, the OVERSPEED warning may be false or justified. When the

AFR A350 FLEET		PR-AEP-NAV P 2/4
FCTM	← B →	04 APR 24

   OVERSPEED VFE warning triggers, the appearance of aircraft buffet is a symptom that the airspeed is indeed excessive
6. The barometric altitude is not consistent with the RA height (when the RA height is displayed)
7. The aerodynamic noise reduces whereas the indicated airspeed increases, or vice versa.

Note: *Due to the fact that the barometric altitude may be erroneous, the aircraft may not be able to accurately maintain level flight. In addition, the ATC transponder may transmit an incorrect altitude to ATC or to other aircraft, which can lead to confusion. Therefore, the flight crew should advise ATC of the situation without delay.*

Figure 41: update of the Airbus A350 FCTM (Source: Air France)

4.2.2 Update of the FCOM

4.2.2.1 Update of the pitch/thrust table

Airbus updated the pitch/thrust table to include pitch/thrust values in all flight phases with excess weights of more than 210 t (only excess weight value available in the FCOM at the time of the incident).

4.2.2.2 Update of the ADIRS - SYSTEM DESCRIPTION-A350 CDSC-34-NAV-20-10-50 chapter

In the description of the FCOM systems, the sentence “*For the flight control laws, the PRIMs cannot reuse a rejected air or inertial data source even if this source is back to normal*” was incorrect. On the Airbus A350, a rejected source can be reused by the flight control laws when it is deemed to be valid again. Airbus modified this FCOM chapter.

L3 The PRIMs continue to monitor the rejected data source. If a rejected data source is consistent again with the other sources, the PRIMs may consider this source valid. In this case, the flight control law would reconfigure to normal law and the CDS automatically reconfigures the PFD.

Figure 42: update of the FCOM A350 DSC-34-NAV-20-10-50, ADIRS- SYSTEM DESCRIPTION-ADIRS MONITORING (Source: Airbus)

4.3 Air France – Measures taken after the occurrence

During the investigation, Air France issued instructions and reminders to ensure maintenance technicians systematically carry out an inspection of the inner face of the radome after a bird, lightning or hail strike.

The organisation responsible for flight safety produced bulletins and presentations for crews to inform them of the safety lessons drawn from the investigation into the F-HTYO incident:

- bulletins pertaining to operation of the A350 radar and the importance of recording radar faults in the ATL to ensure that adequate maintenance actions can be performed;
- bulletins pertaining to the operation of the NAIADS system.

APPENDICES

Appendix I: Airbus A350 FCOM procedures

List of procedures applied by the crew:

- **SURV TOTAL LOSS OF WXR**
- **UNRELIABLE AIR SPEED INDICATION MEMO ITEM**
- **UNRELIABLE AIR SPEED INDICATION procedure**
- **MISC OVERWEIGHT LDG**

Appendix II: Airbus A350 FCTM procedures

List of procedures associated with the incident:

- **HANDLING THE AIRCRAFT IN THE CASE OF SEVERE DAMAGE**
- **UNRELIABLE AIR SPEED INDICATION**

APPENDIX I: Airbus A350 FCOM procedures

SURV TOTAL LOSS OF WXR

AIRFRANCE A350 FLIGHT CREW OPERATING MANUAL	PROCEDURES ABNORMAL AND EMERGENCY PROCEDURES SURV

[ABN] SURV TOTAL LOSS OF WXR

Applicable to: ALL

Ident.: PRO-ABN-SURV-3471AF32-90000028.9000024 / 18 JUL 19

ANNUNCIATIONS

Triggering Conditions:

L2 To display this procedure, the flight crew must press the ABN pb on the ECP , and then select the TOTAL LOSS OF WXR procedure in the SURVEILLANCE section.

L3 This not-sensed procedure is to be performed after SURV SYS 1+2 FAULT or SURV WXR 1+2 FAULT.

Ident.: PRO-ABN-SURV-3471AF32-90000029.9000025 / 18 JUL 19

CONTACT WITH DISPATCH.................................ESTABLISH
WEATHER.................................CONTINUOUSLY MONITOR

L2 *Continuously monitor the weather in contact with dispatch.*

L1 WEATHER AT OVERFLOWN AIRPORTS.................................OBTAIN

L2 *Radio or datalink may be used to contact dispatch, ATC or preceding aircrafts.*

L1 KEEP VMC

L2 *VMC shall be ensured for all flight.*

No weather threat shall be forecast.

The intertropical convergence zone shall not be flown.

L1 FLIGHT TIME.................................CHECK

- **Flight time must not exceed :**
  - 3 hours in night flight.
  - 6 hours in daylight flight.

CABIN CREW.................................ADVISE

L2 *Advise cabin crew that seat belt signs may be required.*

UNRELIABLE AIR SPEED INDICATION: Memory item

[MEM] UNRELIABLE AIR SPEED INDICATION

Ident.: PRO-ABN-NAV-00020895.0001001 / 06 NOV 14
Applicable to: ALL

L2 Note:
1. *This procedure contains items that the flight crew must perform from memory. For more information, Refer to FCTM/PR-AEP-NAV Unreliable Air Speed Indication*
2. *When a safe trajectory is ensured with the below applicable pitch and thrust values, the flight crew must activate the NAV UNRELIABLE AIR SPEED INDICATION not-sensed procedure without delay, Refer to (procedure).*

L1 ● **If the safe conduct of the flight is impacted:**

AP	OFF
A/THR	OFF
FD	OFF

L2 *The flight crew considers the ADR speed unreliable. As a consequence, they must not use the AP / FD and A/THR .*

L1

PITCH / THRUST:	
Below THR RED ALT	12.5 °/TOGA
Above THR RED ALT and Below FL 100	10 °/CLB
Above THR RED ALT and Above FL 100	5 °/CLB
FLAPS (if CONF 0(1)(2)(3))	MAINTAIN CURRENT CONF
FLAPS (if CONF FULL)	SELECT CONF 3 AND MAINTAIN
SPEED BRAKES	CHECK RETRACTED
L/G	UP

UNRELIABLE AIR SPEED INDICATION (levels L1, L2, L3)

[ABN] NAV UNRELIABLE AIR SPEED INDICATION **(Cont'd)**

Ident.: PRO-ABN-NAV-9027W140-00019127.0007001 / 28 JUN 21

AP .... OFF
A/THR .... OFF
FD .... OFF

The flight crew considers the ADR speeds unreliable. As a consequence, they must not use the AP / FD and A/THR .

AIR DATA SWTG ON PF SIDE .... BKUP

The PFD on the PF side displays the backup speed and backup altitude. If available, the backup air data is reliable.

For more information on the display of backup indications, Refer to DSC-34-NAV-20-30 Backup Speed and Backup Altitude Indications.

The air data displayed on the PM side remains based on the ADR s. As a consequence, the PM should consider the air data displayed on its PFD as unreliable.

If the air data on the selected side is not available, consider switching backup speed on the other side.

If the air data is not available on any sides, Refer to PER-PN1 INTRODUCTION.

MIN N1 (ALL ENGs) .... 40 %

The backup speed is displayed on PF side with the AIR DATA selector . When the ADR s are on and are not rejected by PRIM s, the backup speed is only based on FADEC s data. The thrust must be above 40 % N1 to ensure the accuracy of the displayed backup speed.

■ **If CAPT & F/O SPD DISAGREE (>30 KT):**

ADR 1+2+3 P/Bs .... OFF

The backup speed is reliable. The flight crew confirms that the ADR s are unreliable. Therefore, the flight crew must switch off the ADR s.

The RVSM capability is lost (Refer to PRO-SPO-RVSM Required Equipment and Functions).

The PRIM s compare the ISIS air data and the backup air data:

- *If there are no differences, the CDS displays the backup air data on the PFD of the PF (as set with the AIR DATA selector) and the ISIS air data on the PFD of the PM . As a consequence, the alternate law is triggered. In this case, the OVERSPEED alert is not available.*

  For more information on the display of ISIS air data indications, Refer to DSC-34-NAV-20-30 Display of ISIS Speed and Altitude Indications.

Continued on the following page

[ABN] NAV UNRELIABLE AIR SPEED INDICATION **(Cont'd)**

- *In the case of differences, the PRIM s reject the ISIS air data and the CDS displays the backup air data on both PFD s. As a consequence, the direct law is triggered.*

N1 .... AS RQRD

When all ADR s are switched off , the backup speed is based on FADEC s data at high speed but also on AOA probes at low speed. Therefore, the thrust can be set as required.

SPD & ALT .... FLY THE BKUP

Even if the ISIS air data is displayed on one PFD , the PF should use the backup speed and altitude. Indeed, the backup air data is the source of air data which is the most independent from the ADR s (different technology compared to ISIS and ADIRS).

A rapid change of thrust may disturb the backup speed computation. In this case, the backup speed indication fluctuates during a transient.

● **If backup altitude (or speed) is displayed on at least one PFD :**

BKUP SPD ACCURACY : 10 KT
BKUP ALT ACCURACY : 500 FT

The speed and altitude accuracy is downgraded when the PFD displays the backup air data.

● **If the backup speed is only based on AOA probes and backup speed is displayed on at least one PFD :**

MAX SPEED : 300/.80

MAX FL : 300

Due to failures, the PRIM s cannot use the FADEC air data for computation of the backup speed. Therefore, the flight level and speed are limited to ensure the accuracy of the backup speed.

GA THR : TOGA ONLY
CABIN ALT MODE .... MAN

ACFT CRZ FL	CABIN ALT TRGT
430	6000
400	5900
350	5000
300	4200
250	3300
200	2500
150	1600
100	800

Continued on the following page

[ABN] NAV UNRELIABLE AIR SPEED INDICATION (Cont'd)

CABIN ALT TRGT..AS RQRD
WING A-ICE..OFF
AVOID ICING CONDs

- **If CAPT & F/O SPD DISAGREE <30 KT:**

AIR DATA SWTG..AUTO

The ADR s are reliable and can be used for display on both PFDs.

AP & FD..AS RQRD
A/THR OR N1..AS RQRD

The ADR s are reliable. Therefore, the flight crew can use the AP / FD and A/THR .

DEACTIVATE

- **If all ADR s are switched off:**

ASSOCIATED PROCEDURES

F/CTL DIRECT LAW (PROT LOST)

Refer to procedure

The flight controls will revert to DIRECT LAW if the discrepancy between the ISIS and the BACKUP sources is above a monitoring threshold. Otherwise, the flight controls will revert to ALTERNATE LAW.

Continued on the following page

[ABN] NAV UNRELIABLE AIR SPEED INDICATION (Cont'd)

Ident.: PRO-ABN-NAV-9027W140-00020137.0009001 / 26 JUL 17

LIMITATIONS

LIMITATIONS ON ECAM

ALL PHASES

- **If the backup speed is displayed on at least one PFD and is only based on AOA probes:**
  MAX SPEED : 300/.80
  MAX FL : 300
- **If all ADR s are switched off:**
  AVOID ICING CONDs

APPR & LDG

- **If all ADR s are switched off:**
  GA THR : TOGA ONLY

LIMITATIONS ON PFD

ALL PHASES

- **If the backup speed is displayed on at least one PFD and is only based on AOA probes:**
  MAX SPEED : 300/.80
  MAX FL : 300
- **If all ADR s are switched off:**
  AVOID ICING CONDs

DEFERRED PROC

ALL PHASES

- **If all ADR s are switched off:**

> AT TOP OF DES : LDG ELEVN

CABIN ALT TRGT..LDG ELEVN

The automatic cabin pressure control is failed due to all ADR s switched off. Therefore, the flight crew must set the landing field elevation with the CABIN ALT TRGT selector .

Continued on the following page

[ABN] NAV UNRELIABLE AIR SPEED INDICATION (Cont'd)

STATUS

INOP SYS

ALL PHASES

RNP AR
ADR 1+2+3 (1)
TCAS 1+2 (1)
TAWS (1)
ADS-B TRAFFIC 1+2 (1)
CAB PRESS AUTO CTL (1)
WING A-ICE (1)

APPR & LDG

ROW/ROP (1)
BTV (1)
GA SOFT
REACTIVE W/S DET

INFO

- **If backup altitude or speed is displayed on at least one PFD :**
  BKUP SPD ACCURACY : 10 KT
  BKUP ALT ACCURACY : 500 FT
- **If all ADR s are switched off:**
  APPR 1 ONLY

ACFT CRZ FL	CABIN ALT TRGT
430	6000
400	5900
350	5000
300	4200
250	3300
200	2500
150	1600
100	800

MISC OVERWEIGHT LDG

[ABN] MISC OVERWEIGHT LDG

Applicable to: ALL

Ident.: PRO-ABN-MISC-9090W150-00015880.0001001 / 06 NOV 14

ANNUNCIATIONS

Triggering Conditions:

L2 To display this procedure, the flight crew must press the ABN pb on the ECP , and then select the MISC OVERWEIGHT LDG procedure in the MISCELLANEOUS section.

L3 The flight crew must apply this procedure when the aircraft must land above the Maximum Landing Weight (MLW).

Ident.: PRO-ABN-MISC-9090W150-00005196.0001001 / 06 NOV 14

L2 Automatic landing is certified up to the Maximum Landing Weight (MLW). Autoland flight tests have, however, been successful up to the Maximum Takeoff Weight (MTOW).

Depending on the situation (e.g emergency or other) and provided that the runway is approved for automatic landing, the flight crew can decide to perform an autoland up to the maximum takeoff weight.

Continued on the following page

[ABN] MISC OVERWEIGHT LDG (Cont'd)

Ident.: PRO-ABN-MISC-9090W150-00008684.0001001 / 08 JUL 19

JETTISON PROC .... CONSIDER

LDG DIST AFFECTED

- **If another failure affects VAPP :**

  LDG PERF AFFECTED

  Use the ECAM flap setting, if required for abnormal operations. In all other cases:
  - *FULL is preferred for optimized landing performance*
  - *If the aircraft weight is above one of the limiting weight for go-around use FLAP 3 for landing.*

- **FOR APPROACH:**

  PACK 1+2 .... OFF OR ON APU BLEED

  L2 *The selection of the PACKS to OFF (or to APU BLEED) increases the maximum thrust available from the engines, in the case of a go-around.*

  L1 IF LDG CONF 3: USE CONF 1 FOR GO AROUND

  SPEED AT RUNWAY THRESHOLD : VLS

  L2 *This speed target is applicable in manual landing and autoland. Reduce the speed to reach VLS at the runway threshold. Touch down as smoothly as possible to reduce the V/S . The maximum touchdown V/S should not exceed 360 ft/min. The main landing gears must touch down as symmetrically as possible.*

  Note: The VLS that is displayed on the PFD takes into account the actual aircraft configuration, even with slats or flaps, locked or failed.

  However, this line can be inhibited if another failure affects the landing performances with a VAPP increment. In that case the flight crew must follow the VAPP that the ECAM requires.

- L1 **FOR LANDING:**

  INCREASE FLARE HEIGHT

  USE MAX REVERSE ASAP

  L2 *It is recommended to use the reverse as soon as possible, in order to limit the braking action.*

  L1 APPLY BRAKES AS NECESSARY

Continued on the following page

[ABN] MISC OVERWEIGHT LDG (Cont'd)

L2 *It is recommended that the flight crew uses the maximum available runway length to limit the braking energy.*

It is recommended to use the BTV function, and set the runway end as the BTV exit in order to optimize the braking and to minimize the braking energy.

Ident.: PRO-ABN-MISC-9090W150-00008685.0001001 / 04 SEP 14

LIMITATIONS

LIMITATIONS ON ECAM

	APPR & LDG
	LDG PERF AFFECTED

APPENDIX II: Airbus A350 FCTM procedures

HANDLING THE AIRCRAFT IN THE CASE OF SEVERE DAMAGE

In the event of severe damage to the aircraft, the flight crew's immediate action should be to "fly the aircraft". In severe damage cases, it might be necessary for the flight crew to revert to the use of a "back to basics" flying techniques, where bank, pitch, and thrust are the primary parameters to manually control the aircraft. In addition, as for any flight phase, the flight crew must continue to perform all navigation and communication tasks.

If the damage significantly affects aircraft aerodynamics, flight controls, or engines, then aircraft handling qualities may be affected. Therefore, the flight crew should perform an assessment of aircraft handling qualities as soon as possible, in order to identify how pitch, roll, and yaw are controllable.

During assessment of the flight controls, the flight crew should apply smooth sidestick input and should limit the bank angle to 15 °, in order to prevent possible destabilization of the aircraft. In addition, the flight crew should avoid the use of the speedbrakes before the end of the flight, unless necessary.

To assess aircraft handling qualities, the flight crew must keep the following basic principles in mind:

- Elevators, ailerons, and rudder are the primary flight controls
- In addition to the use of the elevators, the use of the THS (via longitudinal trim control) may also be necessary in order to control pitch
- On all Airbus aircraft, engines are mounted under the wing. As a consequence, a thrust increase results in a pitch-up effect, and a thrust decrease results in a pitch-down effect
- If damage to the aircraft is severe, it may be necessary to use not-usual flying techniques to maintain control of the aircraft. Each flight control can be used to compensate for an inoperative or damaged surface. For example, the flight crew can compensate for a lack of roll efficiency via the use of rudder input. As another example, the application of asymmetrical thrust enables the flight crew to indirectly control roll, with a slightly delayed response.

CAUTION	Regardless of the airborne flight condition, and whatever the speed, the flight crew must not apply sudden, full or almost full, opposite rudder pedal inputs. These inputs can induce loads that are above the defined limit loads, and can result in structural damage or failure. The rudder travel limitation is not designed to prevent structural damage or failure in the event of such rudder system inputs.

As soon as control of the aircraft is ensured:

- Depending on the severity of the damage to the aircraft, the flight crew may attempt to use automation. However, if the autopilot and the flight director remain available, their operation may be erratic. Therefore, the flight crew should monitor carefully the AP behaviour, and must be prepared to immediately revert to manual flying techniques
- The flight crew can start ECAM actions, if applicable. An assessment of the indications in the cockpit may provide the flight crew with useful information about affected systems. When possible and depending on the situation, a visual check can also provide important information.

Prior to landing and at an appropriate altitude, the flight crew must perform an assessment of aircraft handling qualities in landing configuration in order to help determine an appropriate strategy for approach and landing. The flight crew must perform this analysis at different speeds down to VAPP . If it becomes difficult to control the aircraft when the aircraft goes below a specific speed, the flight crew must perform the approach landing at a speed above this specific speed. The result of the above-mentioned assessments helps to build the correct follow up strategy. The quantity of flight crew workload required to maintain control of the aircraft is one of the decision factors to take into account for this strategy. Good flight crew coordination is essential throughout the assessment process. The flight crew should share their own understanding and view of the situation with the other flight crewmembers.

UNRELIABLE AIR SPEED INDICATION

INTRODUCTION

In the very remote case where the flight crew detects unreliable air data indication (not detected by the aircraft systems), the flight crew must perform the memory items (if necessary) and apply the NAV UNRELIABLE AIR SPEED INDICATION abnormal not-sensed procedure.

L2 For more information on the memory items, *Refer to FCOM/PRO-ABN-NAV [MEM] UNRELIABLE AIR SPEED INDICATION*.

L1 The unreliable air speed indication procedure has two objectives:

- To confirm that the air data indication is not reliable, and isolate the ADR s (if necessary)
- Enable to fly the aircraft until landing.

The unreliable air speed indication procedure includes the following steps:

1. Memory items (if necessary)
2. Troubleshooting (with manual selection of the backup speed and backup altitude indications for display) and isolation of the ADR s (if necessary)
3. Use the backup speed and backup altitude indications to fly, if the troubleshooting confirms that the ADR s are not reliable.

WHEN TO APPLY THE UNRELIABLE AIR SPEED INDICATION PROCEDURE

The flight crew should consider applying this procedure when they suspect an erroneous speed or altitude indication (not detected by the aircraft systems).

L2 For more information on the ADIRS monitoring, *Refer to FCOM/DSC-34-NAV-20-10-50 ADIRS Monitoring*.

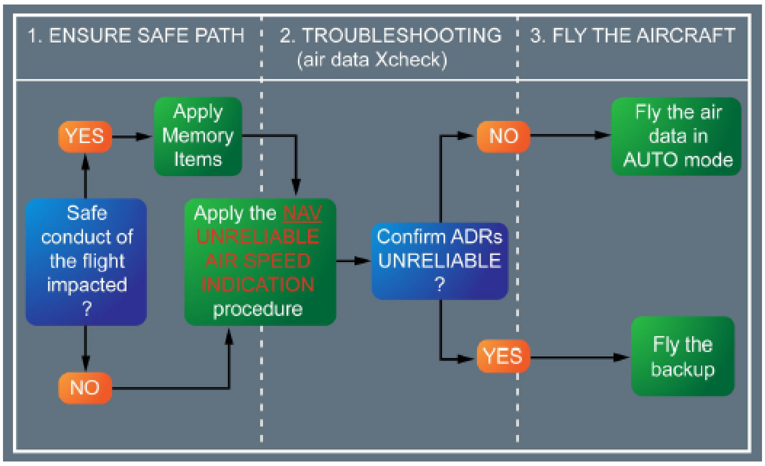
L1 The flight crew can suspect an erroneous speed or altitude indication, in any of the following cases:

1. Fluctuating or unexpected variations in the indicated airspeed or altitude
2. Abnormal correlation between the basic flight parameters (i.e. pitch, thrust, airspeed, altitude and vertical speed indications).
   For example, an erroneous speed or altitude indication can be suspected when one of the following applies:
   - The altitude does not increase, although there is a significant nose-up pitch and high thrust
   - The IAS increases, although there is a significant nose-up pitch
   - The IAS decreases, although there is a significant nose-down pitch
   - The IAS decreases, although there is a nose-down pitch and the aircraft descends.
3. An abnormal behavior of the AP / FD and/or the A/THR
4. The STALL warning triggers and this is in contradiction with the indicated airspeeds. In this case, the flight crew should rely on the STALL warning. Erroneous airspeed data does not affect the STALL warning, because the STALL warning is based on the Angle Of Attack (AOA)
5. The OVERSPEED warning triggers and this is in contradiction with the indicated airspeeds. Depending on the situation, the OVERSPEED warning may be false or justified. When the OVERSPEED VFE warning triggers, the appearance of aircraft buffet is a symptom that the airspeed is indeed excessive
6. The barometric altitude is not consistent with the RA height (when the RA height is displayed)
7. The aerodynamic noise reduces whereas the indicated airspeed increases, or vice versa.

Note: *Due to the fact that the barometric altitude may be erroneous, the aircraft may not be able to accurately maintain level flight. In addition, the ATC transponder may transmit an incorrect altitude to ATC or to other aircraft, which can lead to confusion. Therefore, the flight crew should advise ATC of the situation without delay.*

HOW TO APPLY THE UNRELIABLE AIR SPEED INDICATION PROCEDURE

This procedure is divided into three different phases, as follows:



The flight crew must ensure a safe path. If safe conduct of the flight is affected, the flight crew must apply the memory items.

Safe conduct of the flight is affected when the flight crew is not sure to be able to safely fly the aircraft in the short term, with the current parameters, i.e.:
- The flight crew has lost situation awareness, or
- The current pitch and thrust settings are not appropriate for the current flight conditions, or
- The aircraft has an unexpected flight path for the current flight conditions.

The memory items enable the flight crew to rapidly establish safe flight conditions for a limited period of time, in all phases of flight, and aircraft configurations (i.e. weight, landing gear, and slat/flaps). If the flight crew flies the aircraft with the pitch/thrust values of the memory items for an extended period of time, they may exceed the speed limits of the aircraft. Therefore, the