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Getting to grips with Surveillance

AIRBUS

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FOREWORD

The present brochure describes the surveillance in the broad sense of the term, from an airborne system perspective (TCAS, Transponder, WXR, TAWS, ROPS….).

The present brochure provides supplementary information to existing Flight Operations documents (FCOM, FCTM). Therefore, the present brochure intentionally limits the set of recommendations. Please refer to existing Flight Operations documents for the complete set of recommendations.

This document is presented for information only, and is not intended to replace ICAO guidelines or National Aviation Authorities (NAA) mandated requirements. The content does not supersede or amend any Airbus type-specific AFM, AMM, FCOM, MMEL, FCTM, ACD or SB.

All brochure holders and users are encouraged to send their questions and suggestions about this document to the following contact:

Tech Request

TechRequest on www.airbusworld.com.
Category: Flight operations / Other topics / CNS/ATM.

ABBREVIATIONS

DEFINITIONS

For the purpose of this document, the following definitions apply:

A

A/C	Aircraft
A/THR	Auto Thrust
ABV	Above
AC	Advisory Circular
ACAS	Aircraft Collision Avoidance System
ACSS	Aviation Communication & Surveillance Systems
ADB	Airport Data Base
ADIRU	Air Data and Inertial Reference Unit
ADR	Air Data Reference
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
AESS	Aircraft Environment Surveillance System
AESU	Aircraft Environment Surveillance Unit
AFM	Aircraft Flight Manual
AFS	Automatic Flight System
AGL	Above Ground Level
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIRB	Airborne
ALA	Approach and Landing Accident
ALAR	Approach and Landing Accident Reduction
ALT RPTG	Altitude Reporting
AMC	Acceptable Means of Compliance
AMDB	Airport Mapping Data Base
AMI	Airline Modifiable Information
AMM	Aircraft Maintenance Manual
ANF	Airport Navigation Function
ANSP	Air Navigation Service Provider
AOA	Angle Of Attack
AOC	Airline Operations Control
AP	Auto Pilot
ARN	Aircraft Registration Number
ASAS	Airborne Separation Assistance System
A-SMGCS	Advanced - Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATS	Air Traffic Service
ATSA or ATSAW	Airborne Traffic Situational Awareness
ATSU	Air Traffic Service Unit

B

BCS	Braking Control System
BLW	Below
BTV	Brake To Vacate

C

CAA	Civil Aviation Authority
CASA	Australian Civil Aviation Safety Authority
CASCADE	Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC
CAT	Clear Air Turbulence
CBT	Computer-Based Training

CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CMV	Concentrator and Multiplexer for Video
CNS/ATM	Communication Navigation Surveillance / Air Traffic Management
CPA	Closest Point of Approach (ACAS)
CPA	Collision Prediction and Alerting (TAWS)
CPDLC	Controller Pilot Data Link Communication
CRISTAL	Co-operative Validation of Surveillance Techniques and Applications
CSD	Customer Service Director

D

DCDU	Datalink Control and Display Unit
DCPC	Direct Controller-Pilot Communication
DMC	Display Management Computer
DME	Distance Measuring Equipment
DSNA	Direction des Services de la Navigation Aérienne
DU	Display Unit

E

EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
ECAM	Electronic Centralized Aircraft Monitoring
EFIS	Electronic Flight Instrument System
EFIS CP	EFIS Control Panel
EGPWM	Enhanced Ground Proximity Warning Module
EGPWS	Enhanced Ground Proximity Warning System
EHS	Mode S Enhanced Surveillance
EIS	Electronic Instrument System
ELS	Mode S Elementary Surveillance
EMMA2	European airport Movement and Management by A-SMGCS
EPE	Estimated Position Error
EPU	Estimated Position Uncertainty
EWD	Engine and Warning Display

F

FAA	Federal Aviation Administration
FAC	Flight Augmentation Computer
FANS	Future Air Navigation Systems
FC	Flight Crew
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Techniques Manual
FCU	Flight Control Unit
FD	Flight Director
FDE	Fault Detection and Exclusion
FE	Flight Envelope
FLS	FMS Landing System
FM	Flight Management
FMA	Flight Mode Annunciator
FMGEC	Flight Management Guidance and Envelope Computer
FMS	Flight Management System
FOBN	Flight Operations Briefing Note
FPA	Flight Path Angle
FSF	Flight Safety Foundation
FWS	Flight Warning System

G

G/S	Glide Slope
GCAS	Ground Collision Avoidance System
GCS	Ground Clutter Suppression
GPIRS	Global Positioning and Inertial Reference System
GPS	Global Positioning System
GPS-SU	GPS Single Unit

GPWC	Ground Proximity Warning Computer
GPWS	Ground Proximity Warning System
GS	Ground Speed

H

HFOM	Horizontal Figure Of Merit
HIL	Horizontal Integrity Limit
HPL	Horizontal Protection Limit

I

IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
ID	Identification
IMC	Instrument Meteorological Conditions
IR	Inertial Reference
ITP	In Trail Procedure

K

KCCU	Keyboard and Cursor Control Unit

L

LAHSO	Land And Hold Short Operations
LDA	Landing Distance Available
LDG	Landing
LGERS	Landing Gear Extension and Retraction System
LSK	Line Select Key

M

MAC	Mean Aerodynamic Chord
MCDU	Multipurpose Control & Display Unit
MFD	Multi Function Display
MMEL	Master Minimum Equipment List
MMO	Maximum Operating Mach
MMR	Multi-Mode Receiver
MNPS	Minimum Navigation Performance Specification
MSL	Mean Sea Level
MTCD	Minimum Terrain Clearance Distance
MTOW	Maximum Take Off Weight

N

NAC	Navigational Accuracy Category
NAS	National Airspace System
NASA	USA National Aeronautics and Space Administration
NATOTS	North Atlantic Organized Track System
NATS	National Air Traffic Services (UK)
ND	Navigation Display
NGATS or NextGen	Next Generation Air Transportation System (USA)
NIC	Navigational Integrity Category
NLC	Noctilucent Cloud
NOTAM	Notice To Air Men
NPRM	Notice of Proposed Rule Making
NUC	Navigation Uncertainty Category

O

OANS	On-board Airport Navigation System
OIT	Operator Information Telex
OTS	Organized Track System

P

P/N	Part Number
PAC	Path Attenuation Compensation
PANS-ATM	Procedures for Air Navigation Services - Air Traffic Management
PANS-OPS	Procedures for Air Navigation Services - Operations
PANS-RAC	Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services
PBCS	Performance-Based Communication and Surveillance
PDA	Premature Descent Alert
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Non Flying
PPOS	Present Position
PRIM	Primary Flight Control and Guidance Computer
PSR	Primary Surveillance Radar
PWS	Predictive Wind Shear

R

R/T	Receiver / Transmitter
RA	Radio Altitude
RA	Resolution Advisory (ACAS)
RAAS	Runway Awareness and Advisory System
RADAR	Radio Detection And Ranging

RAIM	Receiver Autonomous Integrity Monitoring
RCD	RAAS Configuration Database
RCP	Required Communication Performance
RFCF	Runway Field Clearance Floor
RMP	Radio Management Panel
RNP AR	Required Navigation Performance Authorization Required
ROP	Runway end Overrun Protection
ROT	Runway Occupancy Time
ROW	Runway end Overrun Warning
RSP	Required Surveillance Performance
RTO	Rejected Take Off
RVSM	Reduced Vertical Separation Minima
RWY	Runway

S

S&M	Sequencing and Merging
SA	Selective Availability
SARPs	Standards And Recommended Practices
SAT	Static Air Temperature
SB	Service Bulletin
SCP	Soft Control Panel
SF	Severity Factor
SIL	Service Information Letter
SIL	Surveillance Integrity Level
SKM	Systems Knowledge Modules
SMR	Surface Movement Radar
SOP	Standard Operating Procedure
SPI	Special Position Identification
SPP	Soft Pin Programming
SQWK	Squawk
SSR	Secondary Surveillance Radar
STBY	Stand-By
STC	Sensitivity Time Control
SURF	Surface

T

T/TISS	Traffic and Terrain Integrated Surveillance System
T2CAS	Traffic and Terrain Collision Avoidance System
T3CAS	Transponder, Traffic and Terrain Collision Avoidance System
TA	Traffic Advisory
TAAATS	The Australian Advanced Air Traffic System
TAU	It is not an acronym but the Greek letter τ
TAWS	Terrain Awareness and Warning System
TCAS	Traffic alert and Collision Avoidance System
TCF	Terrain Clearance Floor
THD	Terrain Hazard Display
THRT	Threat
TIBA	Traffic Information Broadcasts by Aircraft
TOS	Take-Off Securing
TOM	Take-Off Monitoring

U

UAP	Upper Airspace Program (Australia)
UAT	Universal Access Transceiver

V

V/S	Vertical Speed
VD	Vertical Display
VDL	VHF Data Link
VLS	Lowest Selectable Speed
VMC	Visual Meteorological Conditions
VMO	Maximum Operating Speed
VSA	Visual Separation on Approach
VSI	Vertical Speed Indicator

W

WAM	Wide Area Multi-lateration
WGS84	World Geodetic System revised in 1984
WX	Weather
WXR	Weather Radar

X

XLS	Landing System (ILS, FLS, GLS)
XPDR	Transponder

REFERENCES

REF 1 ICAO documents available at http://www.icao.int/icao/en/sales:

- **Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM), Doc 4444,** Sixteenth Edition, 2016.
- **Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS), Doc 8168,** Fifth Edition, 2006.
- **Regional Supplementary Procedures, Doc 7030,** Fifth Edition, 2008,
- **Manual on Low-level Wind Shear and Turbulence, Doc 9817,** First Edition, 2005.
- **Airborne Collision Avoidance System (ACAS) Manual, Doc 9863,** Second Edition, 2012.
- **Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services, Doc 8585,** Edition 185, July 2018.
- **Operation of Aircraft – International Commercial Air Transport – Aeroplanes, Annex 6, Part I,** Eleventh Edition, July 2018.
- **Aeronautical Telecommunications – Communication Procedures including those with PANS status, Annex 10, Volume II,** Seventh Edition, July 2016.
- **Aeronautical Telecommunications – Surveillance and Collision Avoidance Systems, Annex 10,** Volume IV, Fifth Edition, July 2014.
- **Air Traffic Services, Annex 11,** Fifteenth Edition, July 2018.

REF 2 Eurocontrol documents:

- **ACAS II Bulletins** available at https://www.eurocontrol.int/publications?title=&field_term_publication_type_tid=233&year[value][year]=
- **Additional information on Mode S transponder, ADS-B, WAM technologiers** available at https://www.eurocontrol.int/

REF 3 European Aviation Safety Agency (EASA) documents:

- **Rules of Air Operations,** AIR-OPS, (EU) 965/2012.
- **Certification Considerations for the communication, navigation and surveillance systems,** AMC 20-24 and CS-ACNS available at https://www.easa.europa.eu/regulations

REF 4 Federal Aviation Administration (FAA) documents:

- **Aviation Weather for Pilots and Flight Operations Personnel,** AC 00-6A, January 1975.
- **Thunderstorms**, AC 00-24B, January 1983.
- **Atmospheric Turbulence Avoidance,** AC 00-30B, September 1997.

- **Pilot Wind Shear Guide,** AC 00-54, November 1988.
- **Recommended Radiation Safety Precautions for Ground Operation of Airborne Weather Radar**, AC 20-68B, August 1980.
- **Airworthiness Criteria for the Approval of Airborne Wind Shear Warning Systems in Transport Category,** AC 25-12, November 1987.
- **Aircraft Wake Turbulence,** AC 90-23F, February 2002.
- **Guidelines for Operational Approval of Wind Shear Training Programs,** AC 120-50A, September 1996.
- **Aircraft Surveillance Systems and Applications,** AC 120-86, September 2005.
- **Automatic Dependent Surveillance—Broadcast (ADS–B) Out systems,** AC 20-165B, December 2015,
- **Recent Rulemaking** available at http://www.faa.gov/regulations_policies/

  http://www.faa.gov/regulations_policies/rulemaking/recently_published/.

REF 5 Civil Aviation Safety Authority (CASA) Australia documents available at http://www.casa.gov.au:

- **Airworthiness Approval of Airborne Automatic Dependent Surveillance Broadcast Equipment,** AC 21-45, April 2007,.
- **Civil Aviation Order 20.18.**

REF 6 Airservives Australia documents about ADS-B operations available at http://www.airservicesaustralia.com/projects/ads-b/

- **Flight Operations Information Package,**
- **CASA Pilot Information Booklet.**

REF 7 Transport Canada documents:

- **Automatic Dependent Surveillance – Broadcast,** AC 700-009, Second edition, November 2011, available at http://www.tc.gc.ca/CivilAviation/IMSdoc/ACs/menu.htm.

REF 8 NAV Canada documents:

- **Introduction of Automatic Dependent Surveillance Broadcast (ADS-B) Airspace in the Vicinity of Hudson Bay,** AIP ENR 1.6 available at http://www.navcanada.ca/EN/products-and-services/Pages/AIP-part-2-current.aspx.
- **NAV CANADA ADS-B Information Brochure** available at http://www.navcanada.ca/EN/products-and-services/Pages/on-board-operational-initiatives-ads-b.aspx

REF 9 Flight Safety Foundation publications on Approach-and-Landing Accidents (ALA) and Controlled Flight Into Terrain (CFIT) at http://www.flightsafety.org (“Technical Initiatives” section: ALAR and CFIT).

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REF 10 Flight Crew Operating Manual (FCOM) as available in your company.

REF 11 Flight Crew Techniques Manual (FCTM) as available in your company.

REF 12 Systems Knowledge Modules (SKM), computer Based Training (CBT), e-learning/e-training, ACE training, Flight Crew Courses, as per your aircraft model.

https://services.airbus.com/training

https://www.airbus.com/aircraft/support-services/training.html

REF 13 Safety First Magazine on Airbus World (Content Library/ publications) at https://w3.airbus.com/newairbusworld/faces/Home?_afrLoop=4611562144519623&_afrWindowMode=0&_afrWindowId=null&_adf.ctrl-state=nh23zyupy_1#!%40%2Forace%2Fwebcenter%2Fportalapp%2Fpages%2FcontentCatalogue.jspx%40%3F_adf.ctrl-state%3Dnh23zyupy_5

REF 14 In-Service Information (ISI) on Airbus World at www.airbusworld.com_

REF 15 ADS-B OUT Capability Declaration as referenced in your AFM.

REF 16 TECHREQUEST tool. Contact us using Techrequest tool or ask your Flight Operations Support Director (FOSD).

REF 17 Getting to grips with FANS on Airbus World in Content Library/ Flight operations/operational expertise at

https://w3.airbus.com/newairbusworld/faces/Home?_afrLoop=4611562144519623&_afrWindowMode=0&_afrWindowId=null&_adf.ctrl-state=nh23zyupy_1#!%40%2Forace%2Fwebcenter%2Fportalapp%2Fpages%2FcontentCatalogue.jspx%40%3F_adf.ctrl-state%3Dnh23zyupy_5.

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#0 INTRODUCTION

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Since the advent of the air transportation, safety has been the keystone of this business. Safety rests on three pillars, which are **Communication**, **Navigation** and **Surveillance**. Communication and Navigation had been developed before the air transportation became massive. The traffic getting denser and denser, Surveillance became more and more necessary.

The very first survt eillance tool appeared in the 1930's: the radar. Widely used during the Second World War, the radar has come into general use for various purposes (air traffic control, weather monitoring, road speed control, etc). While the air traffic becomes denser, safety calls for new surveillance tools other than the radar. Thus, several surveillance systems were developed like:

- The **Transponder that works with the ground Secondary Surveillance Radar (SSR)**
- The **Traffic Collision Avoidance System (TCAS)**
- The **Terrain Awareness and Warning System (TAWS)**
- The **Weather Radar (WXR)**

All these systems work for a better awareness of the traffic and the environment around the aircraft for either the flight crew or the air traffic controller.

Today technology allows getting a more accurate awareness of traffic and environment, and support flight crew with new functions. This is the purpose of **Automatic Dependent Surveillance – Broadcast (ADS-B)**, **Airborne Traffic Situational Awareness (ATSAW)**, **Runway Overrun Prevention System (ROPS), Take-Off Securing (TOS), or Weather Ahead** functions. And the constant traffic growth will call for other new systems to meet the safety requirements.

In three paragraphs, the reader may have noticed the endless list of surveillance systems available in the cockpit. Therefore, **the aim of this brochure** is for our customers:

- Already equipped with one of these systems:
  - To decode all these acronyms
  - To understand how these systems work
  - To efficiently use these systems.
- Not equipped with some of these systems: to select the right systems according to their needs.

NOTE:

These systems may be integrated in a single box to reduce their size and weight, and ease the management of the spares:

Honeywell proposes the Aircraft Environment Surveillance System (AESS) on A350/A380 aircraft. AESS is composed of SSR with ADS-B +TCAS+TAWS+WXR systems.

ACSS proposed the T2CAS and T3CAS on A320/A330/A340 aircraft. T2CAS is composed of TCAS+TAWS System. ACSS T2CAS has been superseded by T3CAS. T3CAS is composed of TCAS+TAWS+Transponder (SSR with ADS-B).

0.1 WHAT IS SURVEILLANCE?

The definition of surveillance is a question of perspective: either flight crew's perspective or air traffic controller's one.

0.1.1 SURVEILLANCE FROM THE FLIGHT CREW'S PERSPECTIVE

At the flight crew level, there are two kinds of surveillance: the air-to-ground surveillance and the air-to-air one.

Flight crews and air traffic controllers commonly share the **air-to-ground surveillance**. The air-to-ground surveillance enables the air traffic controller to manage the traffic in a safe and efficient manner. The air-to-ground surveillance uses:

- When inside radar coverage, the well-known transponder coupled with SSR
- When outside radar coverage, voice position reports at regular intervals or ADS-C application
- In specific areas, ADS-B.

The **air-to-air surveillance** is in the interest of flight crews only. It provides the flight crew with:

Assistance to build an aircraft environment awareness regarding external hazards (traffic, terrain, weather)

Alerts against these external hazards.

0.1.2 SURVEILLANCE FROM THE AIR TRAFFIC CONTROLLER'S PERSPECTIVE

At the air traffic controller level, the surveillance may be either **cooperative** or **non-cooperative**, **dependent** or **independent** according to the type of the ground receiver and the aircraft equipment. Refer to 1 - Aircraft identification and position reporting for more details.

0.2 HOW TO READ THE BROCHURE?

It is agreed that there is a wealth of literature about aircraft systems available for pilots (e.g. FCOM, FCTM). Consequently, the present brochure does not supersede documents that already exist. The present brochure provides information to:

- Better understand how surveillance systems work
- Compare different surveillance systems that fulfill the same function
- Describe new surveillance systems expected in the near future.

0.2.1. SURVEILLANCE SYSTEMS AND FUNCTIONS

The present brochure describes surveillance systems from an operational perspective. Therefore, each chapter of the present brochure describes a surveillance function. Each surveillance function refers to one or several systems.

The 5 main surveillance functions are:

1. **The Aircraft Identification and Position Reporting:** The most commonly used system is the transponder coupled with a SSR. But other systems like ADS-C or ADS-B are available to fulfill this function.
2. **The Traffic Surveillance:** The well-known TCAS provides alerts and guidance to avoid aircraft that are too close. The ATSAW application clearly identifies surrounding aircraft and their characteristics (e.g. heading, speed, wake vortex category, etc).
3. **The Terrain Surveillance:** Enhanced Ground Proximity Warning System (EGPWS) and TAWS module of Traffic and Terrain Collision Avoidance System (T2CAS) are TAWS to prevent Controlled Flight Into Terrain (CFIT).
4. **The Airport Surveillance:** OANS/ANF displays the aircraft position on an airport map to improve the flight crew situational awareness. The ROW/ROP and TOS functions provide warnings (visual and aural) and protection during approaches and take-off. RAAS is a module of EGPWS and provides aural messages regarding the aircraft position on or out the runway.
5. **The Weather Surveillance:** The weather radar detects and displays wet meteorological activities (i.e. clouds, precipitations, turbulence) on Navigation Displays (NDs). The weather detection uses different methods (Autotilt, Multiscan, or 3D buffer) according to the manufacturer.

These surveillance function can be combined in one single system. For instances:

T3CAS combines Aircraft Identification and Position Reporting, Traffic Surveillance, and Terrain Surveillance.

AESS combines all the function above except the Runway Surveillance.

0.2.2. CHAPTER STRUCTURE

Each of the following chapters describes one of the five functions listed above. For an easy reading, all of the chapters apply the same structure as follows:

- **Description of the system** that fulfills the function described in the chapter.
- **Operational recommendations** for safe and efficient operations.
- **Regulations** in terms of carriage requirements at ICAO, EASA and FAA levels (for other areas, refer to local regulations).
- **Manufacturers** of systems that fulfill the function to identify the different available solutions.
- **Way Forward** expected in the near future to improve the fulfillment of the function.

Each time several systems of fairly different technologies fulfill a given function, the description of each system follows the same structure. Therefore, it is easier to compare the systems.

At the end of each chapter, a summary provides the essential information: **"Please bear in mind…"**.

NOTE:

The description of a system focuses on the basic principles. Consequently, a system is not exhaustively described. For instance, the Electronic Centralized Aircraft Monitoring (ECAM) alerts when a failure occurs are not described. The reader should refer to her/his Flight Crew Operating Manual (FCOM) when necessary.

0.2.3. CAPTIONS

Light yellow highlight summaries "Please bear in mind…"

Dark blue Highlight tips and important remarks

OPS+

An OPS+ flag identifies features that provide significant operational benefits.

#01 AIRCRAFT IDENTIFICATION AND POSITION REPORTING

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1.8. WAY FORWARD

Since the beginning of the aviation history, air traffic controllers have used the surveillance radar for years. Today, other surveillance methods are available with the emergence of new technologies: Automatic Dependent Surveillance – Contract (ADS-C), Automatic Dependent Surveillance – Broadcast (ADS-B), and Wide Area Multilateration (WAM). These new surveillance methods aim at the same goal: the fulfillment of the aircraft identification and position reporting function in areas where the installation of radar is not cost-effective.

Regardless of the technology, a surveillance method may be either:

- **Dependent:** The aircraft sends its position to the ground station, or
- **Independent:** The aircraft does not send any position data to the ground station. The ground station calculates the aircraft position, or
- **Cooperative:** The method requires an active system onboard the aircraft, or
- **Non-cooperative:** The method does not require any system onboard the aircraft.

	INDEPENDENT	DEPENDENT
Non-cooperative	PSR	
Cooperative	SSR – Mode A, C, S, WAM	ADS-C, ADS-B

This chapter reviews all the surveillance methods available for the aircraft identification and position reporting function.

1.1. DESCRIPTION OF TRANSPONDER

The aircraft identification and position reporting function requires a transponder onboard where a Secondary Surveillance Radar (SSR[1]) is in operation. The SSR interrogates the transponder on 1030 MHz and waits for a reply from the transponder on 1090 MHz (refer to Figure 1-1). Based on this principle, the SSR operates in three different modes: Mode A, Mode C, and Mode S.

The interrogation mode determines the reply content. For instance, when the ground station interrogates an aircraft for its altitude, the transponder replies in Mode C. Other modes exist (Modes 1, 2, 4 and 5) but they are used in military aviation only.

Surveillance method based on SSR is:

- **Cooperative** as the SSR interrogates the airborne transponders to identify the aircraft
- **Independent** as the SSR calculates the horizontal[2] aircraft position (i.e. bearing) according to the signal from the transponder reply.

The Primary Surveillance Radar (PSR) is used for military purposes, as it detects any vehicles that reflect the radar signal, and for civilian purposes coupled with an SSR. The surveillance method using a PSR is then non-cooperative and independent.

Figure 1-1: SSR interrogation and transponder reply

1 In some documents, the reader may find the acronym ATCRBS for Air Traffic Control Radar Beacon System. It designates the SSR.

2 The SSR determines the altitude via a Mode C interrogation. The transponder includes the barometric altitude in its reply.

Most readers would certainly know what are behind Mode A and Mode C, as they have operated these modes for years. But, recently the reader may have heard about the Mode S and various designations (e.g. ELS, EHS, extended squitter, ADS-B). The following paragraphs provide the reader with a clear view of the different modes.

1.1.1. MODE A

When a SSR interrogates a transponder in Mode A, the transponder replies with the aircraft identification (**SQWK code** – also called **Mode A code** – on four octal digits from 0000 to 7777). The SQWK code format permits 4096 different codes.

The ATC controller may have difficulties to differentiate aircraft:

- When an aircraft enters the ATC sector and transmits the same SQWK code than another aircraft already present in the ATC sector, or
- When plots of several aircraft on the ATC controller's screen appear in a small area.

The **IDENT function** (also called **Special Position Identification, SPI**), when activated by the flight crew, highlights the aircraft plot on the ATC controller's screen. This function is available in Mode A, C, or S.

1.1.2. MODE C

When a SSR interrogates a transponder in Mode C, the transponder replies with **the aircraft barometric altitude.**

1.1.3. MODE S (ELS/EHS/ADS-B)

When a SSR interrogates a transponder in Mode S, the transponder replies with a large set of surveillance data (e.g. flight number, 24-bit address, speeds, heading, track, selected altitude, air/ground status, etc).

There are three types of interrogation:

1. **All Call interrogation:** All Mode A and C transponders reply. Mode S transponders do not reply to this interrogation.
2. **Mode S All Call interrogation:** It is a variant of the All Call interrogation where only Mode S transponders reply. The reply contains the 24-bit address that enables selective interrogations.
3. **Selective[3] interrogation:** The SSR selectively interrogates a Mode S transponder.A selective interrogation prevents multiple replies from other transponders and alleviates the occupancy of the reply frequency. In Mode S, the SSR uses the 24-bit address to interrogate a selected aircraft. Refer to 1.1.3.6 – 24-bit Address or Mode S Address.

A Mode S transponder is able to respond to Modes A and C interrogations.

A Mode S SSR is either basic or capable of **Elementary Surveillance (ELS)/ Enhanced Surveillance (EHS)**/ADS-B OUT:

3 Mode S stands for Selective.

- **Basic:** The Mode S SSR performs selective interrogations to a given aircraft in order to get the SQWK code via Mode A, the altitude via Mode C, and other information (e.g. Airborne/Ground status).
- **Capable of ELS/EHS:** In addition to the basic capability, ELS and EHS interrogations enable the collection of several data, on ground requests, such as the flight number, speeds, heading, track, selected altitude, etc.
- **Capable of ADS-B OUT:** In addition to the basic capability, ADS-B OUT squitters enable the collection of several data automatically, such as the aircraft latitude and longitude, flight number, speeds, heading, track, selected altitude, etc.

Thanks to the Mode S, the ground can selectively collect a large set of data. Therefore, the reader may find the designation "Mode S data link" in the literature.

COMM A and COMM B

Comm A is communication protocol for an interrogation of 56 or 112 bits on 1030 MHz from the ground to the aircraft.

Comm B is a communication protocol for a reply of 56 or 112 bits on 1090 MHz (following a Comm A interrogation) from the aircraft to the ground. The Mode S ELS/EHS is sometimes called GCIB. It indicates that data are transmitted following an interrogation from the ground. GCIB is different from Extended Squitters (refer to 1.1.3.8 – Extended Squitter) that transmit data without solicitation.

1.1.3.1. ELEMENTARY SURVEILLANCE (ELS)

The Elementary surveillance refers to a set of Mode S data link messages. These messages convey parameters such as:

- The aircraft 24-bit address,
- The flight number,
- The aircraft altitude,
- The RA report, etc.

1.1.3.2. ENHANCED SURVEILLANCE (EHS)

The Enhanced surveillance refers to the data link message set of the Elementary surveillance plus an additional set of data link messages. These additional messages convey parameters such as:

- The selected altitude,
- The barometric pressure setting,
- The roll angle,
- The track angle rate,
- The true track angle,
- The ground speed,
- The true air speed,
- The magnetic heading,
- The indicated airspeed,
- The Mach number, etc.

THE MODE S LEXICON

The entry into operation of Mode S introduces new terms. Hereinafter, the Mode S lexicon describes the main terms.

24-BIT ADDRESS OR MODE S ADDRESS

The 24-bit address is also called Mode S address of aircraft ICAO code. The 24-bit address format permits 16 777 216 different addresses. Therefore, each aircraft has its own 24-bit address, and a selective interrogation is possible.

The State of Registry delivers the 24-bit address with the aircraft registration documents. The 24-bit address is usually given on 6 digits (hexadecimal format) or on 8 digits (octal format).

NOTE:

A specific mode called COMM B Broadcast indicates in mode S replies to the ground that a TCAS RA event or modification of the Flight Number occurred.

NOTE:

ADS-B OUT should not be confused with ADS-B IN. From the own aircraft perspective, ADS-B IN refers to the capability to acquire, process and provide to the flight crew surveillance data from other aircraft capable of ADS-B OUT. ADS-B IN is part of a TCAS capable of ATSAW function, Air Traffic Situational Awareness. Refer to 2.2 – Description of ATSAW.

1.1.3.3. AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST OUT (ADS-B OUT)

ADS-B OUT is an application to transmit surveillance data from aircraft to ATC ground stations and between aircraft themselves, and to receive surveillance data from other aircraft.

Automatic: No action is required from the flight crew.

Dependent: The aircraft provides the surveillance data to the ATC ground station. The GPS sensor provides aircraft position and speed for ADS-B transmission.

Surveillance: The ATC controller or flight crews from other aircraft use data broadcast from own aircraft to have a picture of the traffic.

Broadcast: In opposition to Modes A, C, and S operations, ADS-B periodically transmits surveillance data to the ATC ground station without preliminary interrogation from a ground station. Compared to ADS-Contract (ADS-C, refer to 1.4 – Aircraft identification and Position Reporting with FANS), ADS-B transmits surveillance data to the ATC ground station (ADS-B OUT), without specific connection between the aircraft and the ATC ground station.

ADS-B MEDIUM

The **1090 MHz Extended Squitter (1090 ES)** is the medium used to transmit ADS-B data on large commercial aircraft such as Airbus aircraft. The reader may find another medium to transmit ADS-B data: the 978 MHz **Universal Access Transceiver (UAT)**, that is only used in US airspace by general aviation.

EXTENDED SQUITTER

A squitter is an unsolicited transmission. Distance Measuring Equipment (DME) was the first equipment to use squitters. The ground DME station broadcast squitters. When the aircraft is in the range of the ground DME station, the airborne DME unit receives the squitter. Then, the airborne DME unit interrogates the ground DME station to get the range information. The use of squitters prevents unnecessary transmissions.

In ADS-B operations, a squitter designates the set of surveillance data broadcast by a Mode S transponder capable of ADS-B OUT. Squitters from Mode S transponders are of two types: short (56 bits) or extended (112 bits). The short **squitter** contains the aircraft 24-bit address amongst other pieces of information (communication protocol information on 32 bits). The **extended squitter** contains in addition, but not limited to:

- Longitude, latitude, barometric altitude, GPS height, surveillance status, etc.
- Movement, ground track, etc.
- Flight number, aircraft category, etc.
- Aircraft intention: selected altitude, selected heading, barometric pressure setting.
- GPS velocity, vertical rate, etc.

NOTE:

- The update rate of the transmitted date may vary from à 0.5 seconds to 5 seconds depending on the data type and flight phase (airborne or on-ground)
- The aircraft category identifies several types of category: From "no reporting" to surface vehicle or space vehicle (with light, medium, or heavy sub-categories representing the turbulence class for the aircraft).

TRANPONDER IN STBY MODE MAKES TCAS SWITCHING TO STBY

When the flight crew set the transponder to STBY or the altitude reporting to OFF, the TCAS switches to its STBY mode (i.e. green TCAS STBY memo on EWD or MEMO display, no TCAS information on PFD and ND). Indeed, the TCAS is not able to determine the vertical separation with the intruder and then not able to evaluate the maneuver to avoid the threat. Refer to **2.1.1.4 – Collision Threat Evaluation.**

NOTE:

The flight crew must not confuse the transponder STBY mode with the TCAS STBY mode. Refer to Safety First Magazine, Edition #4, June 2007 "Do you know your ATC/TCAS panel?" (See AIRBUS References):

On board an aircraft departing from London Heathrow, a serious incident occurred. The flight crew switched the transponder STBY. The aircraft became invisible to ATC radar beacon. The flight crew confuses the TCAS STBY mode with the XPDR STBY mode, following an ECAM procedure (TCAS MODE .....STBY).

TCAS also uses the short squitter (also called acquisition squitter) from Mode S transponder. The own aircraft TCAS listens to short squitters from surrounding aircraft Mode S transponders to detect surrounding aircraft. Surrounding aircraft are identified with their 24-bit address. When TCAS detects a new surrounding aircraft (i.e. a new 24-bit address via the acquisition squitters), TCAS starts selective interrogations and tracking of this new surrounding aircraft. Refer to 2.1.1 – TCAS Principle.

From the own aircraft perspective, ADS-B OUT refers to the capability to broadcast (i.e. to transmit without preliminary interrogation) surveillance data. This capability is part of Mode S transponders installed on AIRBUS aircraft. Refer to 1.2 – Aircraft Identification and Position Reporting with ADS-B. All Mode S transponders compliant with ELS and EHS fitted on AIRBUS aircraft are capable of ADS-B OUT.

1.1.4. TRANSPONDER CONTROLS

The transponder operating modes are the following: STBY, AUTO, ON. In addition, the flight crew may set the altitude reporting function to OFF or ON.

In AUTO mode, when the aircraft is on ground, the transponder inhibits Modes A and C replies and Mode S All Call replies. But Selective Mode S replies and squitters (including ADS-B OUT) are still active.

For more details, please refer to your FCOM in aircraft system description of ATA 34 SURV.

Several ATC/TCAS panels are available for A300/A310/A320/A330/A340 aircraft. An airline may choose one single ATC/TCAS panel for all its entire fleet regardless of the transponder model. Figure 1-2 gives an example of ATC/TCAS panel. Other ATC/TCAS panels are illustrated at https://www.gableseng.com/gei/products/product-category/surveillance/

Figure 1-2: Example of ATC/TCAS panel

Figure 1-3: Secondary Radar (left) and Primary Radar (right)

Figure 1-4: ADS-B ground receiver

1.2. AIRCRAFT IDENTIFICATION AND POSITION REPORTING WITH ADS-B

The objectives of aircraft identification and position reporting with ADS-B are to:

- Provide surveillance services where SSR does not exist. There are some areas where the weak air traffic does not justify the installation of SSR. However, the provision of surveillance services may greatly improve the air traffic management.
- Decommission redundant SSR installations. Indeed, several SSR may cover a same airspace, especially near international boundaries. The use of ADS-B instead of SSR should reduce ATC charges.

The benefits of ADS-B upon SSR are:

- **Cost effectiveness:** as the ADS-B receiver is far less complex than the SSR (e.g. the ADS-B receiver does not have any moving parts contrary to SSR with a rotating antenna), an ADS-B receiver costs ten time less than a SSR
- **Better surveillance quality** thanks to GPS position[4] and higher refresh rate (ADS-B: 0.5 s, SSR: 5 s)
- **Improved traffic situational awareness in the cockpit** thanks to ADS-B IN applications (refer to 2.2.1 – Description of ATSAW)
- **Reduced electro-magnetic pollution** thanks to the use of squitters. Contrary to SSRs, ADS-B receivers do not emit any signals. In addition, emissions from SSRs are more powerful than the ones from aircraft.

Any ATC ground stations equipped with ADS-B receivers are able to collect data broadcast by surrounding ADS-B aircraft. There are three types of ADS-B service according to the area where the ADS-B service is provided: in non-radar areas, in radar areas, on airport surfaces.

1.2.1. ADS-B SURVEILLANCE IN NON-RADAR AREAS (ADS-B NRA)

The ADS-B-NRA service provides surveillance services in areas where radar surveillance currently does not exist. It is applicable to airspace classes A to G. The most famous example is the deployment of ADS-B over the entire Australian upper airspace (refer to http://www.airservicesaustralia.com/projects/ads-b/upper-airspace-program/.)

The ADS-B NRA service provides a cost effective solution to achieve benefits in terms of capacity, efficiency and safety in a similar way as it could be achieved with an SSR.

NOTE:

Airbus certified a modification to A320/A330/A340/A300-600/A310 aircraft that enables ADS-B NRA operations.

However, operators may need an operational approval from their Authorities before starting ADS-B NRA operations, depending on their NAA. Refer to 1.6.1 – Operational Approval of ADS-B OUT. But most of the local Authorities do not require operational approval anymore, relying on aircraft airworthiness approval of the installation (available in the AFM in section Limitations/ATA 34/mode S – ADS-B OUT).

4 As a dependent surveillance method, ADS-B transmits the aircraft GPS position to the ground.

1.2.2. ADS-B SURVEILLANCE IN RADAR AREAS (ADS-B RAD)

The ADS-B-RAD service enables to decommission redundant SSRs and to provide the same level of surveillance service in areas where radar surveillance currently exists. It applies to en-route and terminal phases of flight in airspace classes A to E.

The application improves safety and reduces surveillance costs through the replacement of some SSRs with ADS B receivers.

Airbus certified A350 and a modification to A320/A330/A340/A380 aircraft eligible for ADS-B RAD operations. However, operators may need an operational approval from their Authorities before starting ADS-B RAD operations depending on their NAA. Refer to 1.6.2 – Operational Approval of ADS-B OUT

But most of the local Authorities do not require operational approval anymore, relying on aircraft airworthiness approval of the installation (available in the AFM in section Limitations/ATA 34/mode S – ADS-B OUT).

NOTE:

In Europe, ATC ground stations will still use a minimum number of SSR. The use of ADS-B ground receivers combined with a minimum number of SSR is more cost-effective than an exclusive set of SSR.

1.2.3. ADS-B SURVEILLANCE ON AIRPORT SURFACES (ADS-B APT)

The ADS-B APT service provides ATC controllers with a new surveillance tool of movements on airport surface. It covers aircraft and ground vehicles equipped with an ADS-B emitter. The ADS-B APT service may be used as either a supplement or substitute for existing ground installations (e.g. Surface Movement Radar – SMR).

NOTE:

Additional information on ADS-B technology is available on internet (refer to https://www.skybrary.aero/index.php/Automatic_Dependent_Surveillance_Broadcast_(ADS-B))

THE ADS-B LEXICON

ADS-B, as a new technology, brings its set of new terms. The most commonly used when talking about ADS-B are the following. Technical terms may not be of operational interest but may be useful during discussions with engineers.

GENERIC EMERGENCY INDICATOR

The Generic Emergency Indicator is an element of ADS-B messages, coded on two bits. It provides the Surveillance Status that can be either:

- No change of the SQWK code, or
- Emergency condition (each time 7500, 7600, or 7700 is set on the transponder control panel), or
- Change in SQWK code (each time a new code different from 7500, 7600 or 7700 is set). This Surveillance Status is active for 18 seconds following the SQWK code change, or
- SPI condition (when the IDENT function is activated). This Surveillance Status is active for 18 seconds following the IDENT function activation.

The Generic Emergency Indicator does not indicate either the nature of the emergency or the SQWK code.

NOTE:

Discrete Emergency Code are not transmitted by all the transponder types.

DISCRETE EMERGENCY CODES

The Discrete Emergency Code is an element of ADS-B messages, coded on three bits. It provides the nature of the emergency and/or urgency:

- **Emergency modes:**
  - General emergency
  - Communication failure
  - Unlawful interference
- **Urgency modes:**
  - Minimum fuel
  - Medical.

DO-260,DO-260A AND DO-260B

DO-260 "Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B)" defines the standards for ADS-B application. DO-260A is a revision of DO-260.

DO-260 and DO-260A provide the minimum XPDR standard for ADS-B OUT operations in Non Radar Aispace

From an operational view, the main differences are that DO-260 requires the transmission of the Generic Emergency Indicator and Discrete Emergency Codes. And DO-260A requires, in addition, the transmission of the transponder SQWK code. This latter requirement would permit a smooth transition from SSR to ADS-B operations for ATC controllers as they are used to working with SQWK codes.

From a technical point of view, the main differences, in addition to the ones quoted above, are that DO-260 requires the transmission of the Navigational Uncertainty Category (NUC), whereas DO-260A requires the Navigation Integrity Category (NIC), the Navigational Accuracy Category (NAC) and the Surveillance Integrity Level (SIL) instead of NUC.

DO-260B provides the minimum XPDR standard for ADS-B OUT operations in Radar airspace in addition to Non Radar Airspace capability. It introduces ADS-B OUT failure report, introduced mainly the selected barometric setting, geometric altitude and improved definition of GPS integrity and accuracy parameters.

GEOGRAPHICAL FILTERING OF SQWK CODE

When surveillance experts defined the ADS-B transmissions at the beginning, two philosophies stood out: the US American one supporting the need for the transmission of the SQWK code (for a some transition from SSR to ADS-B operations), and the European one seeing no need for SQWK code.

Consequently, the industry had decided at that time the SQWK code to be transmitted through ADS-B only over the USA territory. Outside USA airspaces, the SQWK code was not transmitted. This was the Geographic Filtering of SQWK code defined in DO-260A.

At the time of writing the document, the European philosophy has been revised considering the usefulness of SQWK codes in ADS-B transmissions. Consequently, DO-260 A Change 2 abolishes the Geographic Filtering of SQWK code.

VERSION NUMBER

The Version Number is required as per DO-260A and identifies the format of ADS-B messages. Version Number 0 (or when no version number is transmitted) refers to DO-260, Version Number 1 to DO-260A and version Number 2 to DO-260B minimum standard.

RECEIVER AUTONOMOUS INTEGRITY MONITORING (RAIM) / FAULT DETECTION AND EXCLUSION (FDE)

This capability may be required for ADS-B OUT installations (e.g. in Australia, refer to CAO 20.18).

The RAIM/FDE function performs a monitoring of the GPS position integrity. It measures the confidence in the correctness of the parameters provided by the GPS constellation. It enables the detection and, when possible, the exclusion of a faulty satellite. A GPS receiver is able to perform the RAIM/Fault Detection (FD) function when 5 satellites are visible (4 satellites enables the calculation of a 3D position; the 5th satellite enables the fault detection).

The FDE function is an enhanced version of RAIM. In addition to the fault detection, FDE is able to exclude the faulty satellite. As a consequence, the navigation can rely on GPS satellites without interruption. To that end, the FDE function requires 6 satellites (4 satellites for the 3D position, 1 satellite for the fault detection and 1 for the exclusion).

It has to be noted that the FDE function is able to detect and exclude one and only one faulty satellite. If a second satellite fails, it may be detected but it may not be excluded.

GPS HORIZONTAL FIGURE OF MERIT (HFOM)

HFOM defines the estimated accuracy of the GPS position assuming there is no satellite failure. HFOM is the radius of a circle centered on the current position, such that the probability of the actual position lying inside the circle is 95% or more (or outside the circle with a probability of 5% or less). The higher the HFOM, the lower the estimated accuracy in the GPS position.

HFOM is also known as Estimated Position Uncertainty (EPU)[5] .

GPS HORIZONTAL PROTECTION LIMIT (HPL)

HPL is the radius of a circle centered on the current position, which defines an area that is assured to contain the indicated horizontal position with a given probability.

HPL is also known as Horizontal Integrity Limit (HIL).

HFOM reflects the estimated accuracy of a satellite geometry whereas HPL indicates its estimated integrity. Figure 1-5 illustrates a satellite geometry with:

5 It is different from the Estimated Position Error (EPE) calculated by FM computers. EPE is the drift of the FM position.

Figure 1-5:
Accuracy (HFOM) vs. integrity (HPL)

- A good accuracy (HFOM) thanks to satellite A
- A poor integrity (HPL) due to satellite A.

Indeed, the satellite A position relative to satellites B, C, D reduces the satellite range errors. The satellite A upgrades the accuracy (HFOM). The high correlation between satellites B, C and D allows an easy detection of failure from any of these three satellites. Conversely, the position of satellite A cannot be correlated with other satellites. Consequently, a failure of satellite A may not be detected. The satellite A downgrades the integrity (HPL).

SELECTIVE AVAILABILITY (SA)

The US Department of Defense introduced an artificial error (Selective Availability) into satellite data to downgrade the accuracy of a GPS position to 100 m for civilian users. Without SA, the accuracy of GPS position can reach down to 10 m.

On May 1st 2000, the US Department of Defense switched SA off.

To make the most of the possible accuracy of the GPS system, the GPS sensor must include the SA Awareness function. It takes into account that SA is off and provides more realistic estimates of HFOM and HPL. MMR with SA ON always downgrade the accuracy of the GPS position on a conservative basis.

NAVIGATIONAL UNCERTAINTY CATEGORY (NUC)

DO-260 defines NUC to characterize both the accuracy and the integrity of ADS-B data. NUCP is relative to the position, and NUCR to the velocity. The higher the NUC, the higher the quality of ADS-B data.

NUCP may be derived from HFOM or HPL as per DO-260. However, as illustrated in Figure 1-5, it is preferable to derive NUCP from HPL to take into account a potential satellite failure (as HFOM assumes there is no satellite failure). Transponders proposed on AIRBUS aircraft derive NUCp from HPL first, then from HFOM is HPL if not available.

NAVIGATION INTEGRITY CATEGORY (NIC)

DO-260A/B segregates the accuracy and the integrity of ADS-B data, and defines the NIC instead of the DO-260 NUC integrity information. NIC is derived from HPL and defines the same circle as HPL does. HPL is a radius whereas NIC a category.

NAVIGATIONAL ACCURACY CATEGORY (NAC)

The DO-260A/B NAC takes the place of the DO-260 NUC accuracy information, and is derived from HFOM. NAC defines the same circle as HFOM does. HFOM is a radius and NAC is a category.

NACP is relative to the position and NACV to the velocity.

SURVEILLANCE INTEGRITY LEVEL (SIL)

DO-260A/B introduce SIL. SIL is the probability that the current position is outside the circle defined by NIC without any detection from the systems. SIL refers to a confidence level in provided position.

The higher the NIC, NAC and SIL, the higher the quality of ADS-B data.

Figure 1-6 illustrates the differences between HFOM, HPL, NIC, NAC, and SIL.

Figure 1-6: NIC, NAC.

1.2.4. ADS-B CONTROLS AND INDICATIONS

For the General Aviation community, transponder and ADS-B transmitter are most of the time separate units. Consequently, pilots can independently operate transponder and ADS-B transmissions. For the Air Transport Aviation community, transponder and ADS-B transmitter are merged in a single unit: the transponder Mode S capable of ADS-B OUT.

Per design on A320/A330/A340/A380, it had been elected to make ADS-B transmissions totally transparent to the flight crew on AIRBUS aircraft. Consequently, there are neither new controls nor new indications related to the ADS-B OUT transmissions addressed to the flight crew. The main benefits are the avoidance of heavy modifications (e.g. no new connections with other systems, no change on ATC/TCAS panel) and a minimum impact on cockpit procedures.

A350 aircraft a dedicated button ADS-B RTPG enables to switch off ADS-B OUT only (modes A/C/S ELS/EHS are still active).

Figure 1-7: A350 AESS controls in MFD

STOP ADS-B TRANSMISSION

On AIRBUS aircraft, if the flight crew switches off the transponder or the altitude reporting, it cuts off the transmission of ADS-B data or ADS-B altitude respectively. In addition, it has a major impact on SSR and TCAS operations (e.g. disappearance from controller SSR scope, non coordinated TCAS maneuver, surrounding aircraft equipped with TCAS not able to detect and track own aircraft).

In ADS-B operations, the flight crew uses the same controls of the ATC/TCAS panel for the transmission of the SQWK code[6], IDENT (SPI), and the barometric altitude as in SSR operations (see Figure 1-2).

In appendix B - ADS-B phraseology, some instructions refer to the separate transponder/ADS-B transmitter architecture. When ATC advises such instructions (e.g. STOP ADS-B TRANSMISSION), refer to AIP for alternate procedures or at least Notify ATC if aircraft installation does not allow to switch off ADS-B OUT.

1.3. AIRCRAFT IDENTIFICATION AND POSITION REPORTING WITH WIDE AREA MULTILATERATION

As more and more new systems derived from the CNS/ATM concept[7] come into the daily operational field, the reader may hear about Multi-lateration. At first sight, it seems to be another engineering slang word. It is, and the following is a general description to demystify the Wide Area Multi-lateration (WAM – Multi-lateration technique applied in wide surveillance areas).

The Multi-lateration technique uses the same principle as the localization of a mobile phone with ground stations (i.e. triangulation).

Different ground antennas receive a signal from the aircraft. Each antenna receives the signal at different time due to the relative distance between the antenna and the signal emitter. A central processing unit connected to the ground antennas calculates the aircraft position from the **Time Difference Of Arrival (TDOA)** of the signal at the different ground antennas.

Figure 1-7: Intersection of hyperboloids

With 2 antennas, the TDOA corresponds to a 3D hyperboloid on which the aircraft is located. The calculation of the 3D aircraft position requires 4 antennas. The central processing unit calculates the intersection of the 3 hyperboloids. A configuration with more than 4 antennas permits to calculate an average position with a higher accuracy.

The determination of a 3D position with a 3-antenna configuration requires an additional source (e.g. barometric altitude from Mode C transponder reply) for the aircraft altitude. However, the resulting position is less accurate than the one determined with a configuration of 4 antennas.

The Multi-lateration technique may be either passive (by listening transmissions from the transponder like ADS-B OUT) or active (by interrogating the aircraft like ELS/EHS).

Many signals from the aircraft are available (e.g. SSR, Mode S, DME, etc). The following characteristics drive the choice of the signal:

- The capability of the signal to provide the aircraft identification
- The availability of the signal
- The quality of the signal.

To fulfill the aircraft identification and position reporting functions, the use of transponder and ADS-B signals appear the most appropriate solution. The minimum avionics equipage would be a Mode A/C transponder for active Multi-lateration technique. The embodiment of Mode S transponder or ADS-B avionics would enable the passive Multi-lateration technique.

6 Only some transponders capable of ADS-B are capable to transmit the SQWK code. Refer to ADS-B LEXICON.
7 Refer to Part I of the Getting to Grips with FANS, issue III, April 2007 for a description of the CNS/ATM concept.

The Multi-lateration technique covers all flight phases (i.e. airborne and surface movements). The Multi-lateration technique presents roughly the same advantages than the surveillance based on ADS-B (e.g. coverage of all flight phases, use in areas where the costs of a radar installation is not justified, etc). In addition, the Multi-lateration technique allows the detection of aircraft only equipped with Mode A/C transponders. However, the Multi-lateration technique requires more ground stations than ADS-B. Some airports (e.g. London Heathrow) already use the Multi-lateration technique.

For more details, please refer to

https://www.eurocontrol.int/publications/ads-b-wam-implementation-europe or to the Wide Area Multi-lateration Report from the Dutch National Aerospace Laboratory (NLR).

1.4. AIRCRAFT IDENTIFICATION AND POSITION REPORTING WITH FANS

1.4.1.ADS-C

FANS A/A+ systems (namely ATSU for A320/A330/A340 aircraft and ATC applications for A380/A350 aircraft) host the Automatic Dependent Surveillance – Contract application, whereas Mode S transponders hosts ADS-B OUT.

The ADS-C application is quite different from the ADS-B application. The ADS-C application is only used for ATC purposes, contrary to ADS-B that serves the traffic awareness for both ATC and aircraft capable of ADS-B IN.

The ADS-C application provides surveillance data to map the traffic on ATC controller's screen in areas that are not covered by SSR (i.e. oceanic and remote areas). The ADS-C application takes the place of SSR in those areas but they are not comparable. Indeed, the ADS-C application reports the aircraft position and its intents according to conditions (i.e. contract) fixed by the ATC controller. The ATC controller can set up a periodic, on-event (e.g. when the aircraft sequences a waypoint) or on-demand (i.e. at ATC controller's discretion) contract. When the ATC controller sets up a periodic contract, the ADS-C application reports the aircraft position on a periodic basis between 1minute and 60 minutes. Therefore, the ATC controller cannot use ADS-C to provide the same separation as with SSR.

OPS+

ADS-C removes the requirement for voice position reporting. ADS-C makes also the aircraft eligible for long-range operations with reduced separations (i.e. lateral and longitudinal separations reduced to 50 NM or 30 NM).

The ADS-C coverage is larger than the SSR one thanks to the FANS technology (i.e. a data link through satellites or HF, and ACARS network connects aircraft to ATC centers).

For more details, please refer to the Getting to grips with FANS brochure (see AIRBUS References): ADS-C uses the same interfaces and communication means as ATC datalink applications (CPDLC/ATS623)

1.4.2. PERFORMANCE-BASED COMMUNICATION AND SURVEILLANCE (PBCS)

Following introduction The Performance-Based Communication and Surveillance (PBCS) concept provides performance requirements for communication and surveillance operations. PBCS supports the required performance for Air Traffic Management (ATM). PBCS requirements are defined in ICAO DOC 9869 (Performance-based Communication and Surveillance (PBCS) Manual), and for instance in FAA AC 90-117 for aircraft installation.

The PBCS concept sets the following performance parameters:

- RSP (required Surveillance Performance)
- RCP (Required Communication Performance)

RSP specification defines performance requirements associated to the delivery of surveillance data. Performance requirements are specified for each part of the communication chain (aircraft, ground network, and ATC). The RSP specifications impact ADS-C and SATCOM voice communications on the aircraft.

RSP Specification is identified by a designator (e.g. RSP 180, RSP 400) where the value refers to a maximum time (in seconds) to deliver the surveillance data (e.g. aircraft position) to the ATC.

PBCS also defines the RCP specification that is more related to the communication exchange with controllers (not about the surveillance). For information RCP defines performance requirements associated to a communication transaction. A communication transaction is performed between the ATC controller and the flight crew (clearance, flight information, or request). Performance requirements are specified for each part of the communication chain (aircraft, air/ground network, and ATC). The RCP specifications impact CPDLC and SATCOM voice communications on the aircraft.

RCP Specification is identified by a designator (e.g. RCP 240, RCP 400) where the value refers to the maximum time (in seconds) for the ATC controller to initiate a transaction and receive the response from the flight crew.

This RSP specifications applies to a defined airspace, route, or procedure with optimized operations (e.g. reduced separations).

Airbus aircraft equipped with FANS A+ or FANS A+B or FANS C demonstrated RSP 180 and RSP 400 capabilities.

For example, aircraft equipped with FANS A+ with HFDL and SATCOM are capable of following PBCS capabilities:

AIRCRAFT PERFORMANCE CAPABILITY FOR COMMUNICATION AND SURVEILLANCE	REQUIRED ON-BOARD CONFIGURATION TO MAINTAIN AIRCRAFT PERFORMANCE CAPABILITY	
	Applications supporting aircraft performance	**Communication means supporting applications**
RSP 180	ADS-C	VDL Mode A/2, or SATCOM datalink
RSP 400	ADS-C	HFDL

For more details on the aircraft PBCS capability, please refer to the AFM Limitations section, FCOM/PRO/SPO/46 PBCS or ISI article 46.00.00066.

NOTE:

This document focus on Surveillance items. For additional details on RCP, please refer to the AFM Limitations section, FCOM/PRO/SPO/46 PBCS or ISI article 46.00.00066.

1.5. OPERATIONAL RECOMMENDATIONS

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

1.5.1. FOR TRANSPONDER

1.5.1.1. CONVENTIONAL TRANSPONDER OPERATIONS

1.5.1.1.1. FOR THE AIRLINE

Refer to 2.1.2 – Operational Recommendations for TCAS.

1.5.1.1.2. FOR THE FLIGHT CREW

- **In normal operations, set the transponder to AUTO and the altitude reporting function to ON.** Transponder settings affect TCAS operations.
- **Be sure not to confuse controls when operating the ATC/TCAS control panel.** Refer to Safety First Magazine, Edition #4, June 2007 "Do you know your ATC/TCAS panel?" (See AIRBUS References).
- **Refer to Part III, Section 3, Chapter 1 of Aircraft Operations – Flight Procedures, ICAO Doc 8168-OPS/611, Volume I** for guidelines related to transponder operations (see References).

1.5.1.2. ADS-B OPERATIONS

1.5.1.2.1. FOR THE AIRLINE

OPS+

- **Make sure that your flight crews are familiar with ADS-B** (e.g. technology, phraseology, routine and emergency procedures as published in AIP, etc).
- **Ensure that the operational documentation (AFM, MEL, FCOM) is correctly updated.**
- **Ensure that the aircraft 24-bit address is correctly set in avionics.** Instead of the flight number filled in the ICAO flight plan, ANSP may use the 24-bit address to correlate the aircraft with its logged flight plan. The 24-bit address is delivered with the aircraft registration number. The operator should periodically check the 24-bit address and when the State of registration changes.
- **Refer to the ADS-B OUT Capability Declaration** to support the operational approval process. Refer to 1.6.1 – Operational Approval of ADS-B OUT.
- Refer to OIT 999.0057/08/BB (See AIRBUS References).

1.5.1.2.2. FOR THE FLIGHT CREW

- **Make sure that the flight number in the FMS INIT A page matches the aircraft filled in the item 7 of the ICAO flight plan.** Refer to Appendix 2 of ICAO Doc 4444 – PANS ATM (see References).ANSP systems are able to process ICAO format only. The flight number is up to seven characters long. Do not add any leading zeros, dashes or spaces. According to the FMS standard on board, it may not be possible to modify the flight number when airborne.

NOTE:

With the first generation of FMS, the flight crew cannot change the flight number when the aircraft is airborne. The in-service experience shows that frequent errors are made when entering the flight number into the avionics worldwide. And ATC controllers detect the errors when the aircraft is airborne. Consequently, the new generation of FMS permits to easily change the flight number when airborne. The minimum FMS standard are the Honeywell FMS2 H2 on A320 family, P2 on A330/A340, the Thales/GE FMS2 S4 on A320 family, T2 on A330/350 and all A380 and A350 FMS standards.

- **Insert "CODE/" followed by the 24-bit address (hexadecimal format) in item 18 of the ICAO flight plan** as required by local requirements.
- **Declare ADS-B capability in the ICAO flight plan by inserting following codes in item 10**. Please refer to AIP.

C	Mode C transponder – Mode A and Mode C
E	Mode S transponder with aircraft ID, pressure altitude and extended squitter (ADS-B) capability
H	Mode S transponder with aircraft ID, pressure altitude and enhanced surveillance capability
I	Mode S transponder with aircraft ID, but no pressure altitude capability
L	Mode S with aircraft ID, pressure altitude, extended squitter (ADS- B) and enhanced surveillance capability
P	P Mode S transponder with pressure altitude but no aircraft ID capability
S	Mode S transponder including both pressure altitude and aircraft ID capability
X	X Mode S transponder with neither aircraft ID nor pressure altitude capability
B1	ADS-B 1090MHZ OUT
B2	ADS-B 1090MHZ OUT IN
U1	ADS-B UAT OUT (not applicable to airbus aircraft)
U2	ADS-B UAT OUT IN(not applicable to airbus aircraft)
V1	ADS-B VDL M4 OUT(not applicable to airbus aircraft)
V2	ADS-B VDL M4 OUT IN(not applicable to airbus aircraft)

- **Be sure to master ADS-B procedures** (e.g. principles, coverage, terminology, phraseology, regional – normal and emergency – procedures). Refer to Appendix A – Worldwide ADS-B implementation and Appendix B – ADS-B phraseology for more information.
- Note that with ADS-B surveillance in non-radar areas (NRA), according to the type of transponder on board, the ATC controller may not be able to identify the type of emergency you may encounter (i.e. 7500, 7600 or 7700). Refer to AIP for applicable procedures.
- **To preserve SSR or TCAS operations, do not switch off transponder or altitude reporting when instructed to stop transmitting ADS-B data or ADS-B altitude** (see 1.2.4 – ADS-B Controls and Indications and Appendix B – ADS-B phraseology).
- For more information, refer to (see References):

  Eurocontrol Flight Crew Guidance for Flight Operations in ADS-B only Surveillance Airspaces.

  Airservices Australia Flight Operations Information Package and CASA Pilot Information Booklet.

1.5.2. ADS-C OPERATIONS

1.5.2.1. FOR THE AIRLINE

- Make sure that your flight crews are familiar with ADS-C (e.g. technology, phraseology, routine and emergency procedures as published in AIP, etc).
- Ensure that the operational documentation (AFM, MEL, FCOM) is correctly updated.
- Ensure that the aircraft 24-bit address is correctly set in avionics. Instead of the flight number filled in the ICAO flight plan, ANSP may use the 24-bit address to correlate the aircraft with its logged flight plan. The 24-bit address is delivered with the aircraft registration number. The operator should periodically check the 24-bit address and when the State of registration changes.
- Refer to the Airworthiness Capability Declaration to support the operational approval process.
- For more details, please refer to the Getting to grips with FANS brochure (see AIRBUS References)

1.5.2.2. FOR THE FLIGHT CREW

- Make sure that the flight number in the FMS INIT A page matches the aircraft filled in the item 7 of the ICAO flight plan. Refer to Appendix 2 of ICAO Doc 4444 – PANS ATM (see References).ANSP systems are able to process ICAO format only. The flight number is up to seven characters long. Do not add any leading zeros, dashes or spaces. According to the FMS standard on board, it may not be possible to modify the flight number when airborne.
- Insert "CODE/" followed by the 24-bit address (hexadecimal format) in item 18 of the ICAO flight plan as required by local requirements.
- Declare ADS-C capability in the ICAO flight plan by inserting following code in item 10. Please refer to AIP.

D1	ADS-C FANS 1/A (only if FANS A or C capability installed)
G1	ADS-C ATN (only if FANS C capability installed)

- **Declare RSP capability in the ICAO flight plan by inserting the indicator "SUR/" followed by the appropriate RSP specification (e.g., RSP400 or RSP180).** Please refer to AIP.
- **Be sure to master ADS-C procedures** (e.g. principles, coverage, terminology, phraseology, regional – normal and emergency – procedures). For more details, please refer to the Getting to grips with FANS brochure (see AIRBUS References)
- When operating a PBCS airspace, route or procedure with RCP and RSP requirements:
  If the on-board ATC datalink application or the router or the communication means associated to a required RCP or RSP level are lost, the flight crew should notify ATC that RCP and/or RSP capability is lost at aircraft level.

1.6. REGULATIONS

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

1.6.1. FOR TRANSPONDER AND ADS-B OUT

1.6.1.1. CARRIAGE OF TRANSPONDER

The carriage of transponder capable of Mode C is mandatory in all ICAO member States as per ICAO Annex 6 – Operations of Aircraft – Part I:

"6.19.1 All aeroplanes shall be equipped with a pressure-altitude reporting transponder which operates in accordance with the relevant provisions of Annex 10, Volume IV.

6.19.2 All aeroplanes for which the individual certificate of airworthiness is first issued after 1 January 2009 shall be equipped with a data source that provides pressure-altitude information with a resolution of 7.62 m (25 ft), or better.

6.19.3 After 1 January 2012, all aeroplanes shall be equipped with a data source that provides pressure-altitude information with a resolution of 7.62 m (25 ft), or better.

6.19.4 Recommendation. The Mode S transponder should be provided with the airborne/on-the-ground status if the aeroplane is equipped with an automatic means of detecting such status."

As per EASA AIR OPS ((EU) 965/2012), a transponder capable of Mode C is mandatory and other transponder capabilities may be required for the route being flown.

As per FAA FAR 121.356, a Mode S transponder is mandatory.

Refer to CNS|ATM website available on www.airbusworld.com for ELS/EHS/ADS-B OUT deployment of local regulations.

NOTE:

TCAS compliant with TCAS II Change 7.1 requires a Mode S transponder for its functioning. Therefore, the mandatory carriage of TCAS (refer to 2.1.3 – Regulations for TCAS) implies a mandatory carriage of a Mode S transponder.

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1.6.1.2. OPERATIONAL APPROVAL OF ADS-B OUT

AIRBUS obtained the EASA airworthiness certification for ADS-B NRA on the A320 family aircraft, the A330/A340 family aircraft. The AFM states the ADS-B NRA capability.

Airbus aircraft installations capable of NRA operations demonstrated compliance with European AMC 20-24 – Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application

AIRBUS obtained the EASA airworthiness certification for ADS-B RAD on the A320 family aircraft, the A330/A340 family aircraft, the A380 aircraft and the A350 aircraft. The AFM states the ADS-B RAD capability. Airbus aircraft installations capable of RAD operations demonstrated compliance with

- The European CS-ACNS Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-ACNS
- The US AC 20-165A - Airworthiness Approval of Automatic Dependent Surveillance - Broadcast (ADS-B) Out Systems

AMC 20-24

EASA, CASA Australia, Transport Canada and south asia NAA for instance permit the recognition of the European AMC 20-24 in Australia and Canada for ADS-B NRA. Indeed, the European AMC 20-24 is the most restrictive circular for NRA applications. Consequently, A320/A330/A340 aircraft installations, certified as per the European AMC 20-24, are eligible for ADS-B NRA operations in Australia and Canada. Transponders compliant with DO-260 are eligible for ADS-B NRA operations.

CS-ACNS & AC 20-165

UAE, Europe and Colombia for instance recognize CS-ACNS. FAA recognize only AC 20-165

On A320 family and on A330/A340 family the operator can ether choose a transponder compliant with DO 260A and thus with AMC 20-24 for NRA operations or compliant with DO-260B and thus with CS-ACNS and AC 20-165A for NRA and RAD operations.

On A380 and A350, the transponder is basically compliant DO-260B and thus with CS-ACNS and AC 20-165A for NRA and RAD operations.

Operators may be required to obtain an operational approval before starting ADS-B NRA or RAD operations. But most of the NAA does not require operational approval anymore

The operational approval covers the following items (but not limited to):

- **Operations manuals:** AFM, FCOM and MEL should be updated to reflect the installation of ADS-B components.
- **Flight crew training:** flight crews should be familiar with ADS-B in terms of procedures, phraseology, operating principles and operational requirements (e.g. flight number format).
- **Maintenance:** regular checks of ADS-B equipment should be performed including the verification of the 24-bit address.

Refer to one of the appropriate circulars quoted above for details. In addition, operators should use the ADS-B OUT Capability Declaration referenced in their AFM to support their operational approval with authorities. Please contact contact Airbus via TechRequest or your Customer Service Director (CSD) to get a copy of this document.

OPS+ **Refer to CNS|ATM website available on www.airbusworld.com for ELS/EHS/ADS-B OUT deployment of local regulations.**

1.6.2. FOR PBCS

PBCS (including RSP) may be required to operate routes or airspaces with reduced separations.

Refer to ISI article 46.00.00066 “PBCS (Performance Based Communication and Surveillance)” available on **www.airbusworld.com** for status and guidelines on PBCS.

The AFM states the ADS-C and PBCS capabilities in section limitations/46 INFORMATION SYSTEMS/FANS

OPS+ **Refer to CNS|ATM website available on www.airbusworld.com for ADS-C deployment of local regulations.**

1.7. MANUFACTURERS

1.7.1.FOR TRANSPONDER (WITH ELS/EHS/ADS-B OUT CAPABILITY)

At the time of writing the brochure, Three equipment suppliers are available on AIRBUS aircraft:

- ACSS, or
- Honeywell, or
- Rockwell Collins

*Optional Enhanced Surveillance

Figure 1-8: Transponder architecture

Figure 1-8 provides a simplified view of the transponder architecture.

1.7.2. FOR ADS-C CAPABILITY

For more details, please refer to the Getting to grips with FANS brochure (see AIRBUS References.)

NOTE 1:

The Mode S transponder must receive GPS data in order to broadcast ADS-B data. The GPS source is MMR.

NOTE 2:

The Mode S transponder gets pure GPS data either via ADIRU (for DO-260 and DO-260A installations) or directly from GPS receiver (for DO-260B installations). When collecting GPS data via ADIRU, Only hybrid ADIRUs are able to connect to a GPS source. Therefore, Mode S transponders connected to autonomous ADIRU cannot get GPS data for ADS-B transmissions. Mode S transponders connected to autonomous ADIRU always send a NUC = 0 (i.e. integrity is not known as the aircraft position is not based on GPS).

1.8. WAY FORWARD

At the time of the writing:

- A new transponder equipment standard is defined in Eurocae WG-51 in coordination with RTCA SC-186 to enrich aircraft data set transmitted by ADS-B OUT (new revision C of the DO-260).
- A new datalink standard is experimented: ATN-B2. This standard enables to transmit ADS-C in continental area. SESAR project with airbus participation experiment this technology. The Airbus FANS C is capable to transmit ADS-C reports (e.g. aircraft flight plan computed by the FMS) over ATN B2 network.

PLEASE BEAR IN MIND…

DESCRIPTION

To reply to SSR interrogations, the transponder operates in three modes:

- **Mode A:** transmission of SQUAWK code
- **Mode C:** transmission of barometric altitude
- **Mode S:** Selective interrogations replied with enriched transmissions.

Transponders are also capable of operating in a broadcasting mode (ADS-B). The introduction of ADS-B aims at providing a safer and more cost-effective surveillance service in regard to the traffic growth. The ADS-B technology enables three surveillance services (based on the ADS-B OUT data flow) as per the European CASCADE program:

- **ADS-B NRA:** ADS-B surveillance in Non-Radar Areas with low traffic density
- **ADS-B RAD:** ADS-B surveillance backed up by SSR with high traffic density
- **ADS-B APT:** ADS-B surveillance on airport surfaces.

Basic transponders proposed on AIRBUS aircraft are all capable of Mode A/C/S, ELS/EHS, ADS-B NRA And ADS-B RAD. At the time of writing the brochure, definitions of standards for ADS-B APT are in progress.

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- **The use of the ICAO format (three-letter code)** for the flight number
- The use of **identical flight numbers in the ICAO flight plan and in the FMS INIT A page**
- **An appropriate training regarding ADS-B OUT operations**
- A special attention to local implementations of ADS-B
- **A correct avionics settings** (i.e. 24-bit address)
- **A careful flight planning** (i.e. flight number, surveillance capability, 24-bit address).

Refer to 1.5 – Operational Recommendations for Transponder.

REGULATIONS

The carriage of transponder capable of Mode C is mandatory and the carriage of transponder capable of Mode S is recommended as per ICAO Annex 6 – Operation of Aircraft – Part I. TCAS compliant with TCAS II Change 7 requires a Mode S transponder for its functioning. Therefore, the mandatory carriage of TCAS implies a mandatory carriage of a Mode S transponder.

WAY FORWARD

At the time of writing the brochure, a new transponder standard DO-260C is expected for ADS-B and a new communication network ATN B2 is expected for the transmission of ADS-C in continental area.

Refer to CNS|ATM website available on www.airbusworld.com for local ELS/EHS/ADS-B OUT operational mandates

#02 TRAFFIC SURVEILLANCE

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The Airborne Collision Avoidance System (ACAS), or commonly named Traffic alert and Collision Avoidance System (TCAS) has fulfilled the Traffic Awareness function for years. ACAS stands for the ICAO designation.

Based on gained experience from TCAS operations, AIRBUS developed a new AFS vertical mode (AP/FD TCAS mode). In order to reduce workload and stress of the flight crew during an RA alert, AFS assists the flight crew with FD or AP.

As the ADS-B technology arises, a new tool to fulfill the Traffic Awareness function is now available in the cockpit: the Airborne Traffic Situational Awareness (ATSA or ATSAW, the latter being the AIRBUS designation). The large set of data supported by ADS-B permits the ATSAW application to provide enhanced traffic awareness (e.g. heading and flight number of surrounding aircraft) to the flight crew.

The following chapter describes the Traffic Awareness fulfilled by conventional TCAS and new ATSAW applications.

2.1. AIRCRAFT COLLISION AVOIDANCE SYSTEM - ACAS

2.1.1. DESCRIPTION OF ACAS – TCAS

The concept of airborne collision avoidance system appeared in the early 1950s with the continuous growth of the air traffic at that time. Several midair collisions lead to the development of TCAS by the FAA in the United States of America. Concurrently, ICAO had developed the ACAS standards since the early 1980s and officially recognized ACAS on November 1993. The ICAO Annex 10, Volume IV describes the ACAS requirements, and the ICAO PANS-OPS (Doc 8168) and ICAO PANS-ATM (Doc 4444) define the ACAS operational use.

TCAS provides indications about surrounding aircraft and especially alerts about intruders that may jeopardize the safety of the flight. The indications provide the flight crew with the position of surrounding aircraft relatively to the own aircraft. The alerts are of two types:

- **Traffic Advisories (TA)** that inform the flight crew of the position of intruders
- **Resolution Advisories (RA)** that provide the flight crew with the position of threatening intruders and instructions to avoid them.

2.1.1.1. TCAS DESIGNATION

The ICAO Annex 10, Volume IV defines three types of ACAS functions:

- **ACAS I** is the first generation of TCAS. ACAS I provides Traffic Advisories (TA) and proximity warning of surrounding aircraft to assist the flight crew in the visual acquisition of intruder aircraft. TCAS I is installed in some small aircraft and helicopters in some regions in the world (e.g. aircraft with less than 31 and more than 10 passengers in USA). TCAS I is out of the scope of the present brochure.

TCAS

TCAS is a tool that warns pilots of the presence of other transponder-equipped aircraft which may present a threat of mid-air collision (MAC). TCAS assists the flight crew for the visual acquisition of threatening surrounding aircraft and triggers vertical orders to avoid possible collisions. The flight crew must not use the TCAS for self-separation.

- **ACAS II** is a ACAS I augmented with the capability to provide Resolution Advisories (RA) in the vertical plane. The development of ACAS II started in the early 1990s. Several standards (or Changes) have been defined and the latest one is known as TCAS II Change 7.1 or Version 7.1. The TCAS II Change 7.1 is compliant with ICAO Standards and Recommended Practices (SARPs) for ACAS II. ICAO mandated the carriage of ACAS II Change 7.1 since 2017 (since December 2015 in Europe). The next ACAS II generation is under development through the new ACAS X platform which will be suitable for high density airspaces (as it reduces significantly nuisance alerts) and will better consider specific environment such as parallel approaches (refer to §3.5).
- **ACAS III** is intended to provide TA and RA in both vertical and horizontal planes. At present, no ACAS III system has been developed, and none is likely to appear in the near future due to technical and operational difficulties.

The level of protection provided by TCAS depends of the transponder capability of surrounding aircraft.

		OWN AIRCRAFT	
		ACAS I	**ACAS II**
SURROUNDING AIRCRAFT	**MODE A XPDR**	TA	TA
	MODE C OR S XPDR	TA	TA & RA
	ACAS I	TA	TA & RA
	ACAS II	TA	TA & Coordinated RA[1]

Most equipment installed on AIRBUS aircraft are compliant with TCAS II Change 7.1. Therefore, **TCAS refers to equipment compliant with TCAS II Change 7.1 for the remainder of the document, except when specified.**

Figure 2-1: TCAS interrogation and transponder reply

2.1.1.2. TCAS PRINCIPLE

TCAS works autonomously and independently of the aircraft navigation equipment and ATS ground systems. Therefore, to detect and track any surrounding aircraft, TCAS periodically interrogates surrounding aircraft transponders.

The interrogation principle is similar to the one for SSR.

1. The own aircraft TCAS interrogates the surrounding aircraft transponder.

2. The surrounding aircraft transponder replies to the own aircraft TCAS with data provided by the surrounding aircraft TCAS (e.g. RA generated by the surrounding aircraft TCAS).

Thanks to the interrogation principle, the TCAS computes the following parameters to determine the collision threat:

- The range between aircraft by measuring the elapsed time between the interrogation and the reply

1 Both aircraft must be equipped with Mode S transponders for coordinated maneuvers.

- The relative altitude[2] with the barometric altitude transmitted by Mode C or S transponders
- The variations of range and altitude with successive interrogations
- The bearing of surrounding aircraft with the interferometry principle.

Each threat is treated individually but the TCAS determines the best solution of collision avoidance with respect to all aircraft in its vicinity. At the same time, the TCAS coordinates maneuvers with other TCAS-equipped aircraft. The best solution of collision avoidance is the maneuver that ensures an adequate separation of trajectories with a minimum vertical speed variation.

2.1.1.2.1. DETECTION PHASE

TCAS detects surrounding aircraft by regularly listening to acquisition squitters (refer to 2.1.3.8 – Extended Squitter for more details on squitters) from Mode S transponders of surrounding aircraft. When TCAS records some 24-bit addresses, TCAS starts a cyclical process repeated every second:

- Mode C interrogations to get altitudes of non-Mode S aircraft
- Mode S interrogations to get altitudes of Mode S aircraft via selective calls

Squitter listening.

This principle applies to the detection of aircraft equipped with Mode A or Mode C transponders. When the own aircraft TCAS interrogates in Mode C:

- An aircraft equipped with a Mode A transponder, the latter replies with its SQWK code. TCAS uses this reply for horizontal positioning purpose (i.e. bearing). TCAS does not process the SQWK code itself,
- An aircraft equipped with a Mode C transponder, the latter replies with its standard barometric altitude.

It has to be noticed that own aircraft TCAS only detects surrounding aircraft with an operative transponder.

2.1.1.2.2. TRACKING PHASE

When TCAS detected surrounding aircraft, TCAS tracks them by series of interrogations and replies. These exchanges permit the update of the relative altitude, the range and the bearing for each aircraft, and to determine the variations of range and altitude. **TCAS can track up to 40 aircraft (60 aircraft for the A380/A350 TCAS function) simultaneously and displays the 8 most threatening aircraft.**

Some TCAS are capable of Hybrid Surveillance: the system listens to ADS-B OUT squitters (Passive surveillance), and reduces mode S interrogation rate (Active surveillance) for faraway aircraft. ADS-B OUT Passive Surveillance is regularly validated by Active Surveillance.

2 Mode A transponders does not transmit the barometric altitude. Therefore, the TCAS is not able to compute the relative altitude from a reply provided by a Mode A transponder, and only triggers a TA for aircraft equipped with Mode A transponders.

2.1.1.3. TCAS AND MODE S

TCAS, Mode S transponders and Mode S ground stations use the same frequencies to transmit and receive messages. Thanks to this statement, data exchanged through the Mode S data link allow the coordination of avoidance maneuvers and the communication between aircraft equipped with TCAS and Mode S transponder.

The coordination in avoidance maneuvers is only possible with Mode S equipped aircraft.

2.1.1.3.1. COORDINATED MANEUVERS

The coordination of maneuvers prevents the flight path corrections ordered by each TCAS from resulting in a hazardous situation. It prevents from two aircraft maneuvering in the same direction (e.g. both aircraft climb) that could lead to a worse situation.

In most cases of encounters between two TCAS-equipped aircraft, mutual identification is almost simultaneous. However, there is a sufficient delay to establish the priorities for the coordination process.

The first aircraft to detect a potentially hazardous situation computes an avoidance maneuver sense, and communicates it to the other aircraft. The other aircraft takes the information into account and in turn computes an avoidance maneuver in the opposite sense.

It may happen that two aircraft simultaneously detect and simultaneously transmit coordination messages with avoidance maneuvers in the same sense. In this particular case, the aircraft with the highest 24-bit address reverses the sense of its avoidance maneuver.

In coordinated maneuvers, only one RA reversal is triggered when changes in the encounter geometry occur. Therefore, the initial RA is reversed when:

- The initial RA has been displayed for at least 9 seconds, or
- The aircraft, with the lowest 24-bit address, has a vertical speed greater than 2 500 ft/min (upwards or downwards), and flies in the opposite sense of its initial RA.

This delay provides the two aircraft with sufficient time to respond to the initial RA.

For TCAS compliant with TCAS II Change 7.1 (refer to 3.1.6 – TCAS II Change 7.1), if the aircraft with the highest 24-bit address does not follow its TCAS order, the coordination of maneuvers gives the priority to the other aircraft (i.e. with the lowest 24-bit address).

The coordination of maneuvers may be phased as follows:

1.Detection: The own aircraft TCAS listens to squitters.

2.Acquisition: The own aircraft TCAS receives a squitter, and interrogates the transponder of the intruder identified by the 24-bit address contained in the squitter. The transponder of the intruder replies with several data including its barometric altitude.

3. Tracking: The own aircraft TCAS tracks the intruder with regular interrogations.

4. Coordination: If the intruder becomes a threat, the own aircraft TCAS computes an avoidance maneuver to avoid a risk of collision. The two aircraft initiates a coordination procedure with the exchange of a coordination interrogation and a coordination reply.

2.1.1.3.2. COMMUNICATION WITH ATC GROUND STATIONS

When the TCAS triggers an RA, the TCAS is able to report it to Mode S ground stations. This report informs the ATC controller that the reporting aircraft had performed an avoidance maneuver.

The flight crew must immediately report any RA to the ATC controller, even if TCAS is able to report RA to Mode S ground stations.

2.1.1.4. COLLISION THREAT EVALUATION

Aircraft are categorized (i.e. OTHER, PROXIMATE, TA and RA) according to two criteria: the vertical separation or relative altitude (difference of barometric altitudes) and the range between aircraft. Regular interrogations of surrounding aircraft permit to determine the variations of the vertical separation and of the range. These variations are called vertical rate and range rate.

Figure 2-2: Vertical separation and range

The collision threat evaluation takes into account two criteria determined with respect to the Closest Point of Approach (CPA). CPA is the point of minimum range between the aircraft, assuming that their trajectories do not deviate (Refer to Figure 2-3). The two criteria are:

- The **vertical separation at CPA**
- The **time to reach CPA** or **time to intercept (TAU** or τ[3] **)**.

2.1.1.4.1. VERTICAL SEPARATION

Considering the vertical separation, the range and their variations for a surrounding aircraft, the own aircraft TCAS is able to predict whether the surrounding aircraft will trigger a TA or an RA at CPA.

At CPA, three zones are defined (refer to Figure 3 3). The vertical separation between the intruder and own aircraft at CPA defines the type of advisory to be triggered:

- **Between T0 and T1: TA**
- **Between T1 and T2: Preventive RA,** it instructs the flight crew to avoid certain deviations from current vertical speed. A red sector only is displayed on the Vertical Speed Indicator (VSI)
- **Below T2: Corrective RA,** it instructs to fly within a vertical speed range, displayed in green on VSI. A red sector on VSI indicates the forbidden vertical speed range.

Figure 2-3: Closest Point of Approach (CPA)

Values of T0, T1 and T2 vary according to TAU values (refer to 2.1.1.4.2) and the sensitivity level (refer to 2.1.1.5).

In Figure 2-3, a corrective RA will be triggered because of Aircraft 1 and a TA will be triggered because of Aircraft 2.

3 TAU refers to the Greek letter τ.

2.1.1.4.2. TIME TO INTERCEPT (TAU)

TCAS determines the collision threat with TAU rather than the geometric position of CPA. For two aircraft approaching on the same axis, this time is the ratio of the distance between the aircraft by the sum of their speeds.

$$\text{TAU} = \frac{\text{Distance}}{V_{\text{Own Aircraft}} + V_{\text{Intruder}}} \quad \text{or more generally TAU} = \frac{\text{Range}}{\text{Range rate}}$$

The collision threat increases when TAU decreases. The TCAS triggers advisories when TAU crosses predetermined time threshold.

This method based on TAU prevents advisories from being triggered if the TAU trend is inverted even though the range between two aircraft decreases (e.g. aircraft of parallel airways in opposite directions illustrated in Figure 2-4).

Figure 2-4 : TAU variation with range

NOTE:

In addition to this check in the horizontal plane, TCAS performs similar check in the vertical plane (i.e. based on the ratio of relative altitude by the vertical speeds) for the triggering of a TCAS RA.

Figure 2-5:
TCAS surveillance envelopes

2.1.1.5. TCAS ENVELOPES

The **surveillance envelope** is divided into **four volumes: 2 700 ft and 9 900 ft above, 2 700 ft and 9 900 ft below**. The horizontal range may vary from 14 to 100 NM according to the TCAS manufacturer. Refer to your FCOM for more details.

The flight crew can restrict the TCAS display in a given volume. The flight crew selects the following settings: ALL, ABOVE, or BELOW as per Figure 2-5.

Protection envelopes are also defined to set the threat levels around the aircraft. There are 4 protection envelopes around the aircraft (from the farthest to the closest ones): **OTHER, PROXIMATE, TA and RA**. Refer to Figure 2-8.

The OTHER volume is the volume outside the PROXIMATE volume, from –9900 ft to +9900 ft, and up to the maximum horizontal range. The PROXIMATE volume covers the vertical range from –1 200 ft to +1 200 ft, and the horizontal range up to 6 NM.

The dimensions of TA and RA volumes depend on TAU value. The penetration of the TA or RA volumes triggers Traffic Advisories or Resolution Advisories respectively. TAU varies according to the own aircraft altitude and the TCAS sensitivity level. The higher the own aircraft altitude and the sensitivity level, the higher the time to intercept TAU.

The **sensitivity level** permits a balance between necessary protection and unnecessary advisories. The sensitivity level goes from 1 to 7:

- Level 1 when TCAS is set in STAND BY, failed or the aircraft is on ground. In level 1, TCAS does not transmit any interrogations
- Level 2 when TCAS is set in TA ONLY mode (RA are inhibited)
- Levels 3 to 5 automatically selected according to the own aircraft altitude when TCAS is in TA/RA mode.

Example: For own aircraft altitude from 5 000 to 10 000 ft, the sensitivity level is SL5 and TAU for TA is 40 seconds and TAU for RA is 25 seconds.

For more details, please refer to Introduction to TCAS II Version 7 (see References).

2.1.1.6. TCAS II CHANGE 7.1

The TCAS II Change or Version 7.1 is the result of a workshop composed of DSNA (French Air Navigation Service Directorate) and Egis Avia experts, and sponsored by Eurocontrol. The TCAS II Change 7.1 introduces two major changes:

- The Change Proposal 112E (CP112E) about the reversal logic
- The Change Proposal 115 (CO115) related to the RA “ADJUST VERTICAL SPEED, ADJUST”.

2.1.1.6.1. CP112E – SOLUTION TO THE REVERSAL LOGIC ISSUE

In the TCAS II Change 7.0, an issue has been identified that leads to non-issuance of reversal RA in specific situations. Indeed, in the TCAS II Change 7.0, when the vertical separation is less than 100 ft, the TCAS does not trigger reversal RA. This issue is also known as the "100 ft box" issue.

This issue has been observed in several in-service events. The geometry is always the same: both aircraft are either descending or climbing. The issue has been identified in:

- The accident that occurred in January 2001 in Japan where several passengers were injured. Both aircraft got near to each other approximately by less than 180 m (600 ft) laterally and less than 60 m (200 ft) vertically.
- The collision of Uberlingen over the Lake Constance in July 2002. All passengers and crewmembers were killed.

In both events, the ATC controller had instructed one of the aircraft to maneuver in the opposite direction as ordered by TCAS.

The CP112E introduces a monitoring of the compliance to RA. When the own aircraft does not follow the RA and goes in the opposite direction for a certain time, the "100 ft box" rule is inhibited: reversal of RA is then possible when aircraft get vertically closer than 100 ft.

In addition, the CP112E predicts the vertical separation at CPA, taking into account current vertical speeds. When aircraft are predicted to get nearer than below a given threshold, reversal of RA is authorized for aircraft vertically nearer than 100 ft.

Latencies in RA reversals are tailored in order to make the most of initial RA (RA reversal not too early) and to avoid additional RA reversals (too late RA reversals).

2.1.1.6.2. CP115 – SOLUTION TO THE "ADJUST VERTICAL SPEED, ADJUST" ISSUE

The RA "ADJUST VERTICAL SPEED, ADJUST" is always an order to reduce the vertical speed. Most of the time, an opposite reaction to such an RA leads to a significant reduction of the vertical separation with the intruder and a significant augmentation of the collision risk.

A large number of unintentional opposite reactions to this RA has been observed. The main causes identified are:

- The lack of training on the particular RA "ADJUST VERTICAL SPEED, ADJUST"
- The lack of explicit indications in the RA "ADJUST VERTICAL SPEED, ADJUST"
- The difficulties to interpret VSI indications.

To simplify the procedure, **the CP115 replaces the RA "ADJUST VERTICAL SPEED, ADJUST" by a new RA "LEVEL OFF"**. In the TCAS II Change 7.0, there are currently four RA "ADJUST VERTICAL SPEED, ADJUST" with different vertical speed targets: 0, 500, 1 000, and 2 000 ft/min. The introduction of the new RA "LEVEL OFF" (one RA upwards and one RA downwards) make the last three RA above useless. It reduces the set of RA and simplifies the training.

2.1.1.7. TCAS INDICATIONS

In addition to aural alerts, PFD, ND, and EWD display TCAS indications. The ND provides the surrounding aircraft position. The PFD provides the avoidance maneuver orders. EWD provides memos and warnings relative to the TCAS.

2.1.1.7.1. TCAS DISPLAY

- **Navigation Display – ND**
  - **When TCAS is able to acquire the bearing of surrounding aircraft,** the ND displays surrounding aircraft according to their threat category (i.e. OTHER, PROXIMATE, TA or RA).
  - **For surrounding aircraft equipped with Mode A transponder,** the ND displays the surrounding aircraft according to their bearing and range only.
  - **For surrounding aircraft equipped with Mode C or S transponder (i.e. reporting their altitude)**, the ND displays the surrounding aircraft according to their bearing, range, vertical separation and vertical speed trend.
  - **When TCAS is not able to acquire the bearing (e.g. multi-path propagation) of surrounding aircraft**, the ND displays a literal indication only (e.g. 5.01 NM +01 ↓). The literal indication includes the range, the vertical separation in hundreds of feet and the vertical speed trend. The same color-coding applies as the one used for graphical indications.

The TCAS display on ND is available in ROSE and ARC modes. See Figure 2-7.

- **Primary Flight Display – PFD**

When TCAS is able to order an avoidance maneuver (i.e. with intruder equipped with Mode C or S transponder), on the Vertical Speed Indicator (VSI):

- The **green** sector is the **safe range of vertical speed** (FLY TO sector)
- The **red** sector is **strictly forbidden**.

Figure 2-6: TCAS display on PFD

Figure 2-7:
TCAS display on ND

Figure 2-8: TCAS protection envelopes

NOTE:

TA and RA volumes are based on time (TAU values) instead of distance.

• **Engine and Warning Display – EWD**

When the flight crew sets the TCAS to STBY, the ALT RPTG to OFF, or the XPDR to STBY from the ATC/TCAS panel, the green memo TCAS STBY is displayed on EWD.

2.1.1.7.2. TCAS AURAL ALERTS

TA and RA TCAS displays come with aural alerts. On A300/A310/A320/A330/A340 aircraft, the Flight Warning System (FWS) broadcasts these aural alerts through the loudspeakers, and the flight crew cannot modify their volume. On A380 aircraft, the FWS broadcasts the aural alerts through the loudspeakers and the headsets.

• **Traffic Advisory**

AURAL ALERTS	MEANING
TRAFFIC TRAFFIC	TCAS detects a TA aircraft.

• **Resolution Advisory**

For all the aural alerts listed below, the TCAS detects an RA aircraft, and is able to order avoidance maneuvers (with intruder equipped with Mode C or S transponder).

AURAL ALERTS	MEANING	REQUIRED V/S (ft/min)
CLIMB, CLIMB	**Climb at a vertical speed in the green sector on PFD.**	+1 500
CLIMB, CROSSING CLIMB, CLIMB, CROSSING CLIMB	**Climb at a vertical speed in the green sector on PFD.** The own flight path will cross through the intruder's one.	+1 500
INCREASE CLIMB, INCREASE CLIMB	**Increase the vertical speed to climb.** It is triggered after a CLIMB advisory.	+2 500
CLIMB, CLIMB NOW, CLIMB, CLIMB NOW	**Invert the vertical speed from DESCENT to CLIMB.** It is triggered after a DESCEND advisory when a reversal in sense is required to achieve a safe vertical separation from a maneuvering intruder.	+1 500
DESCEND, DESCEND	**Descent at a vertical speed in the green sector on PFD.**	-1 500
DESCEND, CROSSING DESCEND, DESCEND, CROSSING DESCEND	**Descent at a vertical speed in the green sector on PFD.** The own flight path will cross through the intruder one.	-1 500
INCREASE DESCENT, INCREASE DESCENT	**Increase the vertical speed to descent.** It is triggered after a DESCENT advisory.	-2 500

AURAL ALERTS	MEANING	REQUIRED V/S (ft/min)
DESCEND, DESCEND NOW, DESCEND, DESCEND NOW	**Invert the vertical speed from CLIMB to DESCENT.** It is triggered after a CLIMB advisory when a reversal in sense is required to achieve a safe vertical separation from a maneuvering intruder.	-1 500
ADJUST VERTICAL SPEED, ADJUST (Removed if TCAS II Change 7.1 implemented)	**Reduce the vertical speed to fly the green sector on PFD.** It is a corrective reduce climb or reduce descent, or a weakening of corrective RA.	**Climb** Min 0 Max +2 000 **Descent** Min 0 Max -2 000
LEVEL OFF (TCAS II Change 7.1 only)	**Set the vertical speed to 0.** It replaces the RA ADJUST VERTICAL SPEED, ADJUST. Refer to 2.1.1.6.2.	0
MONITOR VERTICAL SPEED	**Monitor the vertical speed so as to remain out of the red sector.** It is a **preventive advisory**. The TCAS calculated a forbidden vertical speed range (red sector).	
MAINTAIN VERTICAL SPEED, MAINTAIN	**Maintain the current vertical speed.**	**Climb** Min +1 500 Max +4 400 **Descent** Min –1 500 Max –4 400
MAINTAIN VERTICAL SPEED, CROSSING MAINTAIN	**Maintain the current vertical speed.** The own flight path will cross through the intruder one.	**Climb** Min +1 500 Max +4 400 **Descent** Min -1 500 Max -4 400
CLEAR OF CONFLICT	**Calm down.** The collision threat disappeared.	

- **Aural Alert Priority**

The FWS prioritizes aural alert with other systems as follows:

1. Wind shear alert or stall alert
2. TAWS alerts
3. TCAS alerts.

In case of wind shear, stall, or GPWS warnings:

- FWS inhibits TCAS aural alerts
- TCAS converts all RAs into TAs on ND
- TCAS automatically sets the TA ONLY mode.

• Advisory Inhibition

When the own aircraft is below an altitude limit ± margin (+ in climb, - in descent), the TCAS automatically activates some inhibition logics.

ALTITUDE LIMIT	INHIBITION
Above 48000 ft MSL	RA CLIMB CLIMB is inhibited to preserve aircraft performances.
Above 15500 ft MSL	TCAS does not interrogating Mode A aircraft or Mode C aircraft without altitude information (when ALT RPTG of these aircraft is set to OFF). However, TCAS still interrogates Mode S aircraft even they do not report their altitude.
Below 1700 ft AGL	The Ground logic is activated: any aircraft operating in Mode C only that are below 380 ft AGL (relative to the own aircraft, see Figure 3 9) are declared on ground. See note below.
Below 1550 ft AGL	RA INCREASE DESCENT is inhibited.
Below 1100 ft AGL	RA DESCENT is inhibited.
Below 1000 ft AGL	TA ONLY is automatically activated.
Below 500 ft AGL	TA aural alerts are inhibited.

NOTE:

The ground logic only applies to surrounding aircraft that operate in Mode C. Mode S aircraft transmit an explicit indication when airborne or on ground.

Figure 2-9: TCAS inhibitions

NOTE:

For TCAS intruders that do not report their altitude:
- The relative altitude does not appear on ND
- The TCAS never triggers an RA
- The TCAS inhibits the TA when own aircraft altitude is above 15 500 ft.

Figure 2-10: TCAS Intruder With No Reported Altitude

2.1.1.8. TCAS CONTROLS

The flight crew selects the TCAS operating modes via two different switches as follows:

- **STBY:** TCAS inhibits aural and visual indications. The EWD displays the green TCAS STBY memo.
- **TA:** TCAS converts all RAs in TAs (aural and visual alerts). The ND displays the white TA ONLY message.
- **TA/RA:** TCAS operates normally.
- **THRT:** TCAS displays OTHER or PROXIMATE aircraft on ND only if the TCAS already displays a TA or RA aircraft.
- **ALL:** TCAS displays surrounding aircraft in the surveillance envelope between –2 700 ft and +2 700 ft (refer to Figure 2-5).
- **ABV:** TCAS displays surrounding aircraft in the surveillance envelope between –2 700 ft and +9 900 ft (refer to Figure 2-5).
- **BLW:** TCAS displays surrounding aircraft in the surveillance envelope between –9 900 ft and +2 700 ft (refer to Figure 2-5).

Figure 1-2 gives an example of ATC/TCAS panel.

For more details, please refer to your FCOM.

TCAS SWITCHING TO STBY

When the flight crew sets the TCAS to STBY, the transponder to STBY, or the altitude reporting to OFF, TCAS switches to its STBY mode (i.e. green TCAS STBY memo on EWD, no TCAS information4 on PFD and ND). Indeed, TCAS is not able to interrogate intruders or to determine the vertical separation with the intruder. Therefore, TCAS is not able to evaluate the threat. Refer to 2.1.1.4.

2.1.2. OPERATIONAL RECOMMENDATIONS FOR TCAS

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

It is highly recommended to consult the ACAS II bulletins from Eurocontrol to set and maintain a proper safety level in TCAS II operations at http://www.eurocontrol.int/articles/acas-ii-bulletins-and-safety-messages

The Eurocontrol ACAS II bulletins analyze in-service incidents/accidents and provide recommendations that prevent the occurrences of such incidents/accidents. Some of the following recommendations are extracted from the Eurocontrol ACAS II bulletins, available at the time of writing the brochure.

4 Except for A380 ND where a white indication TCAS STBY is displayed when TRAF is selected on EFIS.

2.1.2.1. FOR THE AIRLINE

- **Recurrently train your flight crews** to use TCAS and to respond to RA safely and efficiently (especially responses to RA "ADJUST VERTICAL SPEED, ADJUST"). Refer to your FCOM and FCTM on TCAS.
- **Refer to ICAO Doc 9863 – Airborne Collision Avoidance System (ACAS) Manual and Part III, Section 3, Attachment of Chapter 3 of Aircraft Operations – Flight Procedures, Doc 8168-OPS/611, Volume I** for pilot training guidelines (see References).
- **Insure that the XPDR altitude reporting is accurate.** Inaccurate altitude reporting may lead to unnecessary RA with potential domino effect in RVSM airspaces.

2.1.2.2. FOR THE FLIGHT CREW

- **React immediately and appropriately.** The RA order must be applied without delay and the green sector of the vertical speed scale must not be exceeded. **Do not overreact.**
- **Do not change the flight path on TA alert.** TA is not a dangerous collision threat. However, pay attention when a TA is triggered.
- **ADJUST VERTICAL SPEED = Reduce vertical speed.** Do not invert the maneuver.
- **Take care of VFR traffic whose transponder may not transmit the barometric altitude.** Indeed, Mode C at least is required to trigger RA.
- **Do not use the TCAS to maintain separations with other aircraft.** The ATC controller is responsible for the separation of aircraft. In addition, the TCAS does not provide enough information as SSR does to insure a safe separation.
- **Report RA to ATC as soon as possible.** This might be the only way to inform the ATC controller of an RA. It will prevent the ATC controller issuing conflicting instructions.
- **Always report to ATC when clear of conflict as soon as possible.** This might be the only way the ATC controller has to resume normal operations.
- **Resume initial ATC clearance when clear of conflict.**
- **Limit vertical speed to 1 500 ft/min during the last 2 000 ft of the climb or descent.** It will prevent level busts that could lead to conflict with aircraft above or below the cleared flight level, especially in RVSM airspaces.
- **Check that TCAS is active while approaching a runway for take-off.** An active TCAS at that time enables to check there is no landing traffic before lining up on the runway and to prevent omissions of TCAS activation for take-off.
- **Refer to ICAO Doc 9863 – Airborne Collision Avoidance System (ACAS) Manual and Part III, Section 3, Chapter 3 of Aircraft Operations – Flight Procedures, Doc 8168-OPS/611, Volume I** for operational guidelines (see References).

ALWAYS FOLLOW THE RA

Even when there is:

- An opposite ATC instruction, as the maneuver may be coordinated with the intruder, or
- A traffic information from ATC, as the refreshing rate of the SSR scope may not be quick enough to depict precisely the actual situation, or
- An order to climb when flying in the vicinity of the maximum aircraft ceiling, as a small margin to climb is better than a descent, or
- A visual acquisition, as an aircraft could be wrongly identified.

2.1.3. REGULATIONS FOR TCAS

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

The carriage of ACAS II as per ICAO Annex 10, Volume IV is mandatory in all ICAO member States as per ICAO Annex 6 – Operations of Aircraft – Part I:

"6.19.1 All turbine-engined aeroplanes of a maximum certificated take-off mass in excess of 5 700 kg or authorized to carry more than 19 passengers shall be equipped with an airborne collision avoidance system (ACAS II).

6.19.2 Recommendation.— All aeroplanes should be equipped with an airborne collision avoidance system (ACAS II).

6.19.3 An airborne collision avoidance system shall operate in accordance with the relevant provisions of Annex 10, Volume IV."

As per EASA AIR- OPS (COMMISSION REGULATION (EU) No 965/2012) CAT.IDE.A.155, ACAS II is mandatory.

As per FAA FAR 121.356, ACAS II is mandatory.

2.1.4. MANUFACTURERS FOR TCAS

Three equipment suppliers of TCAS II are available on AIRBUS aircraft:

- ACSS TCAS, or T2CAS/T3CAS with TCAS module, or
- Rockwell Collins TCAS, or
- Honeywell TCAS or AESS with TCAS module.

Figure 2-11 provides a simplified view of the TCAS architecture.

NOTE:

ICAO Annex 10 – Volume IV Surv and ACAS sections 4.3.5.3.1 to 4.3.5.3.3 requires TCAS II version 7.1 on aircraft

Figure 2-11: TCAS architecture

2.1.5. WAY FORWARD

ACAS III functions with lateral maneuvers are not considered for future systems. The future systems are now focusing on the new concept of ACAS X, which remains an ACAS II function, but aims at providing relevant RA considering the aircraft operational environment.

Current TCAS collision avoidance has 4 limitations:

- The current TCAS algorithm will not be able accommodate the projected increase in air traffic density. Current TCAS is not tuned for high density traffic/ airports where there are already RAs that are not relevant and that create stressful situations and traffic density limitations.
- The current TCAS algorithm is based on Active Surveillance. Active Surveillance provides an accurate tracking of the surrounding traffic but tend to congest the 1030/1090 Mhz spectrum which is already overloaded.
- Some Particular operations like CSPO (Closely Spaced Parallel Operations) with runway separated by 3000ft require to set TCAS in “TA only mode” because the pair aircraft is so close to the own aircraft that it would always generate useless RA.
- The current TCAS equipment does not track “ADS-B only” traffic or any unmanned aircraft

The ACAS X system aims at solving those 4 issues.

The ACAS X algorithm is a probabilistic model that copes with high traffic density in order to improve the safety of the flight. Indeed the probabilistic model that relies on a “5 dimensional probability” matrix takes into account all possibilities of maneuver, aircraft trajectories, current operations, pilot response time and so on.

The “5 dimensional probability” matrix is based on Horizontal TAU, relative altitude, own vertical rate, intruder vertical rate and current maneuver.

Figure 2-12: ACAS X Concept

In order to reduce the 1030/1090Mhz spectrum occupancy, ACAS X is capable to use hybrid surveillance for intruders tracking (refer to § 2.1.1.2.2 for Hybrid surveillance principle).

For specific operations such as CSPO with 3000ft runway separation, some specific RA thresholds associated to the selection of relevant traffic will enable to adapt the algorithm to the specific operations that requires reduced separations.

ACAS X is also designed to consider “ADS-B only” aircraft or any unmanned aircraft to guarantee compatible maneuvers.

PLEASE BEAR IN MIND…

DESCRIPTION

TCAS as per TCAS II Change 7.0 fulfills the Traffic Surveillance function. It provides Traffic Advisories (TA), Resolution Advisories (RA), even coordinated RA when own aircraft and intruders are equipped with Mode S transponders.

TCAS II Change 7.1 introduces a new reversal logic and replaces the RA "ADJUST VERTICAL SPEED, ADJUST" by a new RA "LEVEL OFF".

Most TCAS available on AIRBUS aircraft now comply with TCAS II Change 7.1

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- The cognizance of Eurocontrol ACAS II bulletins
- An appropriate and recurrent training on TCAS
- **The conformation to RA in any cases without delay**
- The adequate response to TCAS aural alerts (e.g. ADJUST VERTICAL SPEED, no flight path change based on TA only, no excessive reaction to RA)
- The unreliability of TCAS for aircraft self-separation
- The immediate report to ATC in case of RA and when clear of conflict
- The conformation to the initial ATC clearance when clear of conflict.

Refer to 2.1.2 – Operational Recommendations for TCAS.

REGULATIONS

The carriage of TCAS II is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I and ICAO Annex 10, Volume IV.

WAY FORWARD

New ACAS X system generation will adapt alerting algorithm in accordance to the aircraft operations and will consider ADS-B ONLY or unmanned aircraft.

2.2. AIRBORNE TRAFFIC SITUATIONAL AWARENESS - ATSAW

The aim of ATSAW is to improve the traffic awareness of the flight crew thanks to ADS-B. ATSAW is one of those steps that implement new systems to improve the air traffic management. One of the long-term objectives would be the aircraft self-separation. As a first step, ATSAW is limited to the traffic awareness. In addition, it has to be noted that **ATSAW is part of TCAS computer but it does not address the aircraft collision avoidance**. The ACAS part of the TCAS computer still ensures the aircraft collision avoidance.

The concept of ATSAW covers several operational applications (refer to 2.2.1.2). Manufacturers that propose TCAS computer capable of ATSAW are:

- Honeywell
- ACSS

NOTE:

For the remainder of the document:

- ATSAW function refers to as a part of the airborne system.
- ATSAW applications refer to the operational use of the ATSAW function in a given context.

2.2.1. DESCRIPTION OF ATSAW

The **Airborne Traffic Situational Awareness (ATSAW[5])** function displays traffic information to the flight crew like a TCAS. However, the main differences are:

- **The ATSAW function listens to ADS-B messages broadcast by surrounding aircraft.** The ATSAW function is also called ADS-B IN function (refer to Figure 2-13). The ATSAW function displays only surrounding aircraft equipped with an **ADS-B OUT** emitter that operates on 1090 MHz (e.g. Mode S EHS transponder capable of ADS-B OUT).
- **The ATSAW traffic information is enriched**. Compared to TCAS traffic information, the ATSAW function provides in addition, but not limited to, the flight identification, the orientation, the speed and the wake vortex category of surrounding aircraft (refer to 2.2.1.1).
- **The ATSAW function do not provide any alerts.** For collision avoidance purposes, the flight crew must refer to TCAS indications.

A new TCAS computer supports the ATSAW function. Therefore, TCAS and ATSAW information are seamlessly integrated (refer to §2.2.4.1).

The new TCAS computer still provides TA and RA when aircraft separations are not sufficient. In addition, it provides enriched information to the flight crew thanks to the ATSAW function.

ATSAW

ATSAW function is a tool that assists the flight crew for the visual acquisition of surrounding aircraft capable of ADS-B OUT. The flight crew must not use the ATSAW function for self-separation and collision avoidance.

5 ATSAW is the AIRBUS designation. ATSA is the ICAO standard designation.

TCAS COMPUTER CAPABLE OF ATSAW

The introduction of the ATSAW function into the TCAS computer does not change TCAS operations. The new TCAS computer triggers TA and RA (ACAS function) in the same way as a conventional TCAS computer does. However, the TCAS. ACAS and ATSAW software are fully segregated inside the TCAS computer.

Figure 2-13: ADS-B data broadcast and collection

2.2.1.1. ENRICHED TRAFFIC INFORMATION

As a reminder, a conventional TCAS is able to determine the range, the bearing and the relative altitude of intruders within 30 NM (refer to 2.1.1). The TCAS computer capable of ATSAW is able to listen to ADS-B messages up to 100 NM behind and ahead of the aircraft, and up to 30 NM on either side of the aircraft.

Thanks to the information available in the Extended Squitter (refer to 1.1.3), the ATSAW function provides for any surrounding aircraft capable of ADS-B OUT:

- The flight number[6]
- The position
- The relative altitude
- The vertical tendency
- The distance
- The heading
- The ground speed
- The indicated air speed
- The wake vortex category.

2.2.1.2. ADS-B IN APPLICATIONS

Airbus ATSAW is an ADS-B IN function capable to collect surrounding ADS-B OUT and to process and display traffic information in the cockpit.

The following sections describe different ADS-B IN applications. At the time of writing the brochure, the ATSAW function on AIRBUS aircraft is capable of ATSA AIRB, ITP and VSA applications. Some details on ATSA applications can also be found at

https://www.skybrary.aero/index.php/Airborne_Separation_Assurance_Systems_(ASAS) or https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_90-114A_CHG_1.pdf

6 Refer to Appendix F for details.

2.2.1.2.1. IN FLIGHT: ATSA AIRBORNE (ATSA AIRB)

ATSA AIRB provides the flight crew with information regarding the surrounding traffic when in flight. ATSA AIRB is expected to improve the traffic awareness and the safety in flight.

ATSA AIRB is a general use of ATSAW when the aircraft is airborne. **ATSA AIRB supplements the verbal traffic information from the ATC controller and flight crews of surrounding aircraft**. Therefore, ATSA AIRB is expected to improve the flight safety and efficiency thanks to improved traffic awareness.

The benefits of ATSA AIRB are:

- **An optimization and/or reduction of workload.** With a better knowledge of the traffic situation, the flight crew is able to manage and anticipate tasks. ATSAW AIRB also reduces the mental effort to construct the traffic awareness.
- **A reduction of radio communication.** With a better knowledge of the traffic situation, the flight crew will request fewer updates of traffic information or fewer clearances blocked by surrounding aircraft (e.g. request for a flight level already occupied by another aircraft).
- **A reduction of useless RA.** With a better knowledge of the traffic situation, the flight crew will reduce the vertical speed when the aircraft approaches the cleared flight level. A high vertical speed when the aircraft approaches the cleared flight level may trigger useless RA. Refer to 2.1.2.
- **Early detection of developing situations.** With a better knowledge of the traffic situation, the flight crew can identify dangerous situations with other aircraft or anticipate altitude change opportunities.
- **More cooperative responses from flight crews to ATC instructions.** With a better knowledge of the traffic situation, the flight crew can better understand and accept ATC instructions.

With the existing procedure, the flight crew mentally constructs the traffic picture thanks to

- The transmissions of the ATC controller and other flight crews on a given radio frequency
- Visual scans regularly performed out the window.

However, these methods present some limiting factors:

- Surrounding aircraft are not necessarily on the same frequency (e.g. departure and arrival frequencies).
- The deployment of Controller Pilot Data Link Communication (CPDLC) reduces the amount of information available in the party line.
- The visual scans are limited in front of and above the own aircraft.
- The visual scans provide a rough estimate of the range, the relative altitude, and the vertical tendency.
- Instrument Meteorological Conditions (IMC) limit the visual scans.

ATSAW AIRB improves the construction of traffic awareness as:

- It detects all aircraft capable of ADS-B OUT around the own aircraft.
- It is more precise than visual scans for the location of surrounding aircraft.
- It does not depend of the meteorological conditions.
- It reduces the mental effort of the flight crew to construct the traffic picture.

2.2.1.2.2. IN CRUISE: ATSA IN TRAIL PROCEDURE (ATSA ITP)

ATSA ITP is the use of ATSAW with the In Trail Procedure (ITP). The ITP enables aircraft in oceanic and remote non-radar airspaces to change flight levels on a more frequent basis. The benefits of the ITP are:

- **A reduction of the fuel consumption** by flying the optimum cruise flight level
- **A reduction of emissions** by burning less fuel
- **An improvement of the flight efficiency** by flying flight levels with more favorable winds
- **An increase of the airspace capacity** by musical chair sequence: an ITP aircraft leaving its initial flight level leaves a space for another aircraft.

ATSAW significantly improves the traffic awareness of the flight crew. When the flight crew applies the ITP with ATSAW, the ATC controller may authorize the flight crew to climb or descent with temporarily reduced minima of longitudinal separations in predefined circumstances. Therefore, thanks to the reduced longitudinal separation minima, flight level changes should be more frequent.

The use of ATSAW with the In Trail Procedure is fully described in Appendix C.

NOTE 1:

The ATC controller authorizes reduced longitudinal separation minima during the climb or descent only. The ATC controller re-establishes procedural longitudinal separation minima when the aircraft reaches the new flight level.

NOTE 2:

The ITP procedure based on ADS-B OUT information should not be confused with Climb/Descent Procedure (CDP) based on ADS-C aircraft reports and RNP4 capability.

2.2.1.2.3. DURING APPROACH

- **ATSA Visual Separation on Approach (ATSA VSA)**
  ATSA VSA (also called Enhanced Visual Separation on Approach) is the use of ATSAW with the Visual Separation on Approach (VSA) procedure. The VSA procedure permits the flight crew to maintain a visual separation on the preceding aircraft during the approach when VMC conditions are met. The visual separation is shorter than the standard radar separation. Therefore, the benefits of the VSA procedure are:
  - An increase of the airport landing capacity thanks to the shorter separations between aircraft. The increase is even more significant for airports that operate closely spaced parallel runways. Indeed, at such airports, the VSA procedure permits to simultaneously use several arrival streams with alternation of landings on parallel runways. When the VSA procedure is suspended, some arrival streams are suspended, and the airport landing capacity is reduced.
  - An increase of the airport take-off capacity. The application of the VSA procedure permits the insertion of additional take-offs between landings.
  - A reduced flight time thanks to the increase of the global airport capacity.

ATSA VSA eases the application of the VSA procedure in the following terms:

- The flight crew establishes the visual contact with the preceding aircraft in an **easier and more reliable** way.
- The flight crew is able to **clearly identify the preceding aircraft.**
- The flight crew **anticipates a speed reduction from the preceding aircraft thanks to ATSAW** and maintains the **visual separation with the preceding aircraft more easily.**

In addition, ATSA VSA brings additional benefits to the VSA procedure:

- A reduced probability of wave vortex encounters, as the flight crew is able to better maintain the visual separation.
- A reduced communication workload for the flight crew and the ATC controller, as the visual acquisition of the preceding aircraft is easier.

The use of ATSAW with the VSA procedure is fully described in Appendix D.

• CDTI Assisted Visual Separation (CAVS)

The objective of CDTI (Cockpit Display of traffic Information) Assisted Visual Separation (CAVS) is also to assist pilots in maintaining own separation from an aircraft equipped with ADS-B OUT during successive visual approach procedures. This is an evolution of the ATSA-VSA applications.

The pilot can use the traffic display to support visual acquisition of the preceding aircraft during the approach procedure. Once the preceding aircraft is initially identified on the CDTI, **the pilot is, in contrast to VSA, allowed to use the traffic display to continue approach procedures even if visual contact with the preceding aircraft is temporarily lost** (e.g. lost in the lights at night, or dazzling sunlight).

Figure 2-14 : CAVS concept

But CAVS can only be operated under Visual Meteorological Conditions. CAVS does not modify approach procedure under VMC .

Aircraft installations provide a pilot-selectable range indication. This range indication is set in accordance with individual established company procedures and is intended to assist the pilot in maintaining an operationally desirable distance from the preceding aircraft. In addition the aircraft system a mean to detect a excessive closure rate with the preceding aircraft.

CAVS is only approved to support aircraft performing successive visual approach and landing operations to the same runway. CAVS is applicable for all types of runway configurations where successive visual approaches are in use.

There are no new requirements on ground systems from communication, navigation and surveillance perspectives when CAVS is used. CAVS can be used in the same environments as current operations.

CAVS benefits are similar to ATSA-VSA with more opportunity to maintain the visual procedure all long the final approach until the landing.

The use of the CAVS application is detailed in the FAA AC 90-114A :
https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_90-114A_CHG_1.pdf

• Interval Management (IM)

IM application has been defined to for managing traffic flows and aircraft spacing.

The ground controller issue an IM clearance via direct controller-pilot VHF voice communication or via CPDLC to merge and/or space aircraft safely and effienciently. The aircraft system (also refered to as Flight deck Interval management FIM) enables pilot to conform and maintain the IM clearance.

The objective of the IM application is to achieve and/or maintain an assigned spacing goal between the IM aircraft and the target aircraft. The assigned spacing goal is a time or distance interval between the IM aircraft and a target aircraft assigned by the controller as part of the IM Operation.

Figure 2-15: Interval Management Concept

Air traffic controllers and pilots are provided with new procedures and a new phraseology for IM operations.

During IM operations, the air traffic controller retains responsibility for separation. The pilot is responsible for complying with the clearance.

IM operations can occur during the initial approach , but not limited to approach en vironment (i.e. en-route, arrival, and approach phases).

The benefits of IM operations are :

- **Increased capacity in arrival and approach** environments because aircraft are pre-sequenced, and using fixed RNAV routes where vectoring for spacing is avoided.
- **Continuous descent profile** in high density environments.
- **A reduced communication workload for the flight crew and the ATC controller,** due to the reduced number of speed instructions.

The use of the IM application is detailed in the standard definition "Safety, Performance and Interoperability Requirements Document for Airborne Spacing - Flight deck Interval Management (ASPA-FIM)", RTCA DO-328A / EUROCAE ED-195

2.2.1.2.4. DURING SURFACE OPERATIONS

- **Surface Indicating and Alerting (SURF-IA)**

The Enhanced traffic situational awareness on the airport surface with indications and alerts (SURF-IA).

The SURF-IA application helps to **decrease the likelihood of runway incursions and collisions on or near the airport surface** by increasing pilot awareness of runway traffic information

The SURF-IA application adds two distinct components:

- SURF-IA indications, which are provided for normal operational situations where potential collision hazard exists; and
- SURF-IA alerts, which are provided for non-normal operational situations where collision hazard exists.

SURF-IA indications are expected to have the greatest benefits in the proximity of a runway while approaching, entering, crossing, or holding on a runway.

SURF-IA alerts are intended to draw the pilot's attention to the traffic situation to help prevent collisions between two aircraft or an aircraft and a vehicle.

This application can be used on surface operations as well as late in the approach or landing phase.

Air traffic controller procedures and responsibilities will not change with the SURF-IA application. Furthermore no changes in the basic responsibilities for pilots are required.

The use of the IM application is detailed in the standard definition "Safety Performance and Interoperability Requirements Document for Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA)", RTCA DO-323.

Airbus works on an intermediate step before SURF-IA: a function called SURF-A that provides alerts in case of collision threat around the Runway environment. This function does not display traffic display traffic information on a moving map to ease installation on aircraft.

Refer to 2.2.5 Way forward

2.2.1.3. ATSAW ENVELOPES AND FILTERING LOGIC

2.2.1.3.1. ATSAW ENVELOPES

- **Vertical extension:**
  - For ACSS: The ATSAW envelopes have the same vertical extension as the TCAS envelopes. They depend on the settings of the TCAS control panel (ALL, ABOVE, or BELOW).
  - For Honeywell: The ATSAW envelope goes from – 10 000 ft to + 10 000 ft, regardless of the settings of the TCAS control panel.
- **Horizontal range:** beyond 100 NM longitudinally, 30 NM on either sides of the aircraft.

2.2.1.3.2. FILTERING LOGIC

The TCAS computer limits the display of traffic (ADS-B and/or TCAS – refer to 2.2.1.4.1) that are in the ATSAW envelopes:

- On ND: to the 8 closest aircraft (to avoid clutter)
- On MCDU: to 90 aircraft.

2.2.1.4. ATSAW INDICATIONS

The ATSAW indications are available on ND and MCDU. The TCAS computer updates the ATSAW indications every second.

2.2.1.4.1. ND

The ND displays the ATSAW traffic information in ARC and NAV modes. The ND displays the 8 closest aircraft. The ND with ATSAW traffic information is also called the Cockpit Display of Traffic Information (CDTI).

- **TCAS and ATSAW Symbols**

On ND, the TCAS computer capable of ATSAW displays three types of traffic symbols:

- TCAS Only: The traffic does not transmit ADS-B data. The TCAS computer identifies the traffic with TCAS data only.
- ADS-B Only**:** The traffic transmits ADS-B data and is out of TCAS range. The TCAS computer identifies the traffic with ADS-B data only.
- TCAS+ADS-B: The traffic transmits ADS-B data and is in TCAS range. The TCAS computer identifies the traffic with both TCAS and ADS-B data.

The orientation of ATSAW symbols is the track contained in ADS-B messages.

Thanks to the different ATSAW controls (refer to 2.2.1.5), the ATSAW symbols get different states (Refer to Figure 2-16).

The extended label shows the flight number of the traffic. The full label shows the flight number, the ground speed, and the wake vortex category (L: Light, M: Medium, H: Heavy).

Figure 2-16: ATSAW symbol labels

When a piece of information is missing in ADS-B messages (e.g. ground speed), the piece of information is not displayed on ND.

When the position or the track is not available in ADS-B messages, the corresponding ATSAW symbol:

- **For TCAS+ADS-B:** Becomes a TCAS Only symbol.
- **For ADS-B Only:** Is removed from ND.

Refer also to 2.2.1.4.3 for other cases when ATSAW symbols are not displayed.

A flight crewmember can highlight, select, or both highlight and select an ATSAW symbol. Refer to 2.2.1.5.

When a flight crewmember highlights or selects an ATSAW symbol, the TCAS computer displays the ATSAW symbol with its full label. Refer to Figure 2-17.

NOTE:

The wake vortex category complies with the ICAO PANS-ATM definitions (see References):

LIGHT - aircraft with a MTOW less than 7 000 kg

MEDIUM - aircraft with a MTOW between 7 000 kg and 136 000 kg

HEAVY - aircraft with a MTOW more than 136 000 kg.

Figure 2-17: Highlight and selection of an ATSAW symbol

Figure 2-18: Non-TA aircraft selected and/or highlighted

Note 1: The TCAS computer displays:

- **When it triggers a TA:**
  - All non-TA aircraft with basic labels (refer to Figure 2-16). If a non-TA aircraft is selected and/or highlighted, the TCAS computer displays this non-TA aircraft in cyan with basic labels (refer to Figure 2-18).
  - The TA aircraft using one of the symbols illustrated in Figure 2-19 depending the flight crew setting (selected and/or hightlighted, or not).

Figure 2-19: ATSAW symbols for TA aircraft

- **When it triggers an RA:**
  - Removes the labels for all aircraft (RA and non-RA aircraft). Therefore, the flight crew can easily identify the intruder.
  - Keeps the highlight circle when the highlighted aircraft becomes an RA aircraft.

Figure 2-20: ATSAW symbols for RA aircraft

- **When Clear of Conflict:**
  - Reverts all aircraft to their previous state as before the TA or RA event.

The introduction of the ATSAW function does not modify the ACAS function. When a TA or RA occurs, apply the conventional TCAS procedures.

2.2.1.4.2. MCDU/MFD

On A320/A330 family MCDU, the TCAS computer capable of ATSAW displays three pages:

- The TRAFFIC LIST page
- The TRAFFIC INFORMATION page
- The ITP TRAFFIC LIST page.

The flight crew can access to these pages through the TRAF prompt (LSK 5R) in the MCDU MENU.

On A350 MFD, the TCAS computer capable of ATSAW displays 2 pages:

- The TRAFFIC LIST page with The TRAFFIC INFORMATION in the same page
- The ITP TRAFFIC LIST page.

- **Traffic List Page on A320/330 family**

The TRAFFIC LIST page (refer to Figure 2-21) displays up to 90 aircraft that are in the ATSAW envelopes (refer to 2.2.1.3.1). Two sub-lists compose the Traffic List:

- The sub-list of aircraft displayed on ND: flight numbers are displayed with large characters.

The sub-list of aircraft not displayed on ND: flight numbers are displayed with small characters.

The flight crew can access to these pages through the SURV folder.

These sub-lists are sorted in alphabetical order. When one aircraft does not provide its flight number (dashes replace the flight number), the aircraft is located at the end of the sub-list.

For each aircraft in the Traffic List:

- The flight number and the wake vortex category are displayed. If the wake vortex category is not available, a blank field replace the wake vortex category.
- A prompt gives access to details on the aircraft (Refer to next section).

- **The Traffic List page also:**
  - Gives access to the ITP Traffic List (IN TRAIL PROCEDURE prompt available when the ITP option is activated, refer to 2.2.1.4.3.
  - Provides two functions (TRAF ON and FLT ID ON, refer to 2.2.1.5).

Figure 2-21: A320/A330 MCDU Traffic list page

• Traffic Information Page on A320/A330 family

Figure 2-22: A320/A330 MCDU Traffic Information page

When the flight crew presses one LSK next to a flight number in the Traffic List, the MCDU displays the TRAFFIC INFORMATION page.

The TRAFFIC INFORMATION page contains the information transmitted by the given aircraft via ADS-B.

As described in 2.2.1.4.3, when a piece of information is missing in ADS-B messages, the TCAS is the secondary source for some pieces of information. The second part of the title line shows the sources the TCAS computer used to fill in the TRAFFIC INFORMATION page. In Figure 2-22, the TCAS computer used both ADS-B and TCAS information (see ADS-B/TCAS indication in the title line).

When a piece of information is not available, dashes replace the piece of information (except wake vortex category) in the TRAFFIC INFORMATION page.

Figure 2-23: A320/A330 MCDU Traffic Information page with selected aircraft

From the MCDU, the flight crew may select or deselect (LSK 6R) the aircraft displayed in the TRAFFIC INFORMATION page. The TCAS computer accordingly updates the ND.

The flight crew selects the TRAFFIC LIST RETURN prompt (LSK 6L) to return to the TRAFFIC LIST page.

The flight crew can scroll the Traffic List from the TRAFFIC INFORMATION page with the MCDU SLEW keys (↑↓).

Figure 2-24: A350 Traffic Information page with selected aircraft

• Traffic List Page on A350

Like on A320/A330 family, the TRAFFIC LIST page displays **up to 90 aircraft** that are in the ATSAW envelopes (refer to 2.2.1.3.1).

Two sub-lists compose the Traffic List:

1. The sub-list of aircraft displayed on ND

2. The sub-list of aircraft not displayed on ND: the line are display with a grey background

These sub-lists are sorted in **alphabetical order**. When one aircraft does not provide its flight number (dashes replace the flight number), the aircraft is located at the end of the sub-list.

For each aircraft in the Traffic List, the following items are displayed:

- The flight number
- The Bearing and Range of the traffic
- The relative altitude

The TRAFFIC INFORMATION of the highlighted traffic in the list (in white box in the TRAFFIC LIST) is displayed at the bottom of the page. it contains the information transmitted by the given aircraft via ADS-B.

As described in 2.2.1.4.3, when a piece of information is missing in ADS-B messages, the TCAS is the secondary source for some pieces of information.

From the MFD, the flight crew may select or deselect (SELECT TRAFF ON ND key) the aircraft displayed in the TRAFFIC INFORMATION. The TCAS computer accordingly updates the ND.

When a piece of information is not available, dashes replace the piece of information (except wake vortex category) in the TRAFFIC INFORMATION page

The Traffic List page also:

- Gives access to the ITP Traffic List (IN TRAIL PROCEDURE prompt available when the ITP option is activated, refer to 2.2.1.4.3)
- Allows to display or not the FLT ID on the ND

Figure 2-24 provide the A350 design of MFD pages

2.2.1.4.3. ITP TRAFFIC LIST PAGE

Figure 2-25: ITP Traffic List page

The flight crew uses the ITP TRAFFIC LIST page to initiate the In-Trail Procedure (refer to Appendix C – ATSAW In Trail Procedure (ITP) for details).

The flight crew must enter the desired FL in the amber boxes (LSK 1L).

The FLT ID ON function (LSK 6R) is identical to the one available in the TRAFFIC LIST page (refer to 2.2.1.5).

The flight crew selects the RETURN prompt (LSK 6L) to return to the TRAFFIC LIST page.

When the flight crew entered the desired FL, the TCAS computer computes the opportunity to perform an ITP (refer to C.2.5 – ITP Distance). The ITP Traffic List displays:

- The flight level taken into account for the computation (LSK 1L)
- The opportunity to perform an ITP (LSK 1R)
- The ITP distances to aircraft included in the ITP volume (LSK 3L to 5L, refer to C.2.5 – ITP Distance and C.2.3 – ITP Volume). The ITP Traffic List displays only aircraft that are on the same direction (refer to C.2.2 – Aircraft on the Same Direction).

NOTE:

The ITP Traffic List is sorted as follows:

- When ITP is possible, aircraft are displayed from the farthest one in front of the own aircraft (e.g. 45 NM BEHIND AZE1597) to the farthest one after the own aircraft (e.g. 32 NM AHEAD OF VBN8624).
- When ITP is not possible, aircraft that block the ITP procedure are displayed first.

Figure 2-26: ITP possible

Figure 2-27: ITP possible with detected non-ADS-B aircraft

The TCAS computer displays the message TRAFFIC AT FLXXX RNGYY (refer to Figure 2-27) when:

- A surrounding aircraft is within 80 NM and at the desired FL entered in LSK 1L, or
- There is a TCAS Only aircraft between the current FL and the desired FL, or
- There is an ADS-B Only aircraft on the track at less than 30 NM, or
- There is an aircraft not on the same direction between the current FL and the desired FL.

When the ITP is not possible, the TCAS computer provides the reasons that prevent the ITP:

- Below the in-trail distance (refer to Figure 2-28):
  - DISTANCE when the distance criterion is not met, or
  - REL SPEED when the relative speed criterion is not met, or
  - NO FLT ID when the flight number is not available.

- Next to LSK 2R when there are more than two aircraft in the ITP volume. Refer to Figure 2-29.

Figure 2-28: ITP not possible due to the distance with one aircraft

Figure 2-29: ITP not possible due to the number of aircraft

Figure 2-30: Sorting of the ITP Traffic List

The TCAS computer also indicates when the ITP maneuver is in progress (refer to Figure 2-31), or when a standard procedure instead of ITP is sufficient to perform a climb or a descent (refer to Figure 2-32).

Figure 2-31: ITP in progress

Figure 2-32: ITP not applicable

On A350 the MFD page for ITP is slightly different but have the same functionalities

Figure 2-33: ITP page on A350 MFD Traffic page

• Combination of TCAS and ADS-B Information

TCAS information is based on TCAS measurements (refer to 2.1.1). ADS-B information is based on GPS sensor of surrounding aircraft. Therefore, ADS-B information is supposed to be more accurate than TCAS information.

The TCAS computer uses the best positioning source for display. Most of the time, the TCAS computer will use ATSAW information. However, **the TCAS computer do NOT display the ATSAW symbol of a surrounding aircraft on ND (or the traffic information in the MCDU Traffic List) for the following reasons:**

- When ADS-B information is outdated by 3 s, or
- When the position of the surrounding aircraft received by ADS-B differs from its TCAS position by:
  - 0.5 NM in range, or
  - 200 ft in altitude, or
  - ± 30° in bearing.
  - When the surrounding aircraft transmits:
- For surrounding aircraft equipped with a DO-260 transponder: a NUC value from 0 to 4 inclusive
- For surrounding aircraft equipped with a DO-260A/B transponder:
  - A NIC value between 0 and 5 inclusive, or
  - A SIL value between 0 and 1 inclusive, or
  - A NAC value between 0 and 5 inclusive.
  - When the surrounding aircraft does not transmit its track or position, or
  - When the GPS position of the own aircraft is lost for more than 5 min, or downgraded (HIL higher than 0.5 NM).

The TCAS computer displays the TCAS Only symbol when:

- The TCAS computer does not display the ATSAW symbol for the reasons above
- The TCAS information is available.

• **Information sources for ADS-B traffic**

The following table provides the sources of information displayed for ADS-B traffic.

INFORMATION	PRIMARY SOURCE	SECONDARY SOURCE	REMARKS
Aircraft identification	**ADS-B**	**N/A**	
Position	**ADS-B**	**N/A**	The ADS-B traffic position is taken from GPS sensors of ADS-B traffic. The ADS-B traffic position is checked against its TCAS range (refer to C.2.5 – ITP Distance) for the verification of ADS-B data integrity.
Wake vortex category	**ADS-B**	**N/A**	
IAS	**ADS-B**	**N/A**	
GS	**ADS-B**	**N/A**	
Vertical speed	**ADS-B**	**TCAS**	The TCAS function determines the vertical speed thanks to successive TCAS interrogations.
Relative altitude	**ADS-B**	**TCAS**	The TCAS function determines the relative altitude thanks to the barometric altitude reported in Mode C or S.
Altitude	**ADS-B**	**TCAS**	The TCAS function determines the altitude thanks to the barometric altitude reported in Mode C or S.
Heading	**ADS-B**	**N/A**	
Track	**ADS-B**	**N/A**	
Bearing	**ADS-B**	**N/A**	Calculated from GPS positions of ADS-B and own aircraft.
Distance	**ADS-B**	**N/A**	Calculated from GPS positions of ADS-B and own aircraft. Refer to C.2.5 – ITP Distance.

When some pieces of information are missing, the TCAS computer displays:

• **On ND:** Only available information

• **On MCDU:** Dashes in appropriate fields (except wake vortex category).

The TCAS computer uses the GPS position to locate the own aircraft.

Figure 2-34: A350 MFD SURV CONTROLS page

2.2.1.5. ATSAW CONTROLS

With ATSAW controls, the flight crew can:

- Highlight and/or select an aircraft on ND
- Display or hide ATSAW symbols on ND
- Display or hide flight numbers for all ATSAW symbols on ND.

The ATSAW controls except the selection function are limited to the own side ND. The Captain and the First Officer can independently highlight, display, or hide ATSAW symbols and flight numbers on their own ND. However, when one flight crewmember selects one aircraft on his ND (with the traffic selector or with the MCDU TRAFFIC SELECT function), the ND of the other flight crewmember also displays the selection.

The selected aircraft is a common reference for both flight crewmembers.

• TRAF ON/OFF

On A320/A330 The TRAF ON/OFF function in the MCDU TRAFFIC LIST page (refer to Figure 2-21) displays or hides ATSAW symbols on ND.

On A350, The equivalent ADS-B TRAFFIC ON/OFF function in MFD SURV CONTROLS page displays or hides ATSAW symbols on ND. Refer to Figure 2-34.

When the TRAF ON/OFF (or ADS-B TRAFFIC ON/OFF) function is set to OFF, the TCAS computer:

- Removes ADS-B Only symbols from ND
- Replaces TCAS+ADS-B symbols by TCAS Only symbols on ND (Refer to 2.2.1.4.1)
- Permits the display of the Traffic List on MCDU/MFD.

The TRAF ON/OFF (or ADS-B TRAFFIC ON/OFF) function affects the own side ND only.

• FLT ID ON/OFF

The FLT ID ON/OFF in the TRAFFIC LIST and the ITP TRAFFIC LIST pages (refer to Figure 2-21, Figure 2-25, and Figure 2-24) displays or hides flight numbers of all ATSAW symbols on ND (refer to extended label in 2-16). The FLT ID ON/OFF function is not available when the TRAF ON/OFF function is set to OFF.

The FLT ID ON/OFF function affects the own side ND only.

• **Traffic Selection**

Figure 2-35: Traffic Selection in the cockpit

On A320/A330/A340 the Traffic selection can be performed either via traffic selector on or via traffic list in MCDU page.

On A350 the Traffic selection can be performed either via direct selection on ND or via traffic list in MFD page.

Via Traffic list

The TRAFFIC SELECT/DESELECT function in the TRAFFIC INFORMATION page selects or deselects the given aircraft. The selection/de-selection is accordingly updated on ND. The TRAFFIC SELECT/DESELECT function is coordinated with the Traffic Selector (Refer to Figure 2-35).

Via ND Interactivity

The flight crew uses the Traffic Selector to highlight or select an ADS-B symbol on ND.

On A320/A330/A340 the selection is done with a Traffic Selector, located on either side of the cockpit for each flight crew member.

On A350 the selection is done directly by clicking on the traffic on ND with the cursor.

NOTE 1:

In any TRAF page, the flight number follows the same legend when the flight crew:
- Highlights (flight number in cyan brackets on MCDU), or
- Selects (flight number in cyan on MCDU) the aircraft on ND.

Refer to Figure 2-21, Figure 2-22, Figure 2-23 and Figure 2-24).

NOTE 2:

On A350 MFD traffic page, the highlighted traffic has flight number boxed, and selected traffic in cyan (refer to Figure 2-24).

• **Highlight**

On A320/A330 the flight crew turns the Traffic Selector to highlight an ATSAW symbol on ND. The TCAS computer highlights aircraft as in Figure 2-36. A flight crewmember can highlight only one aircraft at a time on his ND. A quick turn of the Traffic Selector removes the highlight.

Figure 2-36: A320/A330 - Turn Traffic Selector to highlight

On A350, when the cursor is over the traffic, the traffic is highlighted.

Figure 2-37: A350 - Traffic highlight with KCCU

• **Select**

On A320/A330 the flight crew pulls the Traffic Selector to select an ATSAW symbol on ND. Refer to Figure 2-37. The flight crew can select only one aircraft at a time on ND. The selection is shared on both NDs. The flight crew pushes the Traffic Selector to deselect an ATSAW symbol.

Figure 2-38: A320/A330 - Pull Traffic Selector to select

On A350, a click on the traffic allow the selection of this traffic. After selection ADS-B information stay displayed.

Figure 2-39: A350 - Traffic selection with KCCU

2.2.2. OPERATIONAL RECOMMENDATIONS FOR ATSAW

2.2.2.1. FOR THE AIRLINE

- **Train your flight crews** to use the ATSAW function in conjunction with ATSAW applications (ATSA AIRB, ITP, VSA).
- **Pay particular attention to the flight crew training related to ATSA ITP.** The flight crew must be aware of ATSA ITP basics (terminology, phraseology, ITP criteria, normal and contingency procedures, etc).

2.2.2.2. FOR THE FLIGHT CREW

- **Do NOT use the ATSAW function for self-separation and collision avoidance.** The ATSAW function is an awareness tool that assists the flight crew for the visual acquisition of surrounding aircraft capable of ADS-B OUT.
- **Apply the TCAS procedures when a TA or RA occurs**. Responsibilities do not change. ATC remains responsible for aircraft separations.
- **Always correlate ATSAW information with visual information out of the window**. Do not maneuver with information from the ATSAW function only.

2.2.3. REGULATIONS FOR ATSAW

2.2.4. MANUFACTURER FOR ATSAW

To fulfill the Traffic Awareness function with ATSAW, AIRBUS proposes the following two systems: the Honeywell TPA 100B , the ACSS T3CAS, and A350 Honeywell AESS. These TCAS computer capable of ATSAW are also compliant with TCAS II Change 7.1.

ATSAW ITP is an option of ATSAW.

Figure 2-40: ATSAW architecture

Figure 2-40 provides a simplified view of the ATSAW architecture.

2.2.5. WAY FORWARD

Airbus works on two additional ADS-B IN applications:

- ATSAW + is based on ATSAW function with additional display and alerting to improve the management of separations with surrounding traffic (range and ground speed closure rate). This new functions will be used for specific CAVS operations (refer to §2.2.1.2.3), but also in all operations that requires to monitor separations

  ATSAW+ will allow delegating to the flight crew the responsibility to maintain the separation with a traffic in-sight, even if the visual contact with preceding traffic is lost.

  The objective is to reduce number of Go Around, and safely perform approach procedures using own separation from the preceding aircraft more efficiently and possibly more regularly to enhance runway capacity.

- Runway Incursion Traffic Alert Airborne System (RITAAS) function also called SURF-A in the cockpit is an alerting function to prevent traffic ground collision, especially due to runway incursion.

Similarly to the TCAS while in-flight, RITAAS computes the detection of any conflicting traffic (transmitting ADS-B OUT information) on runway during approach or take-off. SURF-A detect ADS-B OUT information from surrounding traffic in the runway areas, monitor the trajectories to trigger and aural alert associated to the a PFD message in case of collision threat.

Alerts can be triggered in different spatial configurations such as ownship line up with traffic incursion on the runway, ownship in final approach with a traffic incursion, ownship taxiing/crossing a runway while a traffic is taking-off or landing.

RITAAS implements a simplified function based on RTCA DO-323 standard for SURF-IA (Indicating & Alerting). RITAAS function does not implement the display of the traffic information on a moving map to ease installation on aircraft

PLEASE BEAR IN MIND…

DESCRIPTION

The ADS-B IN function (ATSAW Airbus solutions) uses ADS-B data to enhance the Traffic Surveillance of the flight crew. A new generation of TCAS computers hosts the ATSAW function. The introduction of the ATSAW function in the TCAS computer does not change the ACAS logic and the TCAS procedures. The ACAS and ATSAW software are fully segregated inside the TCAS computer.

ATSAW applications are: **ATSA AIRB, ATSA VSA, ATSA ITP.**

TCAS computer capable of ATSAW on AIRBUS aircraft are: **Honeywell TPA-100B, Honeywell AESS (A350),** and **ACSS T3CAS**.

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- An appropriate training on ATSAW with different applications (AIRB, ITP, VSA)
- A particular attention to flight crew training to ATSA ITP
- The correlation of ATSAW information with visual information out of the window
- The use of the ATSAW function for traffic awareness only.

Refer to 2.2.2 – Operational Recommendations for ATSAW.

REGULATIONS

At the time of writing the present brochure, no country has required the carriage of ATSAW.

WAY FORWARD

To improve the Traffic Surveillance, Airbus is currently working on traffic alerting in runway environment (RITAAS/SURF-A) and enhanced management of separation with preceding aircraft (ATSAW+).

#03 TERRAIN SURVEILLANCE

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The generic name of the system that fulfills the Terrain Awareness function is **Terrain Awareness and Warning System (TAWS)**. The TAWS alerts the flight crew in a timely manner of hazardous situation ahead of the aircraft to avoid Controlled Flight Into Terrain (CFIT). Honeywell was the first to propose the **Ground Proximity Warning System (GPWS)**, followed by the **Enhanced GPWS (EGPWS)**. Later on, ACSS released an integrated solution combining the Traffic Awareness and the Terrain Awareness functions: the **Transponder, Traffic and Terrain Collision Avoidance System (T3CAS)**. The TCAS part of T3CAS is identical to the stand-alone TCAS 2000. The TAWS part of T3CAS is also called Ground Collision Avoidance System (GCAS).

The present chapter describes the Terrain Awareness function as per Honeywell (E)GPWS, AESS or ACSS T3CAS.

NOTE 1:

This brochure mainly refers to EGPWS, AESS and T3CAS systems. Unless explicitly mentioned T3CAS design applies to T2CAS system.

NOTE 2:

For the description of the EGPWS RAAS function, refer to 4.2.

3.1. DESCRIPTION OF TAWS

The TAWS functions may be split into three categories:

1. Basic TAWS functions for reactive modes 1 to 5 (a mode 6 is available on A300/A310 aircraft only, refer to 3.1.2)
2. Enhanced TAWS functions for predictive functions (e.g. forward looking capability)
3. Optional functions (e.g. peaks mode, obstacle detection, RAAS function on EGPWS).

The following sections describe the TAWS functions regardless of the product designations (EGPWS or T2CAS or T3CAS or AESS). Operational differences are highlighted when necessary.

3.1.1. TAWS PRINCIPLES

The TAWS processing may be depicted as in Figure 3-1. The TAWS captures the aircraft parameters from various sensors and systems. Based on its databases and algorithms, the TAWS evaluates the aircraft situation regarding the surrounding terrain, and triggers alerts and indications in the cockpit when a risk of CFIT is identified. Based on the same database, the TAWS also displays the terrain on ND for the awareness of flight crew.

The distance to the terrain/obstacle is determined according to the topography recorded in the terrain/obstacle database (plains, hills, mountains). In addition, the terrain displayed on ND is made up from the terrain database.

An outdated terrain/obstacle database may lead the TAWS to incorrectly evaluate the CFIT risk or to trigger nuisance alerts. Therefore, it is recommended to always get the latest terrain/obstacle database in the TAWS.

NOTE 1:

The Obstacle database is specific to EGPWS/AESS and T3CAS. The Aircraft Performance database is specific to integrated equipment as T3CAS.

Figure 3-1: TAWS processing

3.1.1.1. TERRAIN DATABASE

The terrain database has a worldwide coverage and is defined according to a standardized Earth model: the World Geodetic System revised in 1984 (WGS84). The WGS84 defines the characteristics of the reference ellipsoid (semi-major axis, semi-minor axis, prime meridian, equator, etc). Based on this model, the Earth surface is divided into grid sets. For each element of the grid sets, the highest altitude above MSL is recorded and defines the terrain altitude in this element.

In order to optimize the database size, the grid set resolution varies according to the flight areas:

EGPWS/AESS	T3CAS
- 5 NM x 5 NM - 2 NM x 2 NM - 1 NM x 1 NM - 0.5 NM x 0.5 NM - 0.25 NM x 0.25 NM (airport vicinity).	In **en-route** areas: 3.0 NM In **terminal** areas within 22 NM from the airport: 0.5 NM In **final areas for mountainous airpor**t (within 6 NM from airport if elevation is 2 000 ft or more): 0.25 NM.

Figure 3-2: Terrain database encoding

3.1.1.2. OBSTACLE DATABASE

EGPWS/AESS and T3CAS contain an Obstacle database, which includes artificial obstacles worldwide. Thanks to this database, EGPWS displays obstacles on ND.

3.1.1.3. RUNWAY DATABASE

The TAWS also include a runway database. Functions that use the runway database are:

- EGPWS/AESS Terrain Clearance Floor (TCF)
- EGPWS/AESS Runway Field Clearance Floor (RFCF)
- EGPWS Runway Awareness and Advisory System (RAAS)
- T3CAS Collision Prediction and Alerting (CPA)
- T3CAS Premature Descent Alert (PDA).
- ROPS function (outside TAWS scope).

It includes runways longer than 3 500 ft (1 067 m) worldwide and runways longer than 2 000 ft (610 m) locally.

3.1.1.4. AIRCRAFT PERFORMANCE DATABASE

The T3CAS and AESS include an Aircraft Performance database. The AESS Terrain Awareness and Display (TAD) and T3CAS Collision Prediction and Alerting (CPA) function takes into account the aircraft performances for the computation of escape maneuvers. The Aircraft Performance database provides conservative climb rates taking into account aircraft weight, altitude, SAT, landing gear and flap/slat configuration, engine out conditions.

3.1.2. REACTIVE (BASIC) TAWS FUNCTIONS

The following table summarizes the different reactive TAWS functions. The penetration of a warning area triggers the call-out written inside. **The charts are illustrative**. The figures on the coordinate axis may slightly differ from a TAWS model to another (GPWS, EGPWS/AESS or T3CAS). However, principles remain the same. For more details, refer to your FCOM.

Mode 1 – Excessive Descent Rate

Mode 2A – Excessive Terrain Closure Rate
Flaps not in landing configuration

Mode 2B – Excessive Terrain Closure Rate

Mode 3 – Excessive Altitude Loss after Take-off
Flaps in landing configuration

Mode 4A – Unsafe Terrain Clearance
Gear up and flaps not in landing configuration

Mode 4B – Unsafe Terrain Clearance
Gear down and flaps not in landing configuration

NOTE 1:

T3CAS Mode 2 is inhibited to avoid inadvertent alerts during approaches. When there is a lateral position error, T3CAS reactivates Mode 2. For the same purposes, EGPWS applies an envelope modulation.

NOTE 2:

EGPWS basic modes are fitted with an audio alert declutter mode: the aural alert is repeated twice, then will remain silent unless the condition degrades by approximately 20%. For T3CAS, once triggered, the aural alert is repeated continuously.

Mode 4C – Unsafe Terrain Clearance (EGPWS only)
Gear up or flaps not in landing configuration

Mode 5 – Excessive Glide Slope Deviation

Figure 3-3 : TAWS reactive (basic) mode 1 to mode 5

TAWS with Steep Approach

The TAWS Mode 1 envelope is slightly modified.

EGPWS Mode 6: Excessive Bank Angle

The EGPWS mode 6 is an option **only available on A300/A310 family aircraft**. It triggers a BANK ANGLE BANK ANGLE aural alert when entering the alert area and each time the roll angle increases by 20%.

Figure 3-4 : TAWS reactive (basic) mode 6

EGPWS Envelope Modulation

The Envelope Modulation function adapts the caution and warning envelopes according to the aircraft lateral position (GPS or FMS). The objective is to avoid inadvertent cautions and warnings during approaches to some airports (e.g. rising terrain just before the runway threshold, airport altitude significantly higher than the surrounding terrain altitude).

The EGPWS/AESS crosschecks the FMS position with navaids data, altimeter and heading data, and stored terrain data to guard against navigation errors.

When the FMS position crosscheck is positive, the Envelope Modulation function uses the aircraft lateral position and the geometric altitude (refer to 3.1.4.1) to reduce the caution and warning envelopes during the approach on specific areas.

3.1.3. PREDICTIVE TAWS FUNCTIONS

EGPWS/AESS or T3CAS only (not GPWS) includes predictive TAWS functions (also known as the enhanced functions for EGPWS). EGPWS/AESS and T3CAS provide different methods for the prediction of collision. The following paragraphs describe their respective predictive functions. A synthetic table provides at the end of this section the equivalence between these different predictive functions.

3.1.3.1. EGPWS/AESS ENHANCED TAWS FUNCTIONS

3.1.3.1.1. EGPWS/AESS TERRAIN AWARENESS AND DISPLAY (TAD)

The TAD function analyses the terrain in caution and warning envelopes (see Figure 3-5) ahead and below the aircraft. When a terrain penetrates one of these envelopes, the TAD function triggers visual and aural alerts.

The envelopes are defined by:

- **A centerline** that lines up with the ground track. A lead angle is added during turns.

Figure 3-5: TAWS terrain caution and warning envelopes

- **A width** that starts at ¼ NM (460 m) and gets wider ahead of the aircraft with an aperture of 3 degrees on either side of the centerline.
- **An altitude floor** that is computed according to the aircraft altitude, the nearest runway altitude, and the range to the nearest runway threshold. It prevents irrelevant alerts at take-off and landing.
- **A slope** that varies with the aircraft Flight Path Angle (FPA).
- **A look-ahead distance** that is computed from the aircraft ground speed and turn rate. It provides an advance alert with adequate time for the flight crew to safely react. The caution look-ahead distance provides 40 to 60 seconds of advance alerting. The warning look-ahead distance is a fraction of the caution look-ahead distance.

The TAWS displays the surrounding terrain on ND according to the aircraft altitude. A color-coding is applied as in Figure 3-6.

The Reference Altitude is projected down along the flight path from the actual aircraft altitude to provide a 30 second advance display when the aircraft is descending more than 1 000 ft/min.

The TAWS provides two different modes of terrain display on ND:

Figure 3-6: TAWS color coding

- **Standard mode**: the terrain is displayed according to the vertical displacement between the terrain elevation and the current aircraft altitude (left side of Figure 2-6). If the aircraft is more than 2 000 ft above the terrain, there is no terrain information displayed.

OPS+

- **Peaks mode:** it displays terrain regarding to the absolute terrain elevation (i.e. referring to the sea level instead of the aircraft elevation). It improves the terrain awareness of the flight crew (right side of Figure 3-6). Practically, if the aircraft is more than 2 000 ft above the terrain, the terrain is still displayed with a gradient of green colors. In addition, the Peaks mode provides two figures in the bottom right corner of the display, which are the highest and lowest terrain elevations. The lowest terrain elevation refers to the lowest terrain information contained in the terrain database.

In case of a late reaction from the flight crew or in case of very steep terrain environments, the vertical pull up maneuver may not clear the CFIT risk. In these cases, the A350 AESS orders a lateral maneuver (AVOID TERRAIN warning).

EGPWS/AESS PEAKS MODE AND RNP AR

The EGPWS Peaks mode has been identified as mandatory during the RNP AR below 0.3NM certification process. Only the EGPWS Peaks mode or T3CAS Eleview feature are eligible for RNP AR below 0.3NM operations.

Terrain AHEAD caution, TERRAIN AHEAD – PULL UP warning, AVOID TERRAIN warning

The AVOID TERRAIN warning is computed thanks to the Aircraft Performance database and is available on A350 AESS. When the system triggers the AVOID TERRAIN warning, the flight crew should consider a lateral avoidance (turn). Refer to your FCOM for the applicable procedure.

Figure 3-7 : TAWS Avoid function envelope

AVOID TERRAIN

The AVOID TERRAIN warning is computed thanks to the Aircraft Performance database (available in AESS and T3CAS). When the system triggers the AVOID TERRAIN warning, the flight crew should consider a lateral avoidance (turn). Refer to your FCOM for the applicable procedure.

Figure 3-8: TCF envelope

3.1.3.1.2. EGPWS/AESS TERRAIN CLEARANCE FLOOR (TCF)

The TCF function provides an additional terrain clearance envelope around the runway against situations where Mode 4 provides limited or no protection. When the aircraft penetrates the terrain clearance envelope, the EGPWS/AESS triggers aural and visual alerts.

TCF alerts take into account the current aircraft location, the reference point of the destination runway, and the radio altitude.

The terrain clearance envelope is defined as in Figure 3-8.

3.1.3.1.3. EGPWS/AESS RUNWAY FIELD CLEARANCE FLOOR (RFCF)

The RFCF function complements the TCF function. It provides a circular envelope centered on the selected runway, extending up to 5 NM from the runway end. The inner limit of the RFCF envelope is set at K NM (K depends of the position error, the runway data quality and geometric altitude quality).

The RFCF function provides alerts for cases where the runway is at high elevation compared to the terrain below the approach path. In these cases, the radio altitude may be so high that the EGPWS does not trigger TCF alerts, whereas the aircraft could be below the runway elevation.

The field clearance is defined as the current aircraft altitude (MSL) minus the elevation of the selected runway.

Figure 3-9: RFCF envelope

3.1.3.2. T3CAS ENHANCED TAWS FUNCTIONS

3.1.3.2.1. T3CAS COLLISION PREDICTION AND ALERTING (CPA)

The CPA function provides the flight crew with alerts indicating that the current flight path is hazardous due to the presence of terrain ahead. The alerts permit a timely initiation of the suitable escape maneuver to avoid a CFIT. A pull up is considered as the basic escape maneuver (PULL UP warning). When the pull up is not possible, the T3CAS announces a turn around maneuver (AVOID TERRAIN warning).

For the prediction of CFIT, the CPA detects the terrain profile (augmented by an additional margin above the terrain element height, called Minimum Terrain Clearance Distance – MTCD) with a clearance sensor. Refer to Figure 3-11.

The terrain profile is extracted from the terrain database. The MTCD depends on the distance to the nearest airport, the height to the airport elevation, and the aircraft vertical speed. The MTCD is composed of a basic term and an offset term.

Figure 3-10: Variation of the basic MTCD

The variation of the basic MTCD is given in Figure 3-10. The offset MTCD varies according to the distance to the airport, and the vertical speed. The shape of the clearance sensor depends on the FPA and the aircraft performances.

Figure 3-11: T3CAS terrain caution and warning envelopes

Three segments compose the clearance sensors (see Figure 3-11):

1. A projection of the current flight path (8 seconds for the warning sensor, 20 seconds for the caution sensor)
2. A vertical maneuver at constant 1.5 G maneuver
3. A projection of the aircraft climb as per Aircraft Performance database.

In mountainous approach areas, the sensors are linearly reduced to about 30 seconds to avoid undue alerts at low altitude.

If the sensor interferes the MTCD for at least 2 seconds, the T3CAS triggers an aural alert (TERRAIN AHEAD caution or warning). In case of a late reaction from the flight crew or in case of very steep terrain environments, the vertical pull up maneuver may not clear the CFIT risk. In these cases, the T3CAS orders a lateral maneuver (AVOID TERRAIN warning).

Figure 3-12: T3CAS horizontal sensor coverage

On the horizontal plane (see Figure 3-12), the sensor opens up by 1.5° on either side of the track. The aperture of the sensor goes up to 90° during turns. The sensor width starts at 100 m (if GPS error < 100 m) or 200 m (if GPS error > 100m).

To avoid undue CPA alerts when the aircraft is close to the runway, CPA alerts are inhibited in normal take-off conditions or when the aircraft is safely converging towards the runway.

The take-off is considered as normal if:

- The vertical speed is not negative for more than 2 seconds
- The distance to the runway threshold is less than 1.9 NM
- Various criteria relative to the variations of MSL altitude, track angle and Radio Altitude are met.

Figure 3-13: Runway convergence envelope

The **Runway Convergence** protection provides alerts when the aircraft performs a premature descent or flies an unsafe approach flight path. The runway convergence protection is available until the aircraft is within 90 ft above the runway.

The T3CAS considers the runway convergence as safe when:

- Landing gears are down and flaps/slats in landing configuration
- The distance to the runway threshold is less than 5 Km (2.7 NM)
- The aircraft remains in the runway convergence envelope
- The aircraft track remains in an inhibition range
- If RA is not valid, the vertical speed is in an inhibition range.

If the runway threshold coordinates are not in runway database, the CPA function is deactivated if the aircraft is within 1.9 NM from the airport reference point (horizontal distance) and within 900 ft from the elevation of the airport reference point (vertical distance). The green TERR STBY memo is displayed on ECAM and Mode 2 is permanently activated.

3.1.3.2.2. T3CAS TERRAIN HAZARD DISPLAY (THD)

The T3CAS provides:

- **The Standard mode** display (similar to EGPWS, see Figure 3-14). In descent, the T3CAS provides an anticipated terrain situational awareness. The Reference Altitude is defined as the aircraft altitude projected 30 seconds along FPA (refer to Figure 3-14).

Figure 3-14: T3CAS color coding

OPS+

T3CAS WITH ELEVIEW AND RNP AR

The Eleview mode has been identified as mandatory during the RNP AR below 0.3NM certification process when T3CAS is embeded. Only the EGPWS Peaks mode or T3CAS Eleview feature are eligible for RNP AR below 0.3NM operations.

- **The Eleview mode** (similar to EGPWS Peaks mode) displays terrain regarding to the absolute terrain elevation (i.e. referring to the sea level instead of the aircraft elevation). It improves the terrain awareness of the flight crew. Practically, if the aircraft is more than 2 000 ft above the terrain, the terrain is still displayed with a gradient of green colors. In addition, the Eleview mode provides two figures in the bottom right corner of the display, which are the highest and lowest terrain elevations. The lowest terrain elevation refers to the lowest terrain information contained in the terrain database.

3.1.3.2.3. T3CAS PREMATURE DESCENT ALERT (PDA)

The PDA function provides alerts when the aircraft is descending and the terrain of concern is below instead of ahead of the aircraft. The PDA is an alternative to the CPA TERRAIN AHEAD caution **each time a level off maneuver, rather than a climb one, is sufficient** to clear the collision risk. The PDA function triggers an aural alert only (TOO LOW TERRAIN). No indication is displayed on ND.

The T3CAS triggers the Premature Descent Alert when:

- The Caution clearance sensor interferes with the MTCD for more than 2 seconds
- No TERRAIN AHEAD caution had been triggered
- The vertical speed is negative
- The level off altitude is above the MTCD
- The radio altitude is invalid or below a given threshold (1 000 ft in en-route phase, 750 ft in terminal phase, 500 ft in final phase).

Figure 3-15: Level off with Premature Descent Alert

3.1.3.3. EGPWS/AESS/T3CAS COMPARISON

	AESS	EGPWS	T3CAS
Mandatory functions	**Reactive modes: Imminent Contact Alerting**		
	Modes 1 to 5 (GPWS) Locally desensitized using envelope modulation		Modes 1 to 5 Mode 2 inhibited when altitude check correct
	Predictive modes: Forward Looking Terrain Alerting		
	Terrain Alerting and Display (TAD) based on Terrain database « Terrain Ahead » « Terrain Ahead Pull Up »		Collision Prediction and Alerting (CPA) based on Terrain and Aircraft Performance databases « Terrain Ahead » « Terrain Ahead Pull Up »
	« Avoid Terrain » (A350 AESS only)		« Avoid Terrain »
	Premature Descent Alerting « Too Low Terrain »		

	AESS	EGPWS	T3CAS
	Terrain Display Terrain Alerting and Display (TAD) based on Terrain database		Terrain Hazard Display (THD) based on Terrain database
	Voice call outs Managed by FWS (500ft or 400ft call out)		
Other functions	**Automatic Deactivation of FMS Source**		
	FAA audio Caution Terrain instead of Terrain Ahead Terrain Terrain Pull up instead of Terrain Ahead Pull Up		
	Bank Angle alerting (A300/310 aircraft only)		
	Geometric Altitude	**Geometric Altitude** (Hybrid or Autonomous GPS Architecture)	**Radio Altitude Blending + GPS altitude activation** (Hybrid or Autonomous GPS Architecture)
	GPS Lateral Position	**GPS Lateral Position** (Hybrid or Autonomous GPS Architecture)	
	Obstacle database	**Obstacle database**	
	Peaks mode	**Peaks mode**	**Eleview mode**
	FLS support (mode 5)		
	*	Runway Awareness and Advisory System (RAAS)	

* Runway Approaching Advisory provided by OANS/ANF on A380/A350 aircraft.

NOTE:

Functions shaded in yellow are basically activated in forwardfit

3.1.4. GPS POSITION IN TAWS ARCHITECTURE

EGPWS/T3CAS

The improvement of TAWS functions relies on the use of the vertical and lateral GPS positions. The use of vertical and lateral GPS positions gets rid of drifts from barometric altitude and FMS position. Such drifts are known to cause spurious alerts (e.g. over-flown aircraft, map shift) and unnecessary go-arounds.

The use of vertical and lateral GPS positions introduces slight modifications in the avionics architecture. According to the aircraft configuration, the new avionics architecture is called:

Figure 3-16: Former TAWS architecture

- **Hybrid architecture** for aircraft equipped with ADIRU 4MCU able to process GPS position. TAWS uses the pure GPS position from MMR or GPS-SU via ADIRU. It is the most commonly used (A320/A330/A340).

- **Autonomous architecture** for aircraft equipped with ADIRU 10MCU not able to process GPS position. TAWS uses the GPS position directly from MMR or GPS-SU. It applies on former AIRBUS aircraft (A300/A310 and former A320).

This architecture is also used for RNP AR specific configuration.

Figure 3-17: Hybrid architecture

Figure 3-18: Autonomous architecture

Both EGPWS (P/N 965-1676-002 and subsequent) and T3CAS include the provisions for the use of the vertical and lateral GPS positions. The use of the vertical and lateral GPS positions is not mandatory and remains an optional feature on both EGPWS and T3CAS. Besides, the installation of new EGPWS or T3CAS does not ensure that the aircraft is protected against spurious alerts. AIRBUS strongly recommends implementing the GPS position into the TAWS architecture, especially when MMRs or GPS-SU are already installed.

The GPS as direct input on TAWS is part of the minimum RNP AR capability. With this configuration TAWS is kept upon total FMGC loss, thus the TAWS can be used as mitigation means for extraction.

Honeywell AESS

The TAWS module selects the position source with the highest accuracy and integrity in the following sequence (by order of priority):

1. GPS position, then
2. GPS-corrected IR data, then
3. FMS position, then
4. IR position.

When all these sources are not valid or not accurate enough:

- If the automatic deactivation of predictive TAWS functions has been selected (pin-programming), AESS automatically deactivates predictive functions (basic TAWS functions remain active).
- If the automatic deactivation of predictive TAWS functions has not been selected, the flight crew must manually switch predictive functions to OFF.

3.1.4.1. EGPWS GEOMETRIC ALTITUDE – T3CAS CPA ALTITUDE

When operating with extreme local temperature variations, in non-standard altitude conditions (i.e. QNH or QFE), or when the altimeter is not set correctly, the barometric altitude may significantly deviate from the current altitude.

To provide efficient alerts with appropriate altitude clearances regardless of temperature/pressure variations, QNH/QFE or manual error settings, new generation TAWS use the Geometric Altitude (also known as Alternate Vertical Position based on GPS for T3CAS). The Geometric Altitude takes into account the GPS altitude, an improved barometric altitude calculation, the radio altitude, and the terrain/runway elevations. The Geometric Altitude provides a more reliable altitude indication to TAWS. Indeed, temperature/pressure variations, altimeter settings (QNH/QFE or manual) do not affect the GPS altitude.

3.1.4.2. USE OF GPS FOR LATERAL POSITIONING

EGPWS/T3CAS

In-service experience has shown that improper IR alignments or erroneous navaid signals may affect FM and ADIRU data. Consequently, the TAWS position (FM position or IR data) may significantly deviate from the current aircraft position. This deviation from the current aircraft position is known as Map Shift.

The TAWS displays the terrain background on ND according to its terrain database and the FM position (with former TAWS architecture). The deviation of the FM position from the current aircraft position induces a shift of the terrain display on ND. The Map Shift may cause some spurious alerts or inhibit real alerts. Figure 3-19 illustrates a Map Shift that leads to spurious alerts.

The Use of GPS for Lateral Positioning (also known as Alternate Lateral Position based on GPS for T3CAS) significantly reduces errors in the calculation of the aircraft position. Consequently, it reduces occurrences of spurious errors.

In addition, the use of GPS for lateral positioning:

- Improves the TAWS performance thanks to a more accurate aircraft position
- Reduces the dependence between the navigation (i.e. FMS) and the surveillance (i.e. TAWS).

Within the former TAWS architecture (refer to Figure 3-16), the position source is:

1. The FM position first, then
2. IR data if the FM position is unavailable.

Within the hybrid (refer to Figure 3-17) or autonomous architecture (refer to Figure 3-18), the selection of the position source applies the following sequence (by order of priority):

1. GPS position, then
2. IR data (from ADIRU 1 on A320/A330/A340 aircraft or IRU 1 for A300/A310 aircraft) combined with the last valid GPS data (GPIRS), then
3. FM position (from FMGEC 1 for A320/A330/A340 aircraft or FMS 1 for A300/A310 aircraft)

NOTE:

The SIL 22-043 describes the root causes of a Map Shift (See AIRBUS References) and proposes some solutions. The following summarizes the root causes:

- **On ground:**
  - Incorrect PPOS at IR initialization,
  - Take-off update: incorrect FM position at take-off power setting,
  - ADIRU auto-calibration malfunction.
- **In flight:**
  - Incorrect Navaids coordinates in FM NAV database,
  - Excessive IR drift.
- **During approach:**
  - LOC update: incorrect LOC data in FM NAV database,
  - Incorrect information provided by Navaids.

When all these sources are not valid or not accurate enough:

- If the automatic deactivation of predictive TAWS functions has been selected (pin-programming), TAWS automatically deactivates predictive functions (basic TAWS functions remain active).
- If the automatic deactivation of predictive TAWS functions has not been selected, the flight crew must manually switch predictive functions to OFF (TERR to OFF, refer to 3.1.7).

Figure 3-19: Map Shift due to an FM position error

Honeywell AESS

The TAWS module selects the position source with the highest accuracy and integrity in the following sequence (by order of priority):

1. GPS position, then
2. GPS-corrected IR data, then
3. FMS position, then
4. IR position.

When all these sources are not valid or not accurate enough:

- If the automatic deactivation of predictive TAWS functions has been selected (pin-programming), AESS automatically deactivates predictive functions (basic TAWS functions remain active).
- If the automatic deactivation of predictive TAWS functions has not been selected, the flight crew must manually switch predictive functions to OFF.

3.1.5. A380/A350 TAWS SPECIFICITIES

The Honeywell AESS TAWS function is equivalent to the reactive and predictive functions provided by the Honeywell EGPWS.

In addition to the EGPWS set of functions, the AESS TAWS function provides an **enlarged ND range** (up to 640 NM) and a **vertical view of the terrain** on Vertical Display (VD).

AESS uses a TAWS RNP to select the position source (GPIRS or FMS), and to define the width of the vertical cuts for vertical terrain view. The TAWS RNP is defined according to the flight phase.

FLIGHT PHASE	Take-off	Terminal	En-route	Approach
CONDITIONS	Below 4000 ft AGL and GS > 60kt	Below 16000 ft and 50 NM from runway	Outside other phases	Below 3500 ft and 10 NM from runway
TAWS RNP (NM)	1	1	2	0.5 or less*

* According to the runway selected into the FMS.

According to the VD path reference (aircraft track, FMS flight plan, or manual azimuth), the TAWS function makes a vertical cut along the VD path reference in the terrain database.

Figure 3-20: Generation of vertical terrain view along FMS flight plan path

Figure 3-21: Generation of vertical terrain view along track

Figure 3-22: Generation of vertical terrain view along azimuth

The width of the vertical cut depends on the VD path reference.

- VD image on FMS flight plan path:
  - **For the active leg:** 2x FMS RNP or 2x FMS EPU, whichever is the greater,
  - **For subsequent legs:** 2x predicted RNP,
- VD image on aircraft track:
  - **2x TAWS RNP,**
- VD image on manually selected azimuth
  - **2x TAWS RNP.**

NOTE:

The RNP value is adapted to the flight phase. Therefore, the corridor width is variable along the flight path.

The terrain database is divided into grids sets (refer to 3.1.1.1). The vertical cut in the terrain database determines a group of grid set elements. The TAWS function retains the highest elements along the VD path reference to build up the terrain elevation profile. Refer to Figure 3-23.

Figure 3-23: Cut through terrain database

Figure 3-24: VD image on aircraft track

Figure 3-25: VD image on FMS flight plan path

Figure 3-26: VD image on manual selected azimuth

The TAWS function always displays the terrain on VD in brown, regardless of the proximity of terrain or obstacles. The TAWS function displays water on VD in cyan as on ND.

VD display modes

When the VD image is on aircraft track and the aircraft is under specific conditions[1], the white indication **VIEW ALONG ACFT TRK** is displayed at the bottom of VD.

When the VD image is on manually selected azimuth, the cyan indication **VIEW ALONG AZIM NNN°** (NNN is the manually selected azimuth) is displayed at the bottom of VD. The eye icon highlights the manual setting.

The AESS also displays a white reference line on ND to illustrate the manually selected azimuth (refer to 3-26).

When the flight crew does not select any new azimuth value during 30 seconds, the VD image automatically returns to a default VD path reference (i.e. along aircraft track or FMS flight plan path). Five seconds before the 30-second timer expires, the white reference line on ND flashes.

The selected azimuth for either terrain or weather analysis is not a fixed bearing. When the aircraft turns, the white reference line sticks to a heading. Practically, the white reference line moves with the compass rose on ND. When the white reference line reaches the +/- 60° limits, the white reference line sticks to the limit until the aircraft turns in the opposite direction.

Figure 3-27 illustrates the reference line behavior during a sequence of a 60° turn to the left followed by a 30° turn to the right. The sequence starts while the aircraft is heading to the North. The azimuth range is amber dashed and the reference line is black.

Figure 3-27: Behavior of the reference line during turns

VD interpretation of elevations

The aircraft altitude on VD is the barometric altitude. Atmospheric conditions (temperature and pressure) influence the barometric altitude. As a consequence:

- At the current aircraft position (i.e. where atmospheric conditions are known), terrain and weather elevation are reliable on VD.
- Ahead of the current aircraft position (i.e. where atmospheric conditions are unknown), terrain and weather elevations are not reliable on VD.

1 For instance, in managed mode, when the aircraft deviates from the flight plan or the XLS approach course. Refer to your FCOM for details.

Figure 3-28 illustrates the case where the air ahead of the aircraft is getting colder. The aircraft is at 5 000 ft. The 5 000 ft isobar gets lower as the air temperature decreases. The terrain elevation below the aircraft is 2 000 ft (mark 1 in Figure 3-28) as atmospheric conditions are known. However, the highest terrain elevation ahead of the aircraft is not 3 000 ft as AESS does not know the atmospheric conditions at that location (mark 2 in Figure 3-28).

Do not directly read elevations on VD as they depend on local atmospheric conditions.

Figure 3-28 – Interpretation of weather and terrain information on VD

3.1.6. TAWS INDICATIONS

This section briefly describes indications and controls. For more details, please refer to your FCOM.

3.1.6.1. TAWS BASIC MODE INDICATIONS

Please refer to 3.1.2 for the aural alerts provided in TAWS basic modes.

For GPWS/EGPWS or T3CAS only:

When the TAWS triggers a caution, the GPWS light comes on.

When the TAWS triggers a warning, the PULL UP light comes on.

For AESS

Terrain indication on PFD contrary to EGPWS or T3CAS that illuminates the PULL UP/GPWS pushbutton.

Figure 3-29: AESS indications on A380 PFD

3.1.6.2. TAWS PREDICTIVE FUNCTIONS

The TAWS display on ND is available in ROSE and ARC modes.

TERRAIN AHEAD CAUTION

TERRAIN AHEAD[2]

- **EGPWS/AESS:** Every 7 seconds until conditions disappear.
- **T3CAS:** When the caution sensor penetrates the MTCD for at least 2 seconds. Every 5 seconds until conditions disappear.

TERRAIN AHEAD WARNING

TERRAIN AHEAD - PULL UP[3]

- **EGPWS/AESS:** Repeated until condition disappears.
- **T3CAS:** When the warning sensor penetrates the MTCD for at least 2 seconds. Repeated until conditions disappear.

TOO LOW TERRAIN

- **EGPWS/AESS TCF:** When the aircraft penetrates the TCF envelope and each time the AGL altitude deteriorates by 20%.
- **T3CAS PDA:** Refer to 3.1.3.2.3 for triggering conditions.

AVOID TERRAIN WARNING

AVOID TERRAIN[4]

T3CAS and A350 AESS - when a pull up maneuver does not clear the CFIT risk. The flight crew should consider a turn (lateral avoidance) as the pull up maneuver (vertical avoidance) is not sufficient. Refer to your FCOM for the applicable procedure.

On ND, black crosses are added in the red area.

2 The European EASA regulations require the wording TERRAIN AHEAD. The FAA regulations require CAUTION TERRAIN.
3 The European EASA regulations require the wording TERRAIN AHEAD – PULL UP. The FAA regulations require TERRAIN TERRAIN – PULL UP.
4 The TERRAIN AHEAD – PULL UP warning (or the equivalent FAA warning) always precedes the AVOID TERRAIN warning.

3.1.6.3. OBSTACLE FUNCTION

The Obstacle option uses the same TAD algorithm for terrain detection. Only the visual and aural alerts differ.

OBSTACLE AHEAD CAUTION	OBSTACLE AHEAD WARNING
OBSTACLE AHEAD[5] every 7 seconds until conditions disappear.	OBSTACLE AHEAD - PULL UP[6] repeated until condition disappears.

The displays on ND are similar to the ones for TERRAIN caution and warning. The term OBST replaces the term TERRAIN. The wording varies in the same way according to the regulations (EASA or FAA). Refer to 3.1.3.1.1.

AESS A350/A380 provide an additional specific depiction of the conflict area on the ND display

3.1.6.4. PEAKS/ELEVIEW MODE

OPS+

Honeywell PEAKS function or ACSS ELEVIEW function indicates in the bottom right hand corner of the ND the lowest and highest terrain elevations (in flight level) within the selected range.

Figure 3-30: Peaks/Eleview mode examples

3.1.6.5. TERRAIN DISPLAY IN POLAR AREAS

EGPWS

The terrain database is coded in latitudes/longitudes (spherical coordinates) and the ND is graduated in NM (plane cylindrical coordinates). The TAWS translates the latitudes/longitudes into distances (i.e. projection of a spherical image on a plan). At high latitudes, discontinuities appear in the terrain display (refer to Figure 3-31). Only EGPWS is affected.

AESS

The terrain database is coded in latitudes/longitudes (spherical coordinates). The displays (ND and VD) are graduated in NM (plane coordinates). The TAWS function translates the latitudes/longitudes into distances (i.e. projection of a spherical image on a plan). Consequently, this translation implies two limitations for the display of terrain.

5 The European EASA regulations require the wording OBSTACLE AHEAD. The FAA regulations require CAUTION OBSTACLE.

6 The European EASA regulations require the wording OBSTACLE AHEAD – PULL UP. The FAA regulations require OBSTACLE OBSTACLE – PULL UP.

Figure 3-31: World map with interrupted Goode's projection

Figure 3-31 illustrates discontinuities when translating a spherical world map into a plane world map. The interrupted Goode's projection shows areas near the Poles with minimal distortion.

Black Bands: Incomplete Terrain Coverage

For low latitudes, the terrain information extracted from the terrain database (spherical coordinates) is adapted to the current latitude for display (plane coordinates) with small distortions.

Near 84° of latitude, the convergence of meridians implies some significant distortions when latitudes/longitudes are translated into distances. In other words, the terrain information cannot be adapted to the current latitude without visible discontinuities. These discontinuities appear as black bands on ND (the amber TERR INOP indication is displayed on VD). When the aircraft gets closer to the North or South Pole, the discontinuities (i.e. black bands) get larger.

Figure 3-32: Terrain display in polar areas

Magenta Areas: Unavailable Terrain Information

The latitude range is - 90° to + 90°. When the aircraft flies to the North Pole, the latitude increases to 90°. When the aircraft passes the North Pole, the latitude decreases from 90° (vice versa across the South Pole). From a mathematical point of view, the latitude should increase when the aircraft flies to and passes the North Pole (i.e. …88°, 89°, 90°, 91°, 92°…). Due to the limits of the latitude range, the TAWS function considers there is no terrain information beyond 90° of latitude. The TAWS function displays the corresponding areas in magenta on ND (the amber TERR INOP indication is displayed on VD).

OPS+

T3CAS

The T3CAS assigns a unique elevation to the region that is above 75° of latitude (North or South). This unique elevation is the highest elevation of the region above 75° of latitude (North or South). Refer to Figure 3.33.

In other words, the T3CAS considers this region as a cylindrical mountain. The height of this cylindrical mountain is equal to the highest elevation in this region.

Figure 3-34 provides the areas contained in the N75° and S75° circles.

Figure 3-33: Unique terrain elevation beyond N75° or S75°

Figure 3-34: Areas beyond N75° and S75°

Figure 3-35: GPWS landing SLATS/FLAPS switch

Figure 3-36: Control panel on Captain side

Figure 3-37: TERR ON ND pushbutton

3.1.7. TAWS CONTROLS

3.1.7.1. A300/A310 CONTROLS

GPWS LANDING SLATS/FLAPS: TAWS activation of the 15/20 slats/flaps configuration for A300-600 (or 20/20 for A310) if the landing is not performed in 30/40 slats/flaps configuration.

GPWS G/S MODE: Inhibition of Mode 5 – Excessive Glide Slope Deviation.

TERR MODE: Inhibition of predictive functions (TAD/TCF for EGPWS or CPA/THD for T3CAS).

GPWS: Inhibition of basic functions.

GPWS Selector switch:

OFF: Inhibition of all warnings.

FLAP OVRD: Inhibition of TOO LOW FLAPS alert.

NORM: All GPWS warnings available.

TERR ON ND: Display of TAWS terrain information on ND.

3.1.7.2. A320/A330/A340 CONTROLS

Figure 3-38: A320 overhead panel

Figure 3-39: A330/A340 overhead panel

TERR: Inhibition of predictive functions (TAD/TCF for EGPWS or CPA/THD for T3CAS).

SYS: Inhibition of basic functions.

G/S MODE: Inhibition of Mode 5 – Excessive Glide Slope Deviation.

FLAP MODE: Inhibition of TOO LOW FLAPS alert.

LDG FLAP 3: Inhibition of TOO LOW FLAPS alert when landing in CONF 3 (A320 family aircraft only).

Figure 3-40: TERR ON ND pushbutton

TERR ON ND: Display of TAWS terrain information on ND.

Note 1: TAWS terrain information and WXR weather information cannot be simultaneously displayed on ND.

Note 2: The TAWS automatically displays terrain information on ND if the TAWS triggers a predictive alert.

SET TERR TO OFF WHEN NAVIGATION ACCURACY CHECK IS NEGATIVE

When GPS PRIMARY is lost (or GPS is not installed) and when the FMS navigation accuracy check negative, the estimated aircraft position is not reliable enough for the terrain awareness. A map shift (refer to Figure 3-19) may occur and false alerts may be triggered.

3.1.7.3. A380 AND A350 CONTROLS

3.1.7.3.1 EFIS CONTROL PANEL (EFIS CP)

Figure 3-41: A380/A350 EFIS Control Panel

With the EFIS CP, in addition to the range selection, the flight crew can select the TERRAIN (TERR) information to be displayed on ND and VD.

The flight crew cannot simultaneously select WX and TERR.

3.1.7.3.2 SURV PANEL

Figure 3-42: A350/A380 AESS Control Panel

With the SURV panel, the flight crew can Deactivate the visual and aural alerts of the TAWS Mode 5 – Excessive glide slope deviation

3.1.7.3.3 SURV PAGES ON MFD

The flight crew controls all the AESS functions (XPDR, TCAS, WXR, TAWS) through the MFD SURV CONTROLS page. On this page, the flight crew can access to TAWS functions (similar to A320/A330/A340, refer to § 3.1.7.2 A320/A330/A340 Controls).

Figure 3-43: A380 MFD SURV CONTROLS page

At any time, the flight crew can reset the default settings (the ones shown in Figure 3-44) with the DEFAULT SETTINGS button in the bottom right corner. A dialog box pops up to confirm the reversion to default settings.

Figure 3-44: DEFAULT SETTINGS confirmation

3.2. OPERATIONAL RECOMMENDATIONS FOR TAWS

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

3.2.1. FOR THE AIRLINE

- **Operate your aircraft with the latest terrain database** provided by the TAWS manufacturer. Refer to SIL 34-080 (See AIRBUS References) for more information on terrain database update. Terrain database can be downloaded at:
  - EGPWS/AESS: https://aerospace.honeywell.com .
  - T3CAS: https://support.acsscustomerservices.com/ACSS/support.aspx .
- Report any repetitive difficulties with a given airport to AIRBUS via your Customer Service Director (CSD).
- Train your flight crews to use TAWS and to respond to TAWS alert safely and efficiently.

NOTE:

States that are ICAO members provide the TAWS manufacturers with the terrain database contents. Each State is responsible for the definition of the terrain database content. The operator is responsible for verifying the correctness of the terrain database contents with the appropriate State in which the operator operates. The operator shall report errors in the terrain database to the appropriate State and its TAWS manufacturer. AIRBUS SAS does not accept any liability for the contents, acquisition, use or update of the terrain database.

GPS POSITION

Airbus Strongly recommends the implementation of the GPS position into the TAWS architecture on A320/A330/A340 families. Refer to 4.1.4 – Introduction of GPS Position into TAWS Architecture and OIT 999.0015/04, 999.0050/06 or 999.0034/07 (See AIRBUS References).

3.2.2. FOR THE FLIGHT CREW

- **Stick to the procedures.** Refer to your FCOM for the appropriate procedures.
- **Know where you are, Know where you should be, and Know where the terrain and obstacles are.**
- **Check the altimeter settings** (reference – standard, QNH, QFE – and units – hPa, inHg, meters, feet).
- **Know how your TAWS operates.**
- **Respond to TAWS alerts without delay in an appropriate manner.**
- **Correlate the results of the navigation accuracy check with the operation of the predictive TAWS functions** (e.g. overhead TERR switched to OFF when GPS PRIMARY is lost and NAV mode cannot be continued – applicable only if the automatic TERR deselection has not been activated).
- **Chase doubts in ATC communications, especially during approach and landing** (e.g. confirmation of radar contact, altimeter settings).
- **On A350/A380 aircraft, Be aware of the mechanism involved in the generation of the vertical terrain view** (e.g. along flight plan, along track, along selected azimuth, atmospheric influences on barometric elevations)

3.3. REGULATIONS FOR TAWS

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

The carriage of TAWS with forward-looking terrain avoidance function (i.e. predictive functions) is mandatory in all ICAO member States as per **ICAO Annex 6 – Operation of Aircraft – Part I:**

"6.15.2 All turbine-engined aeroplanes of a maximum certificated take-off mass in excess of 15 000 kg or authorized to carry more than 30 passengers shall be equipped with a ground proximity warning system which has a forward looking terrain avoidance function."

As per **EASA AIR-OPS CAT.IDE.A.150**

(a) Turbine-powered aeroplanes having an MCTOM of more than 5 700 kg or an MOPSC of more than nine shall be equipped with a TAWS that meets the requirements for Class A equipment as specified in an acceptable standard.

EASA CS-ACNS subpart E gives technical requirement on installation of TAWS.

As per **FAA FAR 91.221**:

No person may operate a turbine-powered U.S.-registered airplane configured with six or more passenger seats, excluding any pilot seat, unless that airplane is equipped with an approved terrain awareness and warning system that as a minimum meets the requirements for Class B equipment in Technical Standard Order.

3.4. MANUFACTURERS FOR TAWS

To fulfill the Terrain Awareness function, AIRBUS proposes the following two systems: the Honeywell EGPWS, AESS, and the ACSS T3CAS, available at the time of writing the brochure.

Figure 3-45: TAWS architecture

Figure 3-45 provides a simplified view of the TAWS architecture.

* Refer to 3.1.4.2 for details.

3.5. WAY FORWARD

At the time of writing the brochure, no new TAWS computer is expected on a short term.

PLEASE BEAR IN MIND…

DESCRIPTION

The Terrain Surveillance function had been previously fulfilled with Ground Proximity Warning System (GPWS) that includes the reactive/basic functions (i.e. Mode 1 to 5).

Today, it is fulfilled by Terrain Awareness System (TAWS) with enhanced functions also known as predictive functions in addition to basic functions. The main TAWS products available on AIRBUS aircraft are:

- **Honeywell EGPWS** with its predictive functions: Terrain Awareness and Display – TAD, Terrain Clearance Floor – TCF, Runway Field Clearance Floor (RFCF) and Peaks and an Obstacle database.
- **ACSS T2CAS** with its predictive functions: Collision Prediction and Alerting – CPA and Terrain Hazard Display – THD.
- **ACSS T3CAS** that includes a transponder, a TCAS, and a TAWS module with Eleview and an Obstacle database.
- **Honeywell AESS (Aircraft Environment Surveillance System)** that includes: a transponder, a TCAS, a TAWS module with peaks and an obstacle database and Weather radar. This system equips A380 and A350.

Refer to 3.1.3.3 to compare all products.

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- A regular update of TAWS terrain database,
- The implementation of the GPS position into the TAWS architecture,
- The activation of predictive TAWS functions,
- An appropriate and recurrent training on TAWS,
- Good knowledge of TAWS operations and escape maneuvers.
- On A350/A380 aircraft, good knowledge of VD display mechanism.

Refer to 3-2 – Operational Recommendations for TAWS.

REGULATIONS

The carriage of TAWS is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I.

WAY FORWARD

At the time of writing the brochure, no new TAWS computer is expected on a short term.

#04 AIRPORT SURVEILLANCE

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The unfortunately “runway incursions” remind the aviation community that the risk is real:

- 1977: Tenerife, Canary Islands, 583 fatalities,
- 2000: Taipei, Taiwan, 83 fatalities,
- 2001: Milan, Italy, 118 fatalities.

Prevention of runway incursions is of prime importance and must be tackled at all levels (i.e. airport and aircraft systems). Researches are on going to improve the airport navigation in terms of safety and efficiency. They include both ground and on-board systems. AIRBUS actively participates in those researches using ATC clearances through CPDLC, or on-board traffic awareness thanks to ADS-B.

In addition the runway incursions, analysis of accidents and incidents has identified that "runway excursions" during take-off or landing, are some of the most common reported annually.

These two examples shows that the airport environment is a key point to adress by on-board surveillance systems.

Today, Four functions are available on AIRBUS aircraft, based on different principles.:

- The **display of the airport moving map** provided by On-board Airport Navigation System (OANS) (and equivalent Airport Navigation Function (ANF) of the Display Global Work Package on A350, refer to §4.1) is a system that provides visual indications: the aircraft position on an interactive airport moving map. Therefore, OANS/ANF provides the flight crew with a precise aircraft position on an airport surface. OANS/ANF is developed by Thales and is integrated in the A380/A350/SA/LR cockpit. In future standards, OANS/ANF will take benefit of emerging technologies (e.g. ground ATC data link clearances, positions of surrounding aircraft thanks to ADS-B).
- The **highlight of approaching runway** provided by the following functions:
  - The Approaching Runway Advisory (ARA), part the OANS/ANF, (refer to §4.1.1.4.5)
  - The Runway Awareness and Advisory System (RAAS) on A320/A330/A340 aircraft is an add-on module of the EGPWS by Honeywell (refer to §4.2). It provides aural indications (call-outs) based on GPS position when operating in the vicinity of a runway (airborne or on ground). RAAS can be installed without OANS.
- The **detection of runway excursion** provided by Runway Overrun Protection System (ROPS package) composed of a Runway end Overrun Warning (ROW) and a Runway end Overrun Protection (ROP) (Refer to §4.3). ROW and ROP provide aural and visual indications when a risk of runway end overrun is detected during the landing phase Some ROPS and BTV visual indications are provided on the OANS display.
- The **monitoring of the take-off operations** provided by the Take-Off Surveillance (TOS) function (refer to §4.4). TOS function provides aural and visual indications able to recover human errors regarding erroneous take-off parameters and operations.

Figure 4-1: example of Airport mapping database of Milano Malpensa Airport.

Figure 4-2: example of Runway database of Milano Malpensa Airport

NOTE 1:

OANS/ANF does not provide information about temporary airport taxi restrictions. In addition, OANS/ANF may not display recent changes (new buildings or construction areas). Refer to NOTAM.

NOTE 2:

NAVBLUE provider proposes some ADBs composed of AMBDs and/or RDBs.

4.1. ON-BOARD AIRPORT NAVIGATION SYSTEM - OANS/ANF

4.1.1.DESCRIPTION OF OANS/ANF

On-board Airport Navigation System (OANS) is a system introduced by the A380, certified on A320/A330/A340 aircraft and then transposed on A350 Airport Navigation function (ANF).

This section mainly presents the A380 design of OANS, but this design is applicable to A350 ANF and A320/A330/A340 OANS. Some clarifications are provided when the design differs.

Its purpose is to locate the aircraft on an airport map displayed on ND. OANS generates the airport map with its own Airport Data Base (ADB). OANS improves the flight crew situational awareness during ground movements on airport surfaces (i.e. ramps, taxis, runways).

OANS is not designed for guidance on ground and does not change the current taxi procedures. The flight crew must correlate the OANS indications with the outside visual references.

The expected benefits of OANS/ANF are to:

- Reduce the flight crew workload in the day-to-day task of navigating around complex airfields
- Contribute to safety improvement on airports that become more complex and busy
- Contribute to potential reduction of taxiing incidents
- Help preventing dangerous errors in surface navigation
- Reduce runway incursion occurrences
- Reduce taxi time, therefore fuel burn and emissions
- Integrate the Brake To Vacate (BTV) function.

4.1.1.1. OANS/ANF TERMINOLOGY

4.1.1.1.1. AIRPORT MAPPING DATA BASE (AMDB)

The Airport Mapping Data Base (AMDB) contains a set of graphical objects that defines one airport. The accuracy of AMDBs is approximately 5 m (16 ft). Refer to Figure 4-1.

4.1.1.1.2. RUNWAY DATA BASE (RDB)

The Runway Data Base (RDB) contains a simplified AMDBs limited to the runway definition (thresholds, length and exits). This enables to use functions such as BTV, ROPS or Approaching Runway Advisory. This RDB can be used to reduce the database size and cost on alternate airports. Refer to Figure 4-2.

4.1.1.1.3. AIRPORT DATA BASE (ADB)

The Airport Data Base (ADB) contains a set of AMDBs and/or RDBs and customization settings (i.e. AMI files). ADB is updated on a 28-day cycle.

Figure 4-3: Coverage volume

4.1.1.1.4. AIRPORT MAP

OANS displays on ND a background picture called the Airport Map. OANS constructs the Airport Map with AMDBs and/or RDBs.

4.1.1.2. COVERAGE VOLUME

The coverage volume is a cylinder centered on the Aerodrome Reference Point (center of the airport map) with a radius of 20 NM and a height of 5 000 ft.

4.1.1.2.1.AIRPORT MAP DISPLAYED IN ARC AND ROSE NAV MODE

The airport map displayed in ARC or ROSE NAV mode is the nearest airport of either the departure airport or the destination airport (as entered in FMS). OANS determines the displayed airport with the coverage volume. If the aircraft is in the coverage volume of an airport stored in ADB, OANS displays the map of this airport.

4.1.1.2.2. AIRPORT MAP DISPLAYED IN PLAN MODE

The airport map displayed in PLAN mode is either:

- The airport selected by the flight crew, or
- The default airport determined by OANS.

The default airport is either the departure airport or the destination airport. OANS determines the default airport as the most suitable airport according to the following parameters:

- The distance between the departure and destination airports
- The distance between the aircraft and the departure or destination airport
- Before or after the transition to the FWS CRUISE phase (i.e. 1 500 fr or 2 min after lift off), particularly for proximate airports (less than 300 NM).

4.1.1.2.3. MAP REFERENCE POINT

The Map Reference Point is the reference point to center the airport map when the flight crew selects the PLAN mode. The Map Reference Point is:

- Either the Aerodrome Reference Point when the aircraft is airborne, or
- The current aircraft position when the aircraft is on ground.

4.1.1.3. OANS/ANF PRINCIPLES

4.1.1.3.1. AIRPORT MOVING MAP

OANS displays an Airport Moving Map on ND at the discretion of the flight crew in ARC, ROSE NAV or PLAN modes. The displayed airport may be:

- Either manually selected by the flight crew (in PLAN mode only), or
- Automatically selected by OANS from either the departure airport or the destination airport entered in FMS.

The Airport Moving Map includes comprehensive information about:

- **Runways:** QFU, stopways, thresholds, centerline, intersections, markings, exit lines, shoulders, LAHSO markings, etc

- **Taxiways:** taxi identifiers, guidance lines, holding positions, shoulders, etc
- **Aprons:** parking stand areas, parking stand locations, stand guidance lines, aerodrome reference points, de-icing areas, etc.

Thanks to a GPS/IRS hybridization, OANS locate the aircraft on the Airport Moving Map with an accuracy of:

- ~36 m for the position (based on MMR data accuracy)
- 0.4° for the heading
- 0.5 kt for the speed.

Nevertheless, the flight crew must always correlate the aircraft position provided by OANS with outside visual references.

The flight crew interacts with OANS/ANF through:

- **EFIS CP:**
  - To select the display mode (ARC, ROSE NAV or PLAN)
  - To activate the OANS display on ND (EFIS CP range selector on ZOOM position)
  - To select the display range (5 NM, 2 NM, 1 NM, 0.5 NM, 0.2 NM).
- **KCCU (A350/A380) /CCD (320/A330/A340):**
  - To select an airport
  - To navigate throughout the Airport Moving Map (drag technique)
  - To set some marks (flags and crosses) for drawing a path
  - To activate the correct database.

Refer to 4.1.1.5 for details.

4.1.1.3.2. APPROACHING RUNWAY ADVISORY

OPS+

OANS triggers the APPROACHING RUNWAY advisory each time the aircraft approaches a runway, a runway intersection, a displaced area, or a stop-way. The APPROACHING RUNWAY advisory is a pulsing message with the name of the runway (refer to 4.1.1.3.2).

Figure 4-4: Detection of runway proximity

The detection of an aircraft approaching a runway is based on the intersection of the Aircraft Protection Volume with the Runway Area. The shape and the orientation of the **Aircraft Protection Volume** depend on the aircraft dynamics (speed, acceleration, turn rate). The **Runway Area** is an area with a 60-m clearance (200 ft) from the runway edges.

OANS triggers the APPROACHING RUNWAY advisory 7 s before the aircraft nose reaches the Runway Area.

OANS displays the APPROACHING RUNWAY advisory when:

- The aircraft is on ground
- The ground speed is below 40 kt
- The aircraft nose is at 7 s from the runway area.

The APPROACHING RUNWAY advisory is displayed for at least 10 s. It is cleared when:

- The aircraft stops, or
- The aircraft nose has been inside the runway area for 2 s, or
- The aircraft has exited the runway area for 7 s, or
- The advisory has been displayed for more than 30 s.

4.1.1.4. OANS/ANF INDICATIONS

The OANS/ANF indications are displayed on ND and are split into three parts.

Figure 4-5: OANS indications

The upper banner includes the ground speed and the airport name.

The airport map is the background of the ND. The flight crew can interact with the airport map thanks to the Interactive Control Menu (refer to 4.1.1.5.5).

The Soft Control Panel provides several controls (e.g. airport selection, activation of new ADB, addition of crosses and flags, etc). Refer to 4.1.1.5.6.

4.1.1.4.1. AIRCRAFT SYMBOL

When OANS is active, the aircraft symbol displayed on ND is magenta instead of yellow. Indeed, as many indications are displayed in yellow, a magenta aircraft symbol provides a better legibility.

For display ranges from 0.5 to 5 NM, the aircraft symbol is displayed with the same size (Figure 4-6).

For the display range of 0.2 NM:

- If the distance from the aircraft nose to the Aircraft Reference Point is zero, the aircraft symbol is displayed with the same size as for other display ranges,
- If the distance from the aircraft nose to the Aircraft Reference Point is not zero, the aircraft symbol is displayed to scale (Figure 4-7).

NOTE 1:

The distance from the aircraft nose to the Aircraft Reference Point is defined via a SPP.

NOTE 2:

The aircraft symbol reference point is the intersection of the two bars. The actual Aircraft Reference Point is the projection of the 25% MAC on the aircraft longitudinal axis.

Figure 4-6

Figure 4-7

The aircraft symbol is not displayed when the aircraft position data from either IRS or MMR are not available or invalid. Consequently, the amber message ARPT NAV POS LOST is displayed on the airport map.

4.1.1.4.2. FMS ACTIVE RUNWAY

The active runway selected in the FMS flight plan is highlighted on the OANS display:

- The runway reference (either on the runway label or the runway threshold) displayed in green
- A green triangle next to the active runway threshold.

Figure 4-8: FMS active runway

Figure 4-9: Destination arrow

NOTE 1:

The FMS destination arrow aims at the reference point of the FMS destination airport. When the aircraft is near the FMS destination airport, the direction of the runway threshold may be significantly different from the direction of the reference point.

4.1.1.4.3. FMS DESTINATION ARROW

The FMS destination arrow indicates the bearing of the FMS destination airport when no parts of the airport are visible. The FMS destination arrow is available in ARC and ROSE NAV modes.

The following indications are provided:

- The **bearing** of the FMS destination airport with an arrow,
- The **ICAO airport code** next to the arrow,
- The **distance** to the FMS destination airport in the top right corner of ND.

4.1.1.4.4 AIRPORT MAP

The Airport is composed of different type of elements extracted from AMDB and RDB or added manually by the pilot (flag/cross).

The following figures provides an overwiev of graphical elements that can be displayed by OANS/ANF:

AMDB ELEMENTS

RUNWAY ELEMENTS

TAXIWAY ELEMENTS

APRON ELEMENTS

PARKING STAND ELEMENTS

LABELS

OANS/ANF identifies the following elements with a label:

- Runways,
- Taxiways,
- Parking stands,
- Stand lines,
- Vertical structures,
- Control towers.

Taxiway example

BRIDGE SYMBOL

The OANS/ANF depicts a bridge as follows.

In addition to the depiction of ADB elements, the flight crew can insert flags as checkpoints to draw the taxiing path and crosses to identify forbidden taxiways.

Flag

The flight crew sets or removes flags along the taxi path with the Interactive Control Menu or the MAP DATA page of the Soft Control Panel. Flags are shared on both Captain and First Officer NDs.

Cross

The flight crew sets or removes crosses along the taxi path with the Interactive Control Menu or the MAP DATA page of the Soft Control Panel. Crosses are shared on both Captain and First Officer NDs.

4.1.1.4.5. APPROACHING RUNWAY ADVISORY (ARA)

When the aircraft approaches a runway, OANS provides an APPROACHING RUNWAY advisory on ND. **In ARC or ROSE NAV mode,** the APPROACHING RUNWAY advisory is NN X – MM Y (e.g. 04 L – 22 R).

- NN is the QFU on the left hand side,
- X is the lateral position of the runway NN (void, L, C or R),
- MM is the QFU on the right hand side,
- Y is the lateral position of the runway MM (void, L, C or R).

When approaching two runways (e.g. runway intersection), the APPROACHING RUNWAY advisory is composed of two lines and displayed as above:

- The bottom line refers to the nearest runway,
- The top line refers to the farthest runway.

In addition, the runway(s) designated by the APPROACHING RUNWAY advisory flash(es) in yellow on the airport map.

In PLAN mode, the APPROACHING RUNWAY advisory is RWY AHEAD: CHANGE MODE.

NOTE:

No audio alerting is generated. This is the key difference with RAAS function which generate audio messages (refer to 4.2.1.1).

NOTE:

On A350 aircraft ANF displays:

- The approaching runway in yellow,
- The runway name in green if inserted in the flight plan.

Figure 4-12: APPROACHING RUNWAY advisory with runway 26R in the flight plan

Figure 4-10: APPROACHING RUNWAY advisory in ARC mode

Figure 4-11: APPROACHING RUNWAY advisory in PLAN mode

4.1.1.4.6. OANS/ANF MESSAGES

Airport Map

MESSAGE	COLOR	TRIGGERING CONDITION
PLEASE WAIT **Or** **ARPT MAP LOADING (A350)**	White	When the OANS processing time (e.g. map loading) exceeds 1 second.
ARPT NOT IN ACTIVE F-PLN	White	In PLAN mode, when: - The displayed airport is not one of the airports entered into the FMS flight plan (departure, destination, alternates), and - The current FWS flight phase is neither APPROACH nor LANDING.
ARPT NAV POS LOST	Amber	When the aircraft position data from either IRS or MMR are not available or invalid. The aircraft symbol is removed from display.
ERASE ALL FLAGS or ERASE ALL CROSSES	White	When selected from the Interactive Control Menu.
NO FMS DEST ARPT (A350)	White	When the airport code to be displayed is not in the FMS database.
ARPT NAV NOT AVAIL (A350)	Amber	When the 350 ANF computes the new map to be displayed.

Soft Control Panel

MESSAGE	COLOR	TRIGGERING CONDITION
NOT IN [filter] DATABASE	White	In the MAP DATA Page, when the OANS does not find a map element in the map element list. [filter] refers to a type of map element (i.e. runway, taxiway, stand, others).
NOT IN [filter] DATABASE **Or ICAO NOT IN DATABASE (A350)**	White	In the AIRPORT SELECTION Page, when the OANS does not find an airport in the airports list.
DATABASE CYCLE NOT VALID	White	In the STATUS page, when the Airport Data Base is outdated.
SET PLAN MODE	White	When the flight crew selects ARC or ROSE NAV mode and PLAN mode is required (i.e. manually selected airport not in FMS flight plan).
CHECK ONSIDE APT DATABASE P/N (A350)	Amber	When airport database part numbers differ between the two sides.

Figure 4-13: A380 EFIS CP range selector

Figure 4-14: A380 EFIS CP mode selector

4.1.1.5. OANS/ANF CONTROLS

4.1.1.5.1. EFIS CP RANGE SELECTOR

When in **ZOOM position**, the EFIS CP range selector activates the OANS display on ND. The OANS display is available with the following range **5 NM, 2 NM, 1 NM, 0.5 NM, 0.2 NM**. These four ranges are available **by rotating the selector counter-clockwise** from the ZOOM position (5NM).

The activation and display of OANS are independent on both sides (Captain, First Officer). Each flight crewmember controls the OANS display on his own ND.

4.1.1.5.2. EFIS CP ND DISPLAY MODE

The OANS display on ND is available in ARC, ROSE NAV and PLAN modes. These modes remain consistent with current ND definition when OANS is active.

Figure 4-15: ND ARC mode

ARC mode

The aircraft symbol is fixed at the bottom of the screen. The Airport Moving Map moves according to the aircraft heading and its position.

The Airport Moving Map is orientated in true or magnetic reference according to the TRUE/MAG push-button setting.

Figure 4-16: ND ROSE NAV mode

ROSE NAV mode

The aircraft symbol is fixed and centered on the screen. The Airport Moving Map moves according to the aircraft heading and its position.

The Airport Moving Map is orientated in true or magnetic reference according to the TRUE/MAG push-button setting.

Figure 4-17: ND PLAN mode

PLAN mode

The airport map is fixed, centered on the Map Reference Point at the time of the PLAN mode selection, and orientated towards to the true north.

The aircraft symbol moves according to its current heading and position.

Figure 4-18: KCCU

Figure 4-19 : CCD

4.1.1.5.3. KCCU/CCD

On A350/A380, the flight crew uses the Keyboard and Cursor Control Unit (KCCU) to interact with the MFD and the ND. The flight crew uses the track ball and the click button to move the airport map (refer to Figure 4-18).

On A320/A330/A340, the Cursor Control Device (CCD) is used to interact with the ND. CCD is Based on similar trackball principle as KCCU. CCDs are located behind each steering handwheel compared to KCCU located on the center pedestal.

4.1.1.5.4. MOVE FUNCTION

The MOVE function uses the **drag technique**. Press down the KCCU click button and drag with the KCCU trackball to move the airport map.

The MOVE function is available in ARC, ROSE NAV or PLAN mode **for three minutes**. However, in PLAN mode, the displacement is limited: the center of the background at the time of pressing down the KCCU click button shall remain on the screen.

When the KCCU click button is released:

- In PLAN mode, the new view displayed on ND is kept,
- In ARC or ROSE NAV mode, the ND display progressively comes back to the initial view.

4.1.1.5.5.INTERACTIVE CONTROL MENU

Figure 4-20: Interactive Control Menu

The Interactive Control Menu enables to:

- Set crosses and flags,
- Remove crosses and flags,
- Go to the MAP DATA page,
- Center the airport map on the aircraft symbol (PLAN mode only).

The flight crew calls the Interactive Control Menu by clicking with the KCCU anywhere on the airport map.

4.1.1.5.6. SOFT CONTROL PANEL

The Soft Control Panel (SCP) provides three pages to interact more with the airport map.

The **MAP DATA page** enables to:

- Access to lists of map elements (runways, taxiways, stands, deicing areas, terminal buildings, control towers)
- Center the airport map on a selected map element
- Set or remove flags or crosses on a selected map element
- Get more information about a selected map element
- Insert runway shifts.

Figure 4-21: MAP DATA page

Figure 4-22: ARPT SEL page

Figure 4-23: STATUS page

The **ARPT SEL page** enables to:

- Select and display an airport from the ADB at flight crew's discretion (PLAN mode only)
- Get more information about an airport.

The **STATUS page** enables to:

- Check the ADB validity and serial number
- Activate a new ADB.

The STATUS page is automatically displayed at first OANS activation[1] when the ADB is outdated, missing or incorrectly loaded.

On A320/A330/A340 aircraft, the design of the soft control panel slightly differ, but the content and functionalities are similar.

Figure 4-24: Soft Control Panel

1 First OANS activation when the aircraft is at the gate.

4.1.2. OPERATIONAL RECOMMENDATIONS FOR OANS/ANF

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

4.1.2.1. FOR THE AIRLINE

- **Do not use OANS/ANF as a guidance tool.** OANS is designed to improve the situational awareness.
- **Keep the OANS/ANF databases up to date.** ADB is updated every 28 days. Please refer directly to your chart provider.

4.1.2.2. FOR THE FLIGHT CREW

- **Do not use OANS/ANF as a guidance tool.** OANS is designed to improve the situational awareness.
- **Always correlate the OANS/ANF aircraft position with outside visual references.**
- **Outside visual references supersede OANS/ANF indications in case of uncertainty.**
- **Consult NOTAM before taxiing and update the ND airport map** with flags and crosses as necessary. The OANS database may not include recent changes as it is updated every 28 days.
- **Chase doubts in ATC communications** (e.g. clearance to cross a runway, to line up for take-off)..
- **PF: Refer to outside visual references. PM: Assist PF with OANS/ANF indications as necessary.**
- **PM: In reduced visibility conditions, announce when approaching active runways.**
- **Before Take-off, when OANS/ANF is no longer used, set the minimum ND range to display the first waypoint after departure, or as required for weather purposes.**

4.1.3. REGULATIONS FOR OANS/ANF

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

At the time of writing the present brochure, there is no mandate for the carriage of OANS.

4.1.4. MANUFACTURER FOR OANS/ANF

Thalès and AIRBUS jointly developed OANS. At the time of writing the present brochure, OANS is available on A320/A330/A340/A380 and A350 aircraft .

Figure 4-25 provides a simplified view of the OANS architecture.

Figure 4-25: OANS/ANF architecture

4.1.5. UPDATE OF OANS/ANF DATABASES

The OANS/ANF uses airport databases compliant with **ARINC 816 – Embedded interchange Format for Airport Mapping Database.** At the time of writing the brochure, only Jeppesen provides ARINC 816 ADB and updates online. Contact your chart provider for more details.

The duration of the upload on aircraft depends on the update file size. The update may take approximately 15 minutes.

NOTE:

A350 ANF is mainly based ARINC 816-0.

4.1.6. WAYFORWARD

OANS will take benefits of emerging technologies. The new functions that may be introduced are the integrations of:

- ADS-B IN data to detect aircraft conflicting with own aircraft path (also known as SURF-IA which combines OANS and SURF-A).

Data link applications to display NOTAM and ATC ground clearances (e.g. taxi path on airport map). This project is part of the development of Mission+ product on EFB (refer to www.navblue.aero).

Some of these functions may be part of Electronic Flight Bag (EFB) applications.

PLEASE BEAR IN MIND…

DESCRIPTION

The On-board Airport Navigation System (OANS) is an A380/A320/A330/A340 system. Airport Navigation Function (ANF) is A350 equivalent system. It improves the flight crew situational awareness during taxi by locating the aircraft on an airport map.

OANS/ANF is NOT designed for guidance on ground and does not change the current taxi procedures. The flight crew must correlate the OANS/ANF indications with the outside visual references.

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- **OANS/ANF is not a guidance tool**
- A regular update of OANS/ANF Airport Data Base (ADB)
- **The check of NOTAM before taxiing**
- **The correlation of OANS/ANF indications with outside visual references.**

Refer to 4.1.2 – Operational Recommendations for OANS/ANF.

REGULATIONS

At the time of writing the present brochure, no country has required the carriage of OANS/ANF.

WAY FORWARD

The future evolutions of OANS/ANF are expected for the integration of:

- The ADS-B data for Traffic Surveillance
- Data link applications to display NOTAM and ATC ground clearances.

4.2. RUNWAY AWARENESS AND ADVISORY SYSTEM - RAAS

4.2.1. DESCRIPTION OF RAAS

RAAS is an add-on module of the **Honeywell EGPWS**. It uses the **GPS position** and the runway data of the **EGPWS terrain database**. The **RAAS Configuration Database (RCD)** enables some customization (e.g. GPS antenna position, female or male voice, units in feet or meters) and the settings of some options (e.g. activation/deactivation of some call-outs, audio volume). The RAAS uses the EGPWS resources to produce the call-outs.

The RAAS is capable of 10 different call-outs. **There are two certified configuration on AIRBUS aircraft that includes 3 call-outs only** (the second certified configuration includes call-outs with lower audio volume). These call-outs are triggered on ground only. The selection of these 3 call-outs is coming out from a long period of evaluations through flight tests and simulator sessions. It has to be noted that a major airline selected the same set of call-outs as a result of an evaluation of several months on other aircraft model.

The following sections describe only the call-outs certified on AIRBUS aircraft. The first two call-outs are **routine advisories** as the RAAS systematically triggers them on each flight. The last call-out is a **non-routine advisory** as the RAAS only triggers it when specific conditions are met. All these call-outs are triggered on ground.

4.2.1.1. APPROACHING RUNWAY – ON GROUND ADVISORY

4.2.1.1.1. PURPOSE

The Approaching Runway advisory informs the flight crew that the aircraft is approaching a runway edge.

The advisory announces the closest runway end (refer to Figure 4-26).

Figure 4-26: RAAS Approaching Runway advisory

4.2.1.1.2. TRIGGERING CONDITIONS

- Ground speed is less than 40 kt
- Aircraft is within a specified distance to the runway. This distance is a function of ground speed and closure angle. The higher the ground speed, the earlier the advisory.
- If more than one runway meet the conditions (e.g. two runways within +/- 20° of heading of each other), the advisory is APPROACHING RUNWAYS.

The RAAS triggers the advisory one time when the aircraft approaches a runway.

NOTE:

The AIRBUS flight tests revealed that the On Runway advisory may interfere with the ATC take-off clearance. The On Runway advisory may partially or completely overlap the clearance. This interference may be considered as a nuisance in daily routine operations, especially when weather and visibility are fine. But it was admitted the On Runway advisory to be helpful, especially when weather and/or visibility are unfavorable. To mitigate the nuisance, the latest certified RCD on AIRBUS aircraft permits to significantly reduce the audio volume of routine advisories.

4.2.1.2. ON RUNWAY ADVISORY

4.2.1.2.1. PURPOSE

The On Runway advisory informs the flight crew on which runway the aircraft is lined-up.

Figure 4-27 RAAS On Runway advisory

4.2.1.2.2. TRIGGERING CONDITIONS

- Aircraft enters a runway
- Aircraft heading is within +/- 20° of runway heading.

The RAAS triggers the advisory one time when the aircraft enters a runway.

4.2.1.3. TAKE-OFF ON TAXIWAY ADVISORY

4.2.1.3.1. PURPOSE

The Take-off On Taxiway advisory informs the flight crew of excessive taxi speed or inadvertent Take-off on taxiway.

NOTE:

To balance the noise from the engine power setting, the volume level of the Take-Off On Taxiway advisory is increased by +3dB compared to EGPWS call-out volume level.

Figure 4-28: RAAS Take-Off On Taxiway advisory

NOTE:

The certified AIRBUS RCD enables only RAAS advisories triggered on ground. Therefore, RAAS advisories would unlikely interfere with other call-outs on ground. Indeed, call-outs triggered on ground in AIRBUS cockpits are:

- Predictive Wind Shear (PWS) alerts from Weather Radar (WXR), and WXR alerts have priority over EGPWS ones,
- V1 and RETARD call-outs, and the RAAS does not trigger advisories at the same aircraft speeds.

4.2.1.3.2. TRIGGERING CONDITIONS

- Ground speed is more than 40 kt
- Aircraft is not on a runway.

The RAAS uses a runway database. Therefore, the RAAS is not able to locate taxiways. Rolling on a pavement that is not a runway at high speeds triggers the Take-Off On Taxiway advisory.

4.2.2. OPERATIONAL RECOMMENDATIONS FOR RAAS

From the AIRBUS flight test campaign, the set of advisories has been limited to three (Approaching Runway, On Runway, Take-Off On Taxiway). AIRBUS has no specific recommendations on RAAS operations.

- Refer to FOBN “Runway and Surface Operations – Preventing Runway Incursions” (See AIRBUS References).

4.2.3. REGULATIONS FOR RAAS

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

At the time of writing the present brochure, there is no mandate for the carriage of RAAS.

4.2.4. MANUFACTURER FOR RAAS

The RAAS is part of the Honeywell EGPWS. Additional information is available at www.honeywell.com.

The RAAS requires recent EGPWS software version and terrain database. Refer to the Honeywell RAAS Product Description available at the link mentioned above.

4.2.5. WAY FORWARD

At the time of writing the present brochure, no evolutions are expected, from AIRBUS perspective, for RAAS in terms of new functions.

PLEASE BEAR IN MIND…

DESCRIPTION

The **Runway Awareness and Advisory System (RAAS)** is one system that fulfills the Runway Surveillance function. It is a module of the Honeywell EGPWS. The RAAS provides advisories about the aircraft position on or out the runway thanks to the **EGPWS runway database.** Therefore, the RAAS is not able to locate taxiways. Anyway, it is able to identify when the aircraft is rolling on a pavement that is not a runway at high speed.

AIRBUS aircraft had been certified with three call-outs out of ten: **Approaching Runway, On Runway and Take-Off On Taxiway.**

The RAAS requires recent EGPWS software version and terrain database.

OPERATIONAL RECOMMENDATIONS

AIRBUS has no recommendations on RAAS operations.

REGULATIONS

At the time of writing the present brochure, no country has required the carriage of RAAS.

WAY FORWARD

At the time of writing the present brochure, no evolutions are expected, from an AIRBUS perspective, for RAAS in terms on new functions.

4.3. RUNWAY OVERRUN PREVENTION SYSTEM - ROPS

4.3.1. DESCRIPTION OF ROPS

4.3.1.1. FUNCTION GOAL

Runway Overrun Prevention System (ROPS) is a safety enhancement function for all braking means (manual and automatic) at landing. ROPS helps the flight crew to anticipate an overrun risk during the landing phase by computing in real time landing distances and comparing them to the runway length. In case of overrun risk, ROPS provides dedicated alerts for the crew to perform a go-around, apply maximum braking and/or use maximum reverse thrust.

4.3.1.2. HISTORY

ROPS was initially certified in 2009 in a STEP 1 on A380 and linked to BTV function (refer to §1.4) as a protection of autobrake modes.

ROPS was enhanced and certified on A380 (in 2011), A320 (in 2013), A330 (in 2015) and A350 (for the Entry Into Service) in a STEP 2 (superseding STEP 1).

The function was extended to the manual braking modes. ROPS was separated from BTV function and became a standalone function protecting against the risk of runway overrun on dry and wet runway states.

Through continuous improvement, ROPS was extended to contaminated runways (all runway conditions are selectable) and additional functionalities were added on A350 in a STEP 3. ROPS design and functionalities on A350 are further described in §4.3.1.8.

ROPS is now basic on A350 and a chargeable option on A320, A330 and A380.

NOTE:

ROPS STEP 1 does not exist anymore on Airbus aircraft.

4.3.1.3. ROW / ROP

ROPS consists in 2 sub-functions ROW and ROP, one for the in-air phase and one for the on-ground phase (cf. Figure 4-29):

- Runway Overrun Warning (ROW) provides in-air alerts in case of detection of a risk of runway overrun. ROW is active until a “transition point” from the in-air phase to the on-ground phase (the “start of braking”).
  - ROW provides reversible aural and visual indications when computed stopping distances exceed the remaining runway length.
  - In that case and by procedure, the flight crew should perform a go-around maneuver.

→ ROW alerts are “Go-Around minded”

- Runway Overrun Protection (ROP) provides on-ground alerts in case of detection of a risk of runway overrun. ROP is active from the transition point.
  - ROP provides aural and visual indications if the current aircraft deceleration or aircraft’s capability to decelerate is not sufficient to safely stop before the end of the runway.
  - In that case and by procedure, the flight crew should apply full pedals braking and set/keep max reverse.

→ ROP alerts are “Stop minded”

Figure 4-29: ROW/ROP philosophy

4.3.1.4. BRAKE TO VACATE (BTV)

To complete ROPS, Airbus also developed the BTV function to ease flight task during landing. BTV function is available on A380 and A350 aircraft. Both BTV and ROPS functions are complementary. The goal of BTV is to manage the braking during the landing roll so as to reach a runway exit selected by the flight crew.

BTV benefits are:

- Optimization of the braking energy, it reduces:
  - The brake temperature (reduction of hydraulic fluid temperature, reduction of carbon brake oxidation;
  - The risk of tire deflation;
  - Tire wear;
  - The turnaround time (reduction of brake cooling time).
- Optimization of the runway occupancy: BTV is able to predict and optimize the Runway Occupancy Time (ROT). When aware of ROT, the ATC controller is able to optimize the flow of arrivals.
- Reduction of environmental impacts: BTV reduces fuel burn thanks to reduced ROT and reduced use of thrust reversers. BTV also reduces emission of carbon dust from brake wear.
- Improvement of the passenger comfort.

NOTE:

This document will focus on surveillance part, performed by ROPS function.

4.3.1.5. ROPS COMMONALITIES

This section is common to the A320, A330, A350 and A380 aircraft families.

4.3.1.5.1. OPERATING DOMAIN

ROPS operating domain:

- Whatever the braking means (auto-brake, pedal braking and BTV (specific to A350 and A380),
- Whatever wind and visibility conditions down to CAT IIIB operations, and whatever aircraft (A/C) landing configuration (weight, center of gravity (CG), aerodynamic configuration, etc.),
- With or without Auto-Pilot (AP),
- On DRY & WET runways (contaminated runways are included with ROPS latest version on A350 also called STEP 3).
- Without failures affecting landing performances. ROPS does not take into account degraded braking capability due to A/C failures.
- If the landing runway is in the terrain or airport database.

The ROPS function is available only on airport or runways that exist and are validated in the database (TAWS or airport database – refer to 4.3.1.5.6).

OPS+

Outside the above operating domain or in case failure affecting aircraft performance, ROPS function is still active and all alerts must be followed as they indicate a high-risk of runway overrun.

4.3.1.5.2. RUNWAY DETECTION

The ROPS function is based on the auto-detection of the landing runway. Given the aircraft position and the ROPS runway database hosted in TAWS (EGPWS or T3CAS STD 2) or Airport Navigation equipment, an algorithm computes the most probable landing runway. The result of the auto-detection becomes the runway on which the aircraft will be protected by the ROPS function. The detection is continuous and thus will update the detected runway in case of late runway change and/or circle to land. At any moment if there is a change of detected runway, the detected runway becomes the new protected runway.

The ROPS function is automatically activated during final approach until the end of the braking, whatever the braking means (manual and automatic).

4.3.1.5.3. IN-AIR ROW FUNCTION

Below 400ft above aiport level (500ft for A350/A380), as long as a landing runway is detected and until the “transition point” is reached, ROW monitors the aircraft performance against the remaining runway length.

ROW continuously computes in real-time two predicted minimal landing distances, one for DRY and one for WET runway state corresponding to the Airbus Factored in-Flight Landing Distances (FLD) using maximum pedal braking.

ROW monitors the position of theses computed DRY and WET minimal landing distances with respect to the runway end. And in case these estimated stopping distances exceed the remaining runway length, ROW alert is triggered and immediately informs the crew.

NOTE:

Specific performance credit for PFC (Porous friction Concrete) / Grooved runways in case of WET conditions is not taken into account by ROPS.

NOTE:

On A350 ROW computation is extended to all runway states including contaminated ones (refer to 4.3.1.8)

• ROW distances computations

ROW stop distances for each runway state are based on Airbus Factored In-Flight Landing distance which include an in-air distance (distance from 50ft to touch-down) and an on-ground distance (from touch-down to stop). The ROW landing distance computation uses the current flight parameters: true airspeed, ground speed (GPIRS), A/C weight, total air temperature, QNH, landing configuration (landing gear, flaps), longitudinal position, radio altitude, runway slope.

When below 4.5° glideslope, the performance model assumes a height of 50ft at the runway threshold. If the aircraft is above 4.5° glideslope, ROPS will longitudinally translate the point at which the aircraft will reach 50ft.

• ROW Alerts

The ROW function monitors the position of the computed wet and dry minimal landing distances with respect to the runway end. In case of detected overrun risk, ROW alerts are triggered. There are two levels of alerts:

- Prediction of overrun in WET condition;
- Prediction of overrun in DRY condition.

The ROW alerts can be triggered below 400 ft AAL (500ft on A380).

Figure 4-30: ROW "IF WET: RWY TOO SHORT" message

• Prediction of overrun in WET condition

When the computed WET minimal landing distance exceeds the end of runway, ROW triggers an alert:

→ An amber message **"IF WET: RWY TOO SHORT"** is displayed on the PFD (Refer to Figure 4-30).

This alert informs the crew of the overrun risk on a WET runway, and it is up to the PF to decide to initiate a go around if the runway is wet or contaminated. If the pilot initiates a go around, the ROW alert is no longer triggered. Moreover, the ROW alert is reversible: if the aircraft situation improves such as the runway overrun risk is no more detected, the ROW alert stops.

• Prediction of overrun in DRY condition

When the computed WET and DRY minimal landing distances exceed the end of runway, ROW triggers an alert (Refer to Figure 4-31):

Once the overrun is detected:

- A red message **"RWY TOO SHORT"** is displayed on the PFD;
- Below 200ft RA: if the risk of runway overrun remains, a repetitive audio "RWY TOO SHORT" is triggered. The audio is inhibited above 200ft RA.

This alert informs the crew of the overrun risk, and then the PF should initiate a go around.

RWY TOO SHORT!! RWY TOO SHORT!!

Figure 4-31: ROW "RWY TOO SHORT" messages and aural alert

NOTE:

The functional monitoring of ROW and ROP functions is also known as “armed” state.

• **ROW Alerts inhibition**

ROW alerts are inhibited in the following cases:

- Go-Around maneuver is detected, or
- ROW/ROP transition is met, or
- The situation improves, and the system no longer detects a risk of runway overrun (ROW alerts are reversible)

4.3.1.5.4. TRANSITION FROM ROW TO ROP

The transition from ROW to ROP may be reversible (the system transitions to ROP logic, but the system can revert back to ROW if the conditions are no longer met) or definitive.

The transition is reversible if:

- **a consolidated “aircraft on ground” condition** is detected:

The ground spoilers are deployed

Aircraft is in a nose-down position

The transition from ROW to ROP is definitive if:

- Either **a confirmed pilot intent to stop** is detected (thrust reverse selected):
- **Or a Go-Around maneuver is at risk:**
  Engine idle reduced to ground idle (CAS < 100 KTS).

4.3.1.5.5.ON-GROUND ROP FUNCTION

From the **“transition point”** (ROW to ROP transition) to 30kt or runway vacation detection, ROP permanently computes in real-time the estimated braking distance-to-stop. ROP monitors the position of the estimated stopping point (considering current position, speed and deceleration) with respect to the runway end. In case of detected overrun risk, ROP alert activates and informs immediately the crew.

• **ROP alerts**

While on ground, after the transition point, ROP monitors the estimated braking distance with respect to the runway end.

If a runway overrun risk is detected and whatever the braking means, ROP triggers following alerts (Figure 4-32).

• ROP triggers alerts to induce the crew to apply maximum braking:

- **“MAX BRAKING”** red message is displayed on the PFD.
- An aural alert is triggered:
  “BRAKE...MAX BRAKING...MAX BRAKING” aural alert is played and repeated as long as a runway overrun risk is detected and if the pilot does not brake with full pedals (i.e. when one of the right or left brake pedal angles exceeds a defined threshold). This aural alert has priority on “SET MAX REVERSE” aural alert;

Figure 4-32: ROP Alert: messages on PFD

NOTE:

On A380 and A350 max braking is automatically applied in case of ROP alert when using BTV or autobrake (refer to 4.3.1.7 and 4.3.1.8)

- ROP triggers alerts to induce the crew to select max reverse:
  - As soon as a runway overrun risk is detected, **"MAX REVERSE"** red message is displayed on the PFD ("MAX BRAKING" message is displayed just above **"MAX REVERSE"**; indeed that corresponds to the operational sequence of actions).
  - **Once maximum braking is applied:**
    An aural alert is triggered:
    "SET MAX REVERSE" aural alert is played and repeated until flight crew select max reverse detent
    "KEEP MAX REVERSE" played once below 80kts CAS if a runway overrun risk is detected and all thrust levers are on the Max reverse position.

ROP alerts are reversible: if the aircraft situation improves such as the runway overrun situation is no more detected, ROP alerts are inhibited.

- **ROP Alerts inhibition**

ROP alerts are inhibited in the following cases:

- Go-Around maneuver is detected, or
- Aircraft is vacating the runway, or
- Aircraft decelerates below 30kt (or 25Kt for A380)

4.3.1.5.6. DATABASE

To work correctly, ROPS needs accurate data about the landing runway. The main information required is:

- The runway thresholds position;
- The Landing Distance Available;
- The runway slope;
- The runway bearing.

This information is used to:

- Detect the landing runway;
- Compute the aircraft position in the runway reference axis;
- Compute the estimated stopping distances and trigger the alerts in case of risk of runway overrun.

On SA/LR, this information is provided by the TAWS: T3CAS or EGPWS database.

On A350, this information is provided by the TAWS: AESS database, and the airport navigation equipment: ANF database.

On A380, this information is provided by the airport navigation equipment: OANS database.

In case of unknown or invalid runway in the TAWS database, ROPS self-inhibits.

4.3.1.5.7. ROPS LOST

- **Self-inhibition**

Figure 4-33: ROPS lost ecam alert

ROPS automatically self-inhibits if one of the following conditions occurs:

- A failure of a mandatory system contributing to ROPS function is detected (primary failure);
- An input (such as GPS integrity/accuracy) used by ROPS is unavailable or outside of a tolerable range;
- If the runway is not available or invalid for ROPS in the terrain database.

If a primary failure which impacts ROPS occurs:

- The associated ECAM alert is triggered with its own behavior,
- The **"ROW/ROP"** label is displayed in the INOP SYS list in STATUS SD page (along with BTV on A350 and A380),

If not a primary failure:

- A **"SURV ROW/ROP LOST"** ECAM alert associated with a single chime and a master caution is triggered,
- The **"ROW/ROP"** label is displayed in the INOP SYS list in STATUS SD page (and BTV is too),
- The ECAM alert is inhibited below 800ft HRA, in order not to disturb the crew during final approach and landing.

- **Manual inhibition**

Figure 4-34 : ROPS INOP SYS on EWD

On SA/LR

ROPS may be deactivated upon “TERRAIN OFF” selection. The procedure will also inhibit the Enhanced Modes of the Terrain Warning function of the TAWS. The procedure should only be used under exceptional circumstances and with crew awareness that the Terrain Warning function is no longer active.

On A380

ROPS may be deactivated using “ARPT NAV” reset pushbutton. The OANS will no longer be available.

On A350

ROPS may be deactivated upon “ROW/ROP OFF” selection. ROW, ROP and BTV will be deactivated.

4.3.1.6. A320/A330/A340 SPECIFICITIES

On A320 and A330/A340 aircraft, ROPS function is based on all description detailed in §2 with additional specificities.

4.3.1.6.1. RUNWAY DETECTION

The runway detection is performed by the TAWS (T3CAS or EGPWS).

The terrain database containing the runway characteristics needed by ROPS is provided by the TAWS (T3CAS or EGPWS).

4.3.1.6.2. ROP FUNCTION

Whatever the braking mode, ROP will not automatically apply maximum braking in case of detection of a risk of runway overrun. Max Manual Pedal Braking must be applied by the pilot (refer to §4.3.1.5.5 on ROP alerts triggering “MAX BRAKING”).

ROP estimates the distance to stop based on a model of aircraft’s deceleration capability.

As ROP on A320/A330/A380 aircraft does not have a dedicated runway state selector, the ROP model will use a conservative runway state:

- If there was an IF WET RWY TOO SHORT message during approach and flight crew continued to land, the ROP model will use a dry runway model.
- Otherwise ROP will use a wet runway model.

4.3.1.7. A380 SPECIFICITIES

The A380 ROPS function is based on all description detailed in §4.3.1.5 with additional specificities.

4.3.1.7.1. LANDING RUNWAY AUTODETECTION FUNCTION

The landing runway is identified by the OANS (On-board Airport Navigation System). ROPS monitoring is based on the runway characteristics provided by the OANS airport database.

Braking mode: BTV

Below 500ft, the protected runway is the runway where the BTV function is armed. At 300ft a detection window is opened to confirm the landing runway.

If the detected landing runway is the BTV armed runway "BTV" will be displayed in blue in the FMA.

BTV

If the detected landing runway is not the BTV armed runway, then "**BTV/ LDG RWY DISAGREE**" is displayed on the Navigation Display and braking mode reverts to Autobrake HI (displayed in blue in the FMA).

HI

Braking mode: Autobrake & manual braking

A detection window is opened between 500ft and 300ft to detect and confirm the landing runway.

If the detected landing runway is the FMS runway, no change of protected runway. If the detected landing runway is not the FMS runway, then the new detected runway becomes the protected runway.

In autobrake mode, the armed level of autobrake is displayed on the FMA:

LO

the FMS runway, then the new detected runway becomes the protected runway.

If the detected landing runway is not in the OANS database, **"UNKNOWN LDG RWY"** is displayed on the Navigation Display.

In autobrake mode, the armed level of autobrake is displayed on the FMA:

4.3.1.7.2. ROW FUNCTION

At 500ft, the dry and wet lines become alive on the Navigation Display.

ROW triggers a specific alert when the minimal braking distance computed for a wet runway state exceeds the remaining runway length i.e. when the wet line exceeds the runway end on the Navigation Display:

Figure 4-35: ROW "RUNWAY TOO SHORT" caution message

ROW triggers another specific alert when the minimal braking distance computed for a dry runway state exceeds the remaining runway length i.e. when the dry line exceeds the runway end on the Navigation Display:

Figure 4-36: ROW "RUNWAY TOO SHORT" warning message

RWY TOO SHORT

ROW triggers an aural alert only below 200ft RA when the aircraft performance is not assessed sufficient to safely stop on the remaining runway length for a dry runway state.

4.3.1.7.3. ROP FUNCTION

After the transition from ROW to ROP, BTV or autobrake activates. The dry and wet estimated stopping distances are replaced by a unique stop bar which is displayed in green on the Navigation Display.

In case of BTV braking mode, the stop bar represents the estimated point where the aircraft will reach a target of 10kt at the runway exit selected by the pilot.

In case of autobrake braking mode, the stop bar represents the estimated point where the aircraft will stop considering the selected level of autobrake.

On the Navigation Display, the blue line materialises the path from the aircraft to the stop bar.

Figure 4-37: ROW Stop bar

As soon as a risk of runway overrun is detected:

- Max braking is automatically applied for a minimum of 5s (limited A-skid) corresponding to a reversion to autobrake HI.
- ROP alerts are triggered to incite the pilot to select maximum reverse thrust:
  - The red message **"MAX REVERSE"** is displayed on the PFD (pulsing for 9s and then steady)
  - If max reverse thrust is not selected yet, the audio alert "SET MAX REVERSE" is triggered.
  - On the Navigation Display, the stop bar and associated path are displayed in red.

Figure 4-38: ROW "MAX REVERSE" message

SET MAX REVERSE

At 80kt if the risk of runway overrun remains, the audio alert "KEEP MAX REVERSE" is triggered.

Braking mode: manual braking

After the transition from ROW to ROP, the dry and wet ROW estimated stopping distances disappear and there is no display of the on-ground estimated stopping distance.

As soon as a risk of runway overrun is detected, the ROP alerts are triggered:

- Same message than described in "ROPS commonalities" is displayed on the PFD
- Same audio alert than described in "ROPS commonalities" is triggered.

There is no specific display on the Navigation Display. There is no automatic maximum braking activation.

4.3.1.7.4. NOTAMS MANAGEMENT

On A380, the ROPS function provides the pilot with a **"runway shift"** functionality, which allows to artificially displace a runway threshold and/or shorten a runway end in case of NOTAM (Notice To Airmen).

4.3.1.8. A350 SPECIFICITIES

The A350 ROPS function is based on all description detailed in §4.3.1.5 with similar HMI described in 4.3.1.7 with additional specificities.

4.3.1.8.1. LANDING RUNWAY AUTODETECTION FUNCTION

ROPS function is based on the auto-detection of the landing runway, which is performed simultaneously by AESS and ANF. Given the aircraft position and runway databases (AMDB for ANF, and terrain database for AESS), an algorithm is able to identify the landing runway.

ROW/ROP uses inputs from one of the following:

- Both ANF and TAWS (use conservative values (minimum LDA)), or
- TAWS only, (if the ANF is not available, or the airport is not in the ANF DB)

If the detected runway is not consistent with the BTV armed runway or if the landing runway is not available in the database, the same displays than for A380 apply.

4.3.1.8.2. RUNWAY STATE SELECTION

On A350, ROPS design:

- Allows to explicitly select the runway condition.
- Protects on all runway states including contaminated ones.

Since the runway state is explicitly selected by the pilot, the system computes a single braking distance and triggers alerts for the selected runway state.

The computation of the braking distance according to each runway state is based on the Airbus in-flight landing distances for all 6 runway states.

Two synchronized means of modification are available for the crew:

- **Hard means:** on the main instrument panel, a dedicated rotary selector is available: this quickly accessible means of selection allows late runway state change during final approach (for instance heavy rainfall during final approach) (Refer to Figure 4-39). This rotary selector is composed of two rings:
  - The outer ring allows selecting the reference, switching between “BRAKING ACTION” and “RWY CONDITION”;
  - The inner ring allows selecting the runway state value and is not cyclical. It can also be pulled and pushed, in order to display or hide the Runway Condition Assessment Matrix (RCAM) on the SD Refer to Figure 4-41.

The selected runway state is reminded on the top of the ND which temporarily highlights the runway state when the value is changing.

Figure 4-39: A350 Brake ICP

Figure 4-40: Integration of runway state selection and A/BRK selector in A350 cockpit

- **Soft means:** in case of failure of the above mentioned hard means, a dedicated combo box is available on the LDG tab panel of Airport Navigation interface to select the runway state (cf. Figure 3).

Figure 4-41: A350 LANDING tab on ANF SCP

Default runway state: The runway state is initialized by default to WET/GOOD at the start of the PRIM (calculator in which BTV and ROPS functions are hosted). It is also reinitialized by default to WET/GOOD at the end of each flight (after PRIM safety tests).

4.3.1.8.3. RUN WAY CONDITION ASSESSMENT MATRIX

To ease the selection, and to provide the crew with additional operational information related to runway state choice, a RCAM can be quickly displayed on SD. This matrix is a simplified version of the one provided in FCOM. This table provides support to select the appropriate RWY CONDITION / BRAKING ACTION and related landing performance code, according to the crew synthesis (as per TALPA ARC standardization), for landing performance assessment:

Destination runway reminder

PERF APPR data header

Selected reference for display on ND
RWY CONDITION or BRAKING ACTION boxed in white.

Selected state :
- **green** if ROW prediction ≤ LDA
- **amber** if ROW prediction >LDA

Contaminated runway states

Orange barber pole
(displayed by the side of runway conditions for which ROPS detects that the runway is too short)

Figure 4-42: Runway Condition Assessment Matrix

SOP requires the pilot to display the RCAM before each runway state modification.

The header of the RCAM provides a reminder of PERF APPR data used by ROPS to compute the ROW prediction: QNH, OAT, VAPP, CONF and WIND. Indeed, the header's aim is to remind the crew of the values inserted on the FMS PERF APPR page, used for the computation and directly leading to the assessment provided in the RCAM.

Figure 4-43: PERF APPR Header

Figure 4-44: ROW stop bars

4.3.1.8.4.ROW FUNCTION

On A350, the same displays than on A380 apply regarding the identification of the detected landing runway on the ND and the identification of the aircraft path in case of BTV or autobrake braking mode.

The only difference comes from the fact that the runway state is explicitely selected by the pilot. Thus, if the selected runway state is wet or contaminated, a single stop bar is displayed, corresponding to the selected runway state is displayed on the ND during the approach (Refer to Figure 4-44).

There is an exception in case of selection of the dry runway state: in that case both estimated stop bar for dry and wet runway states will be dsplayed on the ND during the approach.

Once a risk of runway overrun is detected for the selected runway state:

- Above 200ft AGL:

a **"RWY TOO SHORT"** amber message is displayed on the PFD, flashing for 9s and then remains steady);

- Below 200ft AGL:
  - a **"RWY TOO SHORT"** amber message is displayed on the PFD;
  - a repetitive audio "RWY TOO SHORT" is played;
  - a go-around should be initiated by the crew. If a go-around is performed, these alerts are inhibited.

Figure 4-45: ROW activation in approach

4.3.1.8.5. "PRE-ROP": REDUCED MARGINS

In case of reduced margins detected during landing roll on WET or CONTAM runway (i.e. stopping distance computed with a degraded state is greater than LDA-50m), and if following conditions are met:

- ROW/ROP "transition point" is met;
- And aircraft speed is greater than 80 kts
- At least one thrust lever is not on reverse max position.

Then a single audio "SET MAX REVERSE" is triggered. For all braking modes (including BTV):

- If WET runway state is selected and the aircraft speed is consistent with the use of reversers, this aural message incites the crew to use max reversers if they have not been selected yet.
- If CONTAM runway state is selected and the aircraft speed is consistent with the use of reversers, this aural message incites the crew to use max reversers as requested by SOP.

For BTV only, Pre-ROP triggering prevents BTV from delaying the braking up to a point where an overrun risk would exist if the actual runway state was worse than selected by the pilot.

4.3.1.8.6. MONITORING OF RUNWAY STATE ON GROUND

During rollout, if ROP determines that the deceleration experienced on the landing runway is significantly worse than expected according to the selected runway state, the selected runway state will be downgraded.

In this case:

- A message **"RWY COND DEGRADED"** appears on the 3rd line of the FMA at automatic runway state downgrade.
- This message is displayed until RWY VACATED condition.
- The selected runway state will be automatically downgraded to the N-1 state compared to the previous selection;
- The runway state displayed on ANF will be modified, replaced by the automatically selected one;
- The runway state displayed on ND short feedback will be modified, with the reverse video animation, as in the case of manual change.

This allows a discrete communication to the flight crew of the automatic runway state change without being too intrusive during a flight phase which requires full attention to the outside environment.

Thus this function provides feedback to the flight crew that the runway state was worse than the selected runway state.

4.3.1.8.7. NOTAMS MANAGEMENT

As on A380, A350's ROPS function provides the pilot with a "runway shift" functionality, which allows to artificially shorten a runway threshold and/or end in case of NOTAM (Notice To Airmen).

4.3.2. OPERATIONAL RECOMMENDATIONS

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

4.3.2.1. FOR THE AIRLINE - DISPATCH

The Performance Engineer's Program (PEP) can compute the ROW landing distances. During dispatch, the airline can check the ROW landing distance just as the in-Flight Landing Distance.

Figure 4-46: PEP panel

4.3.2.2. FOR THE FLIGHT CREW

4.3.2.2.1. DESCENT PREPARATION

ROW Landing Distance is based on Airbus Factored In-flight Landing Distance (FLD).

Having ROPS on-board the aircraft does not change the airline procedures. The flight crew should perform the in-Flight Landing Distance evaluation as usual.

In case the airline operates with NAVBLUE FlySmart EFB solution the ROW landing distance can be computed.

If there is a risk of ROW alert then an amber message "EXPECTED ROW ALERT" is displayed on the EFB.

Figure 4-47: EFB display

4.3.2.2.2. GO-AROUND

ROPS does not change company procedures and criteria for go around in case of unstabilized approach. It is an additional safety-net that informs the crew that a Go-Around should be performed.

4.3.2.3. INVALID RUNWAY IN THE DATABASE

In case of unknown or invalid runway in the TAWS database, ROPS self-inhibits automatically.

It is the operator's responsibility to inform the flight crews about the runways that are invalid for ROPS along the scheduled route.

The airline can verify whether a runway is valid for ROPS or not from the TAWS supplier:

- EGPWS / AESS - https://ads.honeywell.com/search/egpwsSearch
  - Download Excel File: Airbus ROPS Latest Version
- T3CAS - https://support.acsscustomerservices.com/ACSS/support.aspx

Sign in

- Publications > T3CAS Terrain Database > T3CAS Terrain Database Airport List

4.3.3. WAY FORWARD

Airbus with its subsidiary NAVBLUE work of following axis to develop the alerting in case of overrun risks:

- Harmonization of ROPS function on all in-production Airbus aircraft families. At the time of the redaction of this document ROPS Step2+ on A320 and A330 aircraft is under development. In order to move toward the A350 ROPS solution, this next evolution will allow the pilot to explicitly select the runway condition, either dry or wet through a dedicated rotatory selector.

- Development of a new technology to use the aircraft itself as a sensor to measure the available runway braking action, and subsequently share that data to the benefit of oncoming traffic. The Airbus aircraft function called "Braking Action Computation Function" (BACF) gives feedback to the flight crew after landing via the MCDU about the braking action computed during landing and also transmits the runway state by ACARS message to the NAVBLUE ground web-service platform called "RunwaySense". The following figures provide an overview of the concept:

Figure 4-46: Integration of BACF & NAVBLUE's RunwaySense within airports and airline operations

Figure 4-47: NAVBLUE's RunwaySense web app, illustrating a detailed view of a runway including runway state information from recently landed aircraft.

More detailed information on BACF and RunwaySense are provided in a Safety First Article available here: http://safetyfirst.airbus.com/using-aircraft-as-a-sensor-on-contaminated-runways/

PLEASE BEAR IN MIND…

DESCRIPTION

Runway Overrun Prevention System (ROPS) helps the flight crew to anticipate an overrun risk during the landing phase by computing in real time landing distances and comparing them to the runway length. In case of overrun risk, ROPS provides dedicated alerts for the crew to perform a go-around, apply maximum braking and/or use maximum reverse thrust.

ROPS consists in 2 sub-functions ROW and ROP:

- Runway Overrun Warning (ROW) provides in-air alerts in case of detection of a risk of runway overrun. ROW alerts are “Go-Around minded”
- Runway Overrun Protection (ROP) provides on-ground alerts in case of detection of a risk of runway overrun.ROP alerts are “Stop minded” (MAX BRAKING/MAX REVERSE)

OPERATIONAL RECOMMENDATIONS

The main recommendations are:

- Use **Performance Engineer’s Program (PEP)** to compute the ROW landing distances. During dispatch, the airline can check the ROW landing distance just as the in-Flight Landing Distance.
- Be aware that **ROPS on-board the aircraft does not change the airline procedures.** The flight crew should perform the in-Flight Landing Distance evaluation as usual.
- Be aware that ROPS does not change company procedures and criteria for go around in case of unstabilized approach. It is an additional safety-net that informs the crew that a Go-Around should be performed.
- **Inform the flight crews about the runways that are invalid for ROPS** along the scheduled route (unknown or invalid runway in the TAWS database automatically inhibits ROPS).

REGULATIONS

At the time of writing the present brochure, no country has required the carriage of ROPS.

WAY FORWARD

Airbus works on harminization of ROPS function on all in-production Airbus aircraft family (especially runway conditions selection).

Airbus with its subsidiary NAVBLUE works Development of a new technology to use the aircraft itself as a sensor to measure the available runway braking action, and subsequently share that data to the benefit of oncoming traffic.

4.4. TAKE-OFF SURVEILLANCE - TOS

4.4.1. DESCRIPTION OF TOS

4.4.1.1. FUNCTIONAL GOAL

The take-off preparation by the pilots entails the computation of the aircraft weights (ZFW (Zero Fuel Weight), TOW (Take-Off Weight)) and respective CG positions, as well as the calculation of the different Take-Off speeds (V1, VR, V2) and thrust rating.

These data may be obtained either by using load sheets and take-off charts, or by means of non-aircraft software applications (i.e. flight operations laptops).

Three types of errors may be made during this process:

- Parameters entered into the tables or into the programs may be wrong (carried load, outside temperature, runway length etc…)
- Computations may be inaccurate (wrong interpretation of charts, bug in the software etc…)
- The data entry process into the Flight Management System (FMS) may be incorrect (distraction, stress etc…).

Each of these types of errors may have consequences on the Take-Off speeds:

- A too low VR inserted through the Multipurpose Control & Display Unit (MCDU), may lead to a tail strike
- A too low V2 may lead to the flight path not clearing the obstacles in an one engine out condition
- A set of too high Take-Off speeds may lead to a runway overrun or too high energy rejected take-off (RTO).

Other possible consequences:

- An error on the A/C configuration at take-off (CONF/TRIM setting) may lead to an “auto rotation” or a nose heavy condition
- A take-off from a different runway from the intended one, or even from a taxiway, may lead to:
  - A collision on ground with another aircraft, vehicle or obstacle
  - A collision in the air with an obstacle
  - An overrun if no lift-off before the end of the runway (even more so if combined with a high temperature FLEX take-off)
  - A low or high energy runaway overrun (in case of RTO)
- A wrong thrust rating may result in a tailstrike, a runway overrun or a shift of the climb path.

Take-Off Securing (TOS) function provides an additional safety net able to detect some human errors regarding erroneous take-off parameters and operations. TOS function objective is to help pilots in identifying abnormal situations before taking-off:

- Take-off (TO) without take-off speeds;
- Tail strikes by checking take-off speeds and ZFW (Zero Fuel Weight);
- Runway overrun by checking lift-off distance compared to remaining runway length;
- Take-off with a non-appropriate take-off power (MCT (Maxi Continuous Thrust) for example);
- Take-off on a runway different from FMS or on a taxiway.

The TOS function is available from the flight preparation to the take-off; it is a safety net, it activates only if an abnormal situation occurs by informing the crew with a type and a level of alert depending on the situation. However, TOS protects only from gross errors and does not cover all situations.

4.4.1.2. TOS 1/TOS 2

The TOS function has been design into two steps :

- **TOS1** was first designed to detect speed consistency error with aircraft take-off configuration in FMS (V1, VR and V2). TOS1 alerts are first triggered at FMS scratchpad during take-off parameters insertion into FMS. This check prevents mainly from tail strikes.

- **TOS2** detects operational aircraft position errors in preflight and at take-off:
- Lift-off distance compatibility with runway used is checked in preflight considering parameters inserted in FMS (including take-off shift to simulate a take-off not started at runway beginning). This results in FMS scratchpad message and an ECAM alert at T.O config test.
- Lift-off distance compatibility with runway used is also performed at take-off considering current aircraft parameters such as current GPS position, current thrust... This results in an ECAM alert.
- Aircraft position check is performed at take-off power to avoid take-off from non planned runways or take-offs from taxiways. This results in an ECAM alert

TOS2 functions informs the pilots as soon as possible in order to initiate a RTO under 100kt if an issue is detected. No alert is triggered after 80kt.

NOTE:

The whole function core is hosted in the FMS (or both FMS and ANF on A350, or both FMS and OANS on A380).

Figure 4-48 : TOS 2 cockpit alerts

4.4.1.3 FUNCTIONAL DESCRIPTION

TOS function is a safety net. Checks implemented in the TOS function do not impact the crew task and no additional workload is observed because no supplementary actions are needed in normal conditions.

The TOS function perfectly integrates in the existing procedures, with three levels of checks:

- **First level concerns checks which are performed during FMS initialization,** in order to verify the consistency of the data entered in the FMS by the crew:
  - **TOS1:** Consistency check of the entered take-off parameters (such as speeds or Trim setting) with regard to the FMS take-off data (such as TOW, altitude, Delta ISA….).
  - **TOS2:** Consistency check of the FMS take-off data (such as TOW, Thrust, Temperature, T.O shift….) with regards to the TORA (Take-Off Run Available). TOS2 checks compatibility between lift-off distance and departure runway selected in the flight plan.

If an inconsistency is detected by TOS1 or TOS2 function, the crew is immediately informed with a message in the MCDU scratchpad. The message guides the pilots on the data to check.

- **Second level concerns checks that are performed during taxi:**
  - **TOS1/TOS2:** All the checks proposed during FMS entry are maintained at take-off CONFIG test, to increase the level of alert if the inconsistency remains despite the MCDU message triggered before;
  - **TOS1/TOS2:** The take-off memo (cf. Figure 2) also takes into account the previous checks. Indeed, when the take-off CONFIG button is pressed:

    If all checks are validated, the blue line take-off CONFIG... TEST becomes green, concatenated and the text is replaced by take-off CONFIG NORMAL;

    If one of the checks is not validated, the associated FWS (Flight Warning System) alert is generated and the blue line take-off CONFIG... TEST remains blue as long as the problem is not corrected.

- **TOS1/TOS2:** Moreover, if while the green take-off CONFIG NORMAL is displayed (i.e.: all checks are validated) a modification is performed in the FMS leading to the invalidation of one TOS check, the green take-off CONFIG NORMAL line turns back into the blue take-off CONFIG... TEST line.
- **TOS2:** The check of the FMS take-off DATA with regards to the TORA is maintained to increase the level of alert (T.O. RWY TOO SHORT) if the inconsistency remain.

Figure 4-49: A320/A330 take-off memo

Figure 4-50: A350/A380 take-off memo

- **Third level concerns checks performed at the thrust application:**
  - **TOS1:** Previous checks are maintained when the pilot sets the take-off power with the thrust levers;
  - **TOS2:** The take-off location is checked in order to avoid taking off on a taxiway, or on a runway different from departure runway defined in the FMS;
  - **TOS2:** The Lift-Off Run (LOR) check is performed at take-off power taking into account the FMS data, real parameters which could be available (thrust levers position, aircraft configuration…) and the real aircraft position on the runway to ensure that the aircraft will have a sufficient runway length to lift-off. Consequently, if the pilot got access to the runway farther than the threshold, the runway length available for take-off is reduced but this reduction is taken into account in the calculation.

It is to be noted that in remote cases of known risk of spurious TOS2 alerts, the crew has the possibility to inhibit TOS2 ECAM alerts thanks to a dedicated push button located on overhead panel.

4.4.1.3.1 ZERO FUEL WEIGHT (ZFW) INPUT RANGE CHECK (TOS1)

This check aims at avoiding erroneous ZFW entry. The ZFW is the aircraft weight including passengers and cargo loads but without fuel.

If the pilot enters a weight higher than the max ZFW authorized or a weight lower than the min ZFW authorized, the white message “ENTRY OUT OF RANGE” is displayed on the MCDU (Multifunction Control and Display Unit) scratchpad (Refer to Figure 4-51). The message is displayed as soon as the data is entered by the pilot.

The pilot should compare this data with the one used in his computerized flight plan (given by the airline dispatch) and correct the FMS value according to the FPLN data if necessary. The ZFW given in the computerized flight plan is a preliminary value. The final ZFW is given by the final load and trim sheet (may be received lately, after boarding for example). When the final load and trim sheet is received, the pilot has to re-compute his take-off performance and then update the FMS.

Figure 4-51: A320/A330 FMS message when the check on ZFW range detects an anomaly

Figure 4-52: A350/A380 FMS message when the check on ZFW range detects an anomaly

4.4.1.3.2 TAKE-OFF SPEEDS CONSISTENCY CHECK (TOS1)

This check aims at verifying that the relationships between the take-off speeds are respected, i.e. V1 ≤ VR and VR ≤ V2.

This check is performed when the pilots insert/modify the take-off speeds in the FMS PERF take-off page. If the check is false, the message “V1/VR/V2 DISAGREE” is displayed on the MCDU scratchpad (Figure 4-53).

Figure 4-53: A320/A330 FMS message when the check on take-off speeds consistency detects an anomaly

Figure 4-54: A350/A380 FMS message when the check on take-off speeds consistency detects an anomaly

This check is maintained at take-off CONFIG test and then at take-off power. If the check is false, a level 2 ECAM alert “T.O V1/VR/V2 DISAGREE” is triggered associated with a single chime audio alert and a Master Caution (cf. Figure 8).

Figure 4-55: A320/A330 ECAM message when the check on take-off speeds consistency detects an anomaly

Figure 4-56: A350/A380 ECAM message when the check on take-off speeds consistency detects an anomaly

4.4.1.3.3 VMC LIMITATION CHECK (TOS1)

This check aims at detecting erroneous speeds with regards to the Velocity of Minimum Control (VMC) minimum speeds. The following checks are performed:

- **V1 ≥ VMCG**. Per regulations, the minimum speed at which an aircraft is defined to be “controllable” (lateral excursion lower than 30 feet) after an engine failure on ground, is referred to as Velocity of Minimum Control on Ground (VMCG). If an engine failure is detected after V1, the take-off must be continued. This implies that the aircraft must be controllable on ground. Therefore, V1 is always greater than VMCG;
- **VR ≥ 1.05 VMCA**. The rudder is used to compensate for the yaw moment caused by thrust asymmetry. There is a minimum speed at which full rudder will be necessary in order to fly a constant heading with leveled wings. The speed that corresponds to a 5-degree bank angle is defined, by regulations, as the minimum control speed and is referred to as Velocity of Minimum Control in the Air (VMCA). Therefore, VR speed is always greater that VMCA, and facilitates control of the aircraft in flight;
- **V2 ≥ 1.10 VMCA**. Flight at V2 ensures that the minimum required climb gradient is achieved, and that the aircraft is controllable. Therefore, V2 speed is always greater than VMCA, and facilitates control of the aircraft in flight.

The covered risk is the loss of aircraft control in case of engine out during take-off run, which could be due to too low speeds (rudder, flaps and slats efficiency is reduced at low speed). The skid becomes too important to be controlled with the control surfaces (rudder, flaps, slats…).

If the check is false, the message “TO SPEEDS TOO LOW” is displayed on the MCDU scratchpad (Figure 4-57).

Figure 4-57: A320/A330 FMS message when the check on VMC/VS1g/VMU limitation detects an anomaly

Figure 4-58: A350/A380 FMS message when the check on VMC/Vs1g/VMU limitation detects an anomaly

This check is maintained at take-off CONFIG test and take-off power. If the check is false, a level 2 ECAM alert "T.O SPEEDS TOO LOW" is triggered, associated with a single chime audio alert and a Master Caution (Figure 4-59).

NOTE:

recent version of FWS can display "TOW AND T.O DATA……CHECK" as per A350/A380 design.

Figure 4-59: A320/A330 ECAM message when the check on VMC/Vs1g/VMU limitation detects an anomaly at take-off CONFIG test or take-off power

Figure 4-60: A350/A380 ECAM message when the check on VMC/Vs1g/VMU limitation detects an anomaly at take-off CONFIG test or take-off power

4.4.1.3.4 VS1G/VMU LIMITATION CHECK (TOS1)

This check aims at detecting a too low VR or V2 and avoiding tail strike at take-off and erroneous speed guidance (V2); the following checks are performed:

- **VR ≥ KVR VR_{MIN}.** VRMIN is a minimum speed for VR representative of VMU and Vs1g limitations. Velocity of Minimum Unstick (VMU) is achieved by pitching the aircraft up to the maximum (tail on the runway, for aircraft that are geometrically-limited) during the take-off roll. The speed at which the aircraft first lifts off is VMU. Therefore, the VR must be such that the lift-off speed is at least KVR times as great as VMU.
- **V2 ≥ 1.13 Vs1g.** Vs1g speed corresponds to the maximum lift-off coefficient (just before the lift starts decreasing). At that moment, the load factor is still equal to one. The V2 speed is at least KV2 times as great as Vs1g in order to be protected from stall at take-off.

With a too low VR, the aircraft has difficulties to rotate and most of the time the pilots apply a higher pitch. Unfortunately, the aircraft has not yet a sufficient energy to lift-off. The pitch angle increases up to a tail strike.

V2 is used to define the initial speed climb up to the acceleration altitude. It is also the minimum speed in one engine inoperative. It is easy to understand that a too low V2 can lead to an uncomfortable situation. The situation is particularly critical if an engine out occurs, if the V2 is too low, the crew can lose aircraft control. If V2 is too low, outside ground effect, a stall can occur.

If the check is false, the message "TO SPEEDS TOO LOW" is displayed on the MCDU scratchpad. it is the same message as the precedent check (cf. Figure 9).

This check maintained at take-off CONFIG test and take-off power. If the check is false, a level 2 ECAM alert "T.O SPEEDS TOO LOW" is triggered, associated with a single chime audio alert (Figure 4-59 & 4-60).

4.4.1.3.5 TRIM SETTING CONSISTENCY CHECK (TOS1)

This check aims at detecting if the trim setting for take-off is identical to the theoretical one calculated in FAC (Flight Augmentation Computer)/ FE (Flight Envelope) from the CG (Center of Gravity) by the FQMS (Fuel Quantity Management System)/FCMC (Fuel Control and Management Computer) in order to avoid auto rotation and/or high nose angle at take-off. The trim setting directly depends on the CG.

Figure 4-61: A320/A330 MCDU take-off perf page, THS setting

The trim setting is inserted by the crew during the flight preparation phase via the MCDU take-off PERF as shown in Figure 11. Using the MCDU keyboard, the pilot inserts in the FLAPS/THS line either UP for a positive value or DN (down) for a negative value of the THS followed by the value.

When the take-off CONFIG test is performed or when the take-off power is set, if the pitch trim setting does not match the FMS expected setting, a level 2 ECAM alert is triggered. This ECAM alert is defined by a single chime audio alert associated with the message “F/CTL PITCH TRIM/MCDU/CG DISAGREE” on A320/A330/A340 aircraft or “F/CTL PITCH TRIM/FMS/CG DISAGREE” on A350/A380 aircraft (Figure 4-62) and a Master Caution.

Figure 4-62: A320/A330 Level 2 trim setting alert

4.4.1.3.6 CONF SETTING CONSISTENCY CHECK (TOS1)

This check aims at detecting inconsistency setting in take-off parameters in order to avoid error in slats/flaps setting which could lead to an increase of take-off distance or even an overrun.

Figure 4-63: A320/A330 MCDU take-off PERF page, Flaps setting

The flaps setting is inserted by the crew during the flight preparation phase via the MCDU take-off PERF page as shown in Figure 13. Using the MCDU keyboard, the pilot inserts in the FLAPS/THS line the expected flap configuration.

When the take-off CONFIG test is performed or when the take-off power is set, if the flaps setting does not match the FMS expected setting, a level 2 ECAM alert is triggered. This ECAM alert is defined by a single chime audio alert associated with the message “F/CTL FLAPS/MCDU DISAGREE” on A320/A330/A340 aircraft (Figure 4-64) or “F/CTL FLAPS/FMS DISAGREE” on A350/A380 aircraft and a Master Caution.

Figure 4-64: A320/A330 Level 2 CONF setting alert

4.4.1.3.7 TAKE-OFF SPEED MISSING CHECK (TOS1)

This check aims at detecting if all the take-off speeds are inserted in the FMS PERF take-off page, in order to avoid a take-off without the take-off speeds annunciations (PFD + audio).

The in-service events showed this situation occurs when the pilots perform a runway change. When the pilots select another runway for take-off, the V1, VR and V2 speeds are invalidated. A message "CHECK TAKE OFF DATA" is then displayed on the MCDU scratchpad. If the pilots do not confirm they want to use the same speeds by clicking the CONFIRM take-off DATA prompt (Figure 4-65) or insert new take-off speeds (due to time pressure or any other reason) the FMS does not take into account these speeds.

Figure 4-65: A320/A330 MCDU take-off PERF page in case of departure runway change

As for the previous checks, this check is inserted in the take-off CONFIG test:

- If one of the take-off speeds is missing when the TO CONFIG P/B is pressed, an ECAM alert is generated and the blue line TO CONFIG…TEST remains unchanged;
- In case of a late runway change after the take-off CONFIG test: if one of the take-off speed is missing, the take-off CONFIG test is invalidated (the green line TO CONFIG NORMAL reverts to the blue line TO CONFIG…TEST).

Consequently, when the take-off CONFIG test is performed or when the take-off power is set, if the take-off speeds are missing, a level 2 ECAM alert is triggered. This ECAM alert is defined by a single chime audio alert associated with the message “T.O SPEEDS NOT INSERTED” (Figure 4-67 & 4-68) and a Master Caution.

Figure 4-67: A320/A330 ECAM alert when the take-off speeds are missing

Figure 4-68: A350/A380 ECAM alarm when the take-off speeds are missing

4.4.1.3.8 LIFT-OFF RUN (LOR) CHECK (TOS2)

The aim is to detect a risk of runway overrun due to a gross error on the take-off data.

The check computes a LOR distance with the data entered in the FMS (TOW, VR, V2, flaps configuration, runway slope, anti-ice, air conditioning, take-off thrust and take-off shift).

Figure 4-69: Lift-Off run computation

This check, integrated in the FMS, is performed at parameters insertion/modification into FMS, at engines start, at take-off CONFIG test and at take-off power.

Three warning levels corresponding to the three different situations are then computed:

- At the gate during flight preparation in the FMS;
- During taxi in the FMS and at Take-Off CONFIG test in the FWS;
- At take-off power in the FWS.

4.4.1.3.8.1 AT THE GATE

In preflight phase, if the take-off power condition is not satisfied, and the LOR check is false, the message “T.O RWY TOO SHORT” is displayed on the MCDU scratchpad (Figure 4-70).

Figure 4-70: A320/A330 FMS message when the LOR check detects a risk of overrun at the gate (take-off power condition is false)

Figure 4-71: A350 FMS message when the LOR check detects a risk of overrun at the gate (take-off power condition is false)

NOTE:

Recent version of FWS can display "TOW AND T.O DATA……CHECK" as per A350/A380 design.

4.4.1.3.8.2 AT TAKE-OFF CONFIG TEST

At take-off CONFIG test, if the last LOR check computation performed by the FMS was false, then an ECAM alert "T.O RWY TOO SHORT" is triggered, associated with a single chime audio alert (Figure 4-72). The message "T.O RWY TOO SHORT" on the MCDU scratchpad is displayed again.

Figure 4-72: A320/A330 ECAM alert when LOR check detects a risk of overrun at take-off CONFIG test (take-off power condition is false)

Figure 4-73: A350 ECAM alert when LOR check detects a risk of overrun at take-off CONFIG test (take-off power condition is false)

4.4.1.3.8.3 AT TAKE-OFF POWER

At take-off power, the LOR check is launched one more time taking into account the aircraft current parameters (runway in use, real position on the runway, configuration, thrust levers position…). If the check is false, the ECAM alert "T.O RWY TOO SHORT" is triggered associated with a continuous and repetitive chime and a Master Warning.

Figure 4-74: A320/A330 ECAM alarm when the LOR check detects a risk of overrun at take-off (take-off power condition is true)

Figure 4-75: A350 ECAM alarm when the LOR check detects a risk of overrun at take-off (take-off power condition is true)

4.4.1.3.9 TAKE-OFF LOCATION (TOS2)

This check aims at avoiding take-off on taxiway or on an unexpected runway.

The runways are defined in the FMS database on A320/A330/A340 aircraft and in the ANF database on A350 aircraft..

In order to reduce the spurious rate that can occur because of the aircraft position inaccuracy, a runway detection zone is defined (values for information only):

Figure 4-76: Extended runway area for a runway 09

The provision before the runway is due to the existence on some runways of a starter extension. The starter extension (not standardized) is set to a fixed value that does not generate spurious alert.

FMS on A320/A330/A340, ANF on A350 aircraft are able to define the aircraft position. It identifies that the aircraft is located on a runway when the selected position is simply inside the runway detection zone. It also uses A/C track to select appropriate runway QFU.

The aircraft location check is launched when the thrust levers are set at a position higher than or equal to the CLB detent and repeated at each FMS computation cycle. It compares the aircraft position with the different runways available on the current airport. Following the check, two different alerts can be triggered depending on the situation (take-off is initiated on a taxiway or on an unexpected runway).

- If the aircraft is not on a runway, the crew is immediately informed with an ECAM alert;
- If the aircraft is on a runway, FMS compares this runway with the departure runway entered by the crew leading to an ECAM alert if a difference is detected.

The FMS performs the aircraft location check at take-off power by comparing the selected position with the FMS navigation database.

4.4.1.3.9.1 TAKE-OFF ON TAXIWAY

This check aims at avoiding take-off on a taxiway by checking the aircraft position with regards to the runways available on the current airport as soon as the thrust levers are set at a position higher or equal to the CLB detent. This check is performed periodically up to 80kt. If the check is false (the aircraft is not on a runway) the ECAM alert “NAV ON TAXIWAY” is triggered (Figure 4-77).

Figure 4-77: A320/A330 ECAM warning when a take-off on a taxiway is detected

Figure 4-78: A350 ECAM warning when a take-off on a taxiway is detected

4.4.1.3.9.2 TAKE-OFF ON AN UNEXPECTED RUNWAY

This check aims at avoiding take-off on an unexpected runway by checking the aircraft position with regards to the FMS selected departure runway. This check is performed periodically up to 80kt. If the check detects that the aircraft is positioned on a runway different from the one entered in the FMS by the crew, a level 2 ECAM alert “NAV NOT ON FMS RUNWAY” is triggered (Figure 4-79), associated to a single chime and a Master Caution.

Figure 4-79 : A320/A330 ECAM caution when a take-off on a runway different from the FMS runway is detected

Figure 4-80: A350 ECAM caution when a take-off on a runway different from the FMS runway is detected.

4.4.1.3.10 FUNCTION ACTIVATION

A dedicated pushbutton is available on the overhead panel to inhibit following ECAM alerts and associated chimes :

- T.O RWY TOO SHORT;
- NAV ON TAXIWAY;
- NAV NOT ON FMS RUNWAY.

NOTE:

For all ECAM messages :

- If the crew performs a RTO, the alert is maintained 30 seconds on ECAM;
- If the crew decides to continue the take-off, the alert disappears when the aircraft reaches lift-off or if the alert conditions are no more met.

(Figure 4-81).

Figure 4-81: take-off SURV OFF pushbutton location on A320 overhead panel

Figure 4-82: take-off SURV OFF pushbutton location on A350 overhead panel

The TOS2 MCDU messages and TOS1 alerts would still be triggered.

4.4.2. OPERATIONAL RECOMMENDATIONS FOR TOS

For details on TOS use and associated procedures, please check your FCOM as they are more frequently updated.

4.4.2.1. FOR THE AIRLINE

- **Train your flight crews** to properly operate TOS. Particular attention should be paid to task sharing, monitoring of TOS indications during the FMS initialization, taxi and take-off.

4.4.2.2. FOR THE FLIGHT CREW

- **Be sure to understand TOS indications** to early detect any abnormal operations during the take-off in order to reduce the number of experienced tail strikes, runway overruns and loss of control during take-off.
- **Consider take-off shift** during the preflight phase in MCDU take-off PERF page.

4.4.3. REGULATIONS FOR TOS

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

At the time of writing the present brochure, there is no mandate for the carriage of the TOS function.

4.4.4. MANUFACTURER FOR TOS

Airbus developed TOS 1 and TOS 2 optional functions that are distributed among several systems, but mainly handled by FMS.

Following figure provides a simplified view of the TOS architecture

Activation of TOS package is managed by FMS Operational Programming Configuration (OPC) on A320/A330/A340 aircraft and through software Pin-Programing (SPP) on A350 and A380 aircraft.

Figure 4-83: TOS Architecture

4.4.5. WAY FORWARD

Airbus studies the implementation of the TOS 2 on A380. and also introduction of the Take-Off Monitoring (TOM) function. TOM function will monitor aircraft acceleration degradation during the take-off roll.

PLEASE BEAR IN MIND…

DESCRIPTION

Take-Off Securing (TOS) function provides an additional safety net able to detect some human errors regarding erroneous take-off parameters and operations. TOS function objective is to help pilots in identifying abnormal situations before taking-off:

TOS 1 detects speed consistency error (with aircraft take-off configuration in FMS (V1, VR, V2, Trim setting, Flaps).

TOS 2 detects operational aircraft position errors in preflight and at take-off (taxiway, wrong runway, runway too short).

OPERATIONAL RECOMMENDATIONS

The main recommendation is to train flight crews to well understand TOS indications and consider take-off shift.

REGULATIONS

At the time of writing the present brochure, no country has required the carriage of TOS.

WAY FORWARD

Airbus studies the implementation of the TOS 2 on A380. and also introduction of the Take-Off Monitoring (TOM) function. TOM function will monitor aircraft acceleration degradation during the take-off roll.

#05 WEATHER SURVEILLANCE

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5.2. REACTIVE WIND SHEAR

Turbulence, wind shear, hail, and thunderstorm are identified as the causes of major incidents or accidents, especially during final approach and take-off. The awareness of these meteorological phenomena improves the flight safety.

Current system to detect, track and monitor these phenomena is the onboard weather radar analysing radar pulses reflected by water drops. Future additional sources may complete this primary detection such as uplinked weather information for instance.

At the time of writing the brochure, three mode of weather radar are available on Airbus aircraft:

- **Manual weather radar:** The weather display is synchronized with the movement of the radar antenna.
- **Automatic weather radar:** The radar automatically scan the front area independently of the display.

5.1. WEATHER RADAR

5.1.1. DESCRIPTION OF WEATHER RADAR

Thanks to the characteristics of weather radar pulses, the weather radar detects precipitations, wind shears, turbulence, prominent terrains, and can also infer additional weather phenomena. The weather radar also provides indications and/or alerts to avoid them. **It has to be noted that the weather radar detects wet meteorological phenomena only:** it means that the weather radar does not detect dry phenomena like Clear Air Turbulence (CAT).

The present chapter provides a basic knowledge about weather radar physics and describes the functions proper to each weather radar type. The description is common to all weather radar types, except when specified. The Appendix G – Aviation meteorology reminders also provides some reminders about meteorological phenomena linked to flight operations.

5.1.1.1. RADAR THEORY

5.1.1.1.1. REFLECTIVITY OF WATER MOLECULES

The weather radar properly detects rains or wet turbulence. Indeed, water molecules in liquid state reflects radar pulses more than ice crystals do. Based on this principle, the reflectivity of precipitations depends on their nature. **The radar pulse weakly reflects on dry snow and dry hail**. In addition, **wet hail presents a higher reflectivity than rain** thanks to the size of hailstone combined with the presence of liquid water molecules on their surface. Most of the time, the radar pulse is not able to penetrate wet hail. The weather behind wet hail is often hidden.

Figure 5-1: Reflectivity of precipitations

Similarly to wet hail, **stratiform rain in the vicinity (at or 3000 ft below of the freezing level)** returns a large portion of the radar pulse.

5.1.1.1.2. REFLECTIVITY OF THUNDERSTORMS

- **The turbulence dome** defines an area of very severe turbulence. It can reach several thousand feet above the visible top, when the thunderstorm is growing
- **The upper part above the altitude of -40°C** (if applicable) contains ice crystals only. It reflects a very small portion of the radar pulse. This part may be invisible on the weather radar image whereas it is clearly visible through the windshield
- **The intermediate part from the freezing level up to the altitude of -40°C** contains ice crystals and super-cooled water. The super-cooled water reflects a portion of the radar pulse. Ice crystals absorb the remainder of the radar pulse
- The lower part up to the freezing level is the most reflective part of the thunderstorm due to the heavy rain.

Figure 5-2: Thunderstorm

The radar or wet top is the highest portion of the thunderstorm the weather radar can detect. It separates the intermediate part from the top part of a thunderstorm.

The visible top is the top of the thunderstorm upper part.

5.1.1.1.3. WIND SHEAR DETECTION

In addition to the basic turbulence, wind shears are considered.

For further detailes on windshear phenomena, refer to Appendix H – Low level Wind shear effects on aircraft performances summarizes the effects of wind shears on aircraft performances.

Two kinds of protection are provided against wind shears:

- The **Predictive Wind Shear (PWS)** performed by the weather radar to avoid wind shear events,
- The **Reactive Wind Shear** performed by the flight controls to escape from wind shear events.

Figure 5-3: Predictive and Reactive Wind Shear

NOTE:

Reactive windshear detection and alerting is not supported by the weather radar. For further details refer to 5.2

5.1.1.1.4. FREQUENCY BAND

As a general physics rule, the propagation (combination of celerity and attenuation) of a wave is closely linked to its length or frequency.Higher the frequency, shorter the wavelength, weaker the propagation.

The weather radar is optimized to detect rains. Therefore, the frequency of the radar pulse is approximately 9333 MHz. Consequently, the weather radar is not able to detect fog, light rains, or dry clouds. In addition, the weather radar may not detect weather behind a heavy rain.

Figure 5-4 gives an idea of the rain reflectivity per frequency band. It has to be noted that cloudburst (rain more than heavy) may block pulses of ground radars. **Therefore, each time an ATC controller announces a heavy rain from his radarscope, the flight crew should consider this heavy rain as extremely severe.**

Figure 5-4: Reflectivity per frequency band

5.1.1.1.5. GAIN

The weather radar measures the precipitation rate (millimeters per hour). For the **calibrated gain,** the precipitation rates are color-coded as follows:

COLOR	PRECIPITATION	PRECIPITATION RATE (MM/H)	REFLECTIVITY FACTOR[1] (DBZ)
Black		PR < 1	Z < 20
Green	Weak	1 < PR < 4	20 < Z < 30
Yellow	Moderate	4 < PR < 12	30 < Z < 40
Red	Strong and higher	12 < PR	40 < Z
Magenta	Turbulence	5 m/s < ΔPR	N/A

NOTE:

Turbulence remains magenta regardless of the gain setting.

The weather radar displays turbulence in magenta each time the variation of precipitation rates (ΔPR) is greater than 5 m/s. It should be noted that **Clear Air Turbulence (CAT) is not detected.**

A variation of the weather radar gain by 10dBZ implies a variation of display by one color level (e.g. green becomes yellow with a variation of +10dBZ, red becomes yellow with a variation of –10dBZ).

5.1.1.1.6. ANTENNA

• Parabolic and Flat Antennas

There are two types of weather radar antenna: parabolic for the first generation of weather radar (on A300/A310 and former A320 aircraft) and flat for the recent generation (on A320/A330/A340 aircraft).

1 The reflectivity factor Z measures the strength of the radar return in a volume of precipitation. Z depends on the number and the size of raindrops in a volume, and is expressed in decibels (dBZ).

Figure 5-5: Antenna beam

CAT'S EYES WITH GAIN IN CAL POSITION

Cat's eyes should not be visible when the gain is set to CAL position. If Cat's eyes are visible with the CAL setting, damages/degradations on antenna or radome should be considered.

- **Parabolic Antenna**
  The parabolic antenna produces a wide main beam and large side lobes. Consequently, the large side lobes present the advantage of scanning below the aircraft, but also drawbacks like ground returns on display and the inability to reliably detect wind shears.
- **Flat Antenna**
  The main beam from a flat antenna is more contained than the one from a parabolic antenna. Moreover, side lobes are smaller. With a flat antenna, the display is more accurate, ground returns are significantly reduced, but the capability to scan below the aircraft is lost.
- **Side Lobes**
  Significant side lobes may be produced by parabolic antennas or may be the result of damages/degradations on the antenna or the radome.
- **Cat's Eyes Phenomenon**
  The Cat's eyes (also known as Altitude rings or Ghost targets) appear at +/- 45° between 4 and 8 NM when the aircraft is at approximately 3000 ft above the ground. They are the results of ground returns due to side lobes. They are not visible when the aircraft is on ground.

Figure 5-6: Cat's eye phenomenon

- **False Wind Shear Alerts**
  The weather radar may wrongly interpret strong returns (such as ground vehicles or other moving intruders) due to large side lobes as wind shears (refer to appendix B for futher details on wind shear phenomena and 5.1.1.2.6 on wind shear detection). This explains why the first generation of weather radars is not able to detect wind shears.
- **Antenna Stabilization**
  The antenna stabilization maintains the antenna scanning parallel to the horizon regardless of the aircraft attitude. The antenna is stabilized in roll and pitch. Thanks to the antenna stabilization, the display of ground returns on ND does not change when the aircraft attitude change.

If the antenna stabilization fails, the radar antenna scans parallel to the wings per default. Consequently, if the aircraft turns, ground returns may cover half of the display (on the side of the turn).

Figure 5-7: Antenna stabilization limits

5.1.1.1.7. RADAR BEAM

- **Diameter and Resolution**
  - Diameter

    The aperture of the radar beam is approximately 3.5°.

    The beam diameter at a given distance may be approximately determined by the following formula:

    Beam diameter [ft] =
    3.5 x (Distance [NM] + "00")

    Example:

    Distance = 50 NM

    Distance + "00" = 5 000

    Beam diameter = 17 500 ft

Figure 5-8: Beam diameters

  - **Range Resolution**

    The radar beam emits pulses to detect weather. For long-range detection (more than approximately 80 NM), high-energy pulses (i.e. wide pulses) are transmitted to compensate the beam attenuation. Therefore, pulses for long-range detection are wider than pulses for short-range detection.

  - When the pulse width is shorter than the distance between two precipitations, the weather radar detects two precipitations.
  - When the pulse width is longer than the distance between two precipitations, the weather radar detects one precipitation.

Shorter the pulse (or shorter the range), better the range resolution.

Consequently, the weather radar may display two distinct precipitations detected at long range as a single block. And when the aircraft gets closer to the precipitations, the weather radar may display the precipitations as two distinct blocks.

- **Azimuth Resolution**

  With an aperture of 3.5°, the width of radar beam significantly increases with the range. An analysis similar to the range resolution may be made with the width of the radar beam.

  Thinner the beam width (or shorter the range), better the azimuth resolution.

Figure 5-9: Range and Azimuth resolutions

- **Attenuation**
  - Beam Attenuation

The energy of the radar pulse attenuates when the radar pulse goes away and returns back to the radar antenna (i.e. absorption and refraction). If the weather radar does not compensate the beam attenuation, the weather radar may display a precipitation:

- As weak (i.e. green) when the aircraft is far from the precipitation
- As strong (i.e. red) when the aircraft is approaching the precipitation.
- Path Attenuation

  Some precipitations may be so strong that the radar beam is not able to penetrate them. Consequently, they mask the weather behind them. This is called the path attenuation or radar shadow.

Figure 5-10: Path attenuation or Radar shadow

- **Sensitivity Time Control**

The **Sensitivity Time Control (STC) compensates the beam attenuation within 80 NM.** The STC increases the radar sensitivity over time while the aircraft is getting closer to a precipitation.

Figure 5-11: Sensitivity Time Control

Thanks to the STC, the display of a given precipitation is more accurate within 80 NM and should not vary in colors (provided that the intensity of the precipitation is constant) when the aircraft is getting closer to the precipitation.

Conventional radar **Radar with Sensitivity Time Control**

Figure 5-12: Weather displays with and without STC

- **Weather, Ground and Sea returns**

  - Weather/Ground Returns

The weather radar links radar returns to a color according to their intensity. As ground returns are of high intensity, colors are then useless to distinguish weather returns from ground ones. The shape of displayed patterns and the use of tilt help in determining the nature of returns (weather or ground):

- **Ground returns:** sharp or broken shape, significant color variation when the tilt setting changes
- **Weather returns:** large and diffuse shape, light color variation when the tilt setting changes.
- Sea Returns

  Returns of large bodies of water (e.g. sea, lake) are different according to the state of the water surface and the direction of waves. Radar returns are weak from calm waters but are strong if the radar pulses hit the downwind side of waves on a choppy water.

Figure 5-13: Radar returns on calm and choppy waters

5.1.1.1.8. INTERFERING RADIO TRANSMITTERS

Radio transmitters that operate a frequency close to the weather radar one (i.e. 9333 MHz) can interfere and produce unusual displays. Those transmitters may be military radar, radar-jamming equipment, or satellite ground earth station.

The Honeywell RDR-4000 and Rockwell Collins WXR 2100 weather radar includes a filter that partly attenuates these interferences.

Figure 5-14 shows a display when the radar does not filter the interferences from radio transmitters.

Figure 5-14: Interfering radio transmitters

CAUTION RADAR AREA

Before activating the weather radar, make sure that:

- No one is within a sector defined by a radius of 5 m and +/-135° from the aircraft centerline,
- No large metallic obstacle is within a sector defined by a radius of 5 m and +/- 90° from the aircraft centerline.

NOTE:

Weather radar technology is such that it has no risk for flight crew's health. The radiations that the flight crew are exposed to with the use of the weather radar were demonstrated to be very low : maximum emission of 10 mW/cm2 is 6 cm behind the antenna, so far away from the cockpit (demonstrated compliance to FAA AC 20-68B).

5.1.1.1.9. RADIATION HAZARDS

Refer to FAA AC 20-68B "Recommended Radiation Safety Precautions for Ground Operation of Airborne Weather Radar".

As a reminder, the following table gives the fuselage cross sections of AIRBUS aircraft. It gives an idea about the radiation hazard clearance.

AIRCRAFT	FUSELAGE DIAMETER
A300/A310	5.64 m
A320 Family	3.85 m
A330/A340	5.64 m
A380*	7.14 m
A350	5.96m

* for A380 aircraft, it is the fuselage width.

Figure 5-15: Radiation hazard boundary

5.1.1.2. WEATHER, TURBULENCE AND WIND SHEAR DETECTION

5.1.1.2.1. COVERAGE

Figure 5-16: Radar coverage

NOTE:

For any radars, the tilt angle refers to the horizon and not to the longitudinal centerline.

The weather and turbulence detections (Honeywell and Rockwell Collins weather radars) cover an area as defined in. Figure 5-16.

For Honeywell radar only, the horizontal plane is divided into five sectors (dashed on Figure 5-16) for Autotilt purposes. Refer to 5.1.1.3.1 – RADAR Technologies Autotilt (Honeywell)

Figure 5-16b: Pitch and Tilt

Figure 5-17: Wind shear detection range

The wind shear detection covers a sector of 60° from the centerline on either side of the aircraft.

Wind shear events are displayed within a sector of:

- 30° for Rockwell Collins radars,
- 40° for Honeywell radars, from the centerline on either side of the aircraft.

5.1.1.2.2. WEATHER RADAR OPERATING MODES

According to the weather radar manufacturer, several operating modes are available. Based on the radar principle, the weather radar is able to detect:

- Weather (or more precisely wet precipitations)
- Turbulence (except Clear Air Turbulence)
- Windshears
- HazardsGround returns (MAP).

From one manufacturer to another, the operating modes may vary. As a general rule, the different operating modes are defined for de-cluttering purposes (i.e. superimposition of different layers of information).

5.1.1.2.3. WX MODE

The weather radar detects wet precipitations up to 320 NM and provides a coded-color display according to their precipitation rates. Refer to 5.1.1.1.5 for the color code.

5.1.1.2.4. WX+T, WX/TURB OR TURB MODE

In addition to weather, the weather radar detects and displays turbulence (except Clear Air Turbulence) in magenta. The detection of turbulence is **limited to a range of 40 NM (60NM for Honeywell RDR-4000 V2 and A350 AESS).**

The detection of turbulence (as well as wind shears) is based on the **Doppler principle**. Indeed, the weather radar detects an area as turbulent if velocities of water droplets are above 5 m/s and the area presents high variations in velocities. The weather radar will not consider an area where water droplet velocities are quite homogeneous as turbulent.

Figure 5-18: Non turbulent and turbulent spectra

The left part of Figure 5-18 shows a wide spectrum of velocities but the numbers of returns for each velocity are quite homogeneous. The variation of velocities is smooth.

The right part of Figure 5-18 shows a wide spectrum with a heterogeneous distribution of velocities. The variation of velocities is irregular and causes turbulence.

The **WX+T** (Rockwell Collins) or the **WX/TURB** (Honeywell) combines weather and turbulence information for display. The **TURB** mode (Rockwell Collins) only shows turbulence information for a better identification of turbulent areas.

5.1.1.2.5. MAP MODE

- In addition to weather, the weather radar also displays ground returns. The colors indicate the various levels of altitude/strength of return of the object (e.g. water is a good reflector and may appear red). It may permit mainly to distinguish peaks from valleys in mountainous regions, but with no guarantee on the quality of the data.

5.1.1.2.6. PWS MODE

The Predictive Wind Shear (PWS) supplements the Reactive Wind Shear (refer to 6.1.4 – Reactive Wind Shear. The PWS provides alerts when the aircraft is ahead of the wind shears for avoidance purposes. The Reactive Wind Shear provides alerts when the aircraft is in the wind shears for escape purposes.

The PWS detection is based on the Doppler principle. A wind shear is an area where wind velocities of opposite directions exist on a short distance. The PWS triggers alerts when wind shears exceed an threshold called Hazard Factor.

- **Hazard Factor F**

The **Hazard Factor F,** developed by NASA, measures the **losses of altitude and airspeed** due to wind shears. It is defined as:

$$F - \frac{Wh}{g} - \frac{V}{As} \text{ with}$$

Wh: Rate of airspeed loss (kt/s)
G: Gravitational acceleration (19.06 kt/s)
V: Vertical downdraft (kt)
As: Airspeed (kt)

$\frac{Wh}{g}$ represents the loss of airspeed, and $-\frac{V}{As}$ the loss of altitude.
The velocity of the vertical down draft V is defined as a negative value.
$-\frac{V}{As}$ is then positive. **Wind shear alerts are triggered when F > 0.13.**

Considering the loss of airspeed only (i.e. V = 0), a variation rate of 2.48 kt/s would be required to trigger the wind shear alerts.

Considering the loss of altitude only (i.e. Wh = 0), a downdraft of 18.2 kt would be required to trigger the wind shear alerts, with an airspeed of 140 kt.

- **PWS Automatic Activation**

Figure 5-19: Envelopes of Wind Shear alerts

The PWS mode automatically activates when the aircraft is below 2 300 ft RA at take-off or landing. The PWS triggers wind shear alerts below 1 200 ft RA.

To prevent inadvertent alerts, the PWS mode automatically activates if the following conditions are met:

- **Honeywell RDR-4B – Autotilt and Rockwell Collins WXR 701:** One transponder is on AUTO or ON, and one of the engines 2 or 3 is running.

- **Rockwell Collins Multiscan series radars:**
  - One of the engines 1 or 2 is running
  - One of the following conditions is met:
    - The ground speed is above 30 kt, or
    - The longitudinal acceleration is above 0.07 g.
- **Honeywell RDR-4000 series:**
  - One engine running (oil pressure level)
  - One of the 2 following condition is true:
    - The ground speed is above 30kt, or
    - longitudinal acceleration is greater than 0.15g during at least 0.5 seconds.

For all weather radar models, the controls of TILT and GAIN are automatic in PWS mode.

For all weather radar models, when the PWS detects a wind shear when the weather radar is OFF (PWS on AUTO), the weather radar automatically switch to:

- WX+T or WX/TURB mode when the ND range is less than 60 NM,
- WX mode when the ND range is more than 60 NM.

When the aircraft passes the wind shear, the weather radar automatically switches back to OFF.

NOTE:

When one weather radar fails (e.g. WXR 1), the PWS function is not available until the weather radar switch is set on the second weather radar (e.g. WXR 2).

5.1.1.3. WEATHER RADAR FUNCTIONS PER MANUFACTURER

The main manufacturers for weather radar on Airbus aircraft are Honeywell and Rockwell Collins. They use three different philosophies for the weather detection: the **Autotilt or 3D buffer for Honeywell,** and the **Multiscan for Rockwell Collins.** These functions are commonly called the automatic mode for weather radars.

The following paragraphs describe functions that are specific to weather radar models, whereas the previous paragraphs were common to both models.

5.1.1.3.1. RADAR TECHNOLOGIES

- **Autotilt (Honeywell)**

The Autotilt function of the Honeywell weather radar automatically adjusts the tilt angle. **The Autotilt function takes into account the aircraft altitude and the terrain information from EGPWS[2] for the tilt angle adjustment.**

For Autotilt purposes, the radar scan is divided into five sectors (refer to Figure 5-16). For each sector, the Autotilt function adjusts the tilt angle (beam 2 in Figure 5-20) according to the terrain altitude from the EGPWS, the aircraft altitude, and the selected range (i.e. geometric adjustment). When in MAP mode and the Autotilt is activated, the weather radar points the radar beam to the ground according to the aircraft altitude and the selected range.

2 Only Honeywell EGPWS is able to provide the terrain altitude to Honeywell Autotilt function. The Autotilt function is not compatible with ACSS T2CAS and T3CAS.

Practically, the Autotilt function prevents errors encountered when the flight crew manually set the tilt angle. Refer to Figure 5-20.

Figure 5-20: Optimization of tilt setting

- Beam 1 is too high. Weather and terrain are over-scanned.
- Beam 2 is the optimum beam determined by the Autotilt function.
- Beam 3 is too low. Weather and terrain are under-scanned.

NOTE:

The Honeywell weather radar with the Autotilt function is based on ground returns. Therefore, the flight crew should pay attention for the interpretation of heavy rains or ground returns.

5.1.1.3.1..1. IN WEATHER MODE

The Autotilt function operates both in short ranges (less than 80 NM) and in long ranges (more than 80 NM). **Above 2 300 ft:**

- If both flight crewmembers set NDs to ranges of the same magnitude (either short or long ranges), the weather radar updates both ND on clockwise and counterclockwise scans. With this scan pattern, the weather radar refreshes the weather display every 4 s.
- If flight crewmembers set NDs to ranges of different magnitude (short and long ranges), the weather radar alternately scans for short and long ranges. With this scan pattern, the weather radar refreshes the weather display every 8 s.

Figure 5-21: Autotilt scans according to range selections

5.1.1.3.1..2. IN PWS MODE

The Autotilt function does not modify the PWS mode. **Below 2300 ft**, the weather radar alternately scans for weather and wind shear (the first sweep for weather, the second sweep for wind shear). In PWS mode, the radar scans are limited to short ranges. With this scan pattern, the weather radar refreshes the weather display every 12 s.

OPS+

• **Multiscan (Rockwell Collins)**

The Multiscan function develops **an ideal radar beam that would detect significant weather right below the aircraft up to 320 NM, taking into account the curvature of the Earth.**

Figure 5-22: Ideal beam and Multiscan

To that end, the Multiscan function uses two radar beams: **the upper beam to scan medium ranges, the lower beam to scan short and long ranges.** The Multiscan function automatically adjusts the tilt and gain settings. The information from both beam is stored in a database and is cleared of ground returns thanks to the **Ground Clutter Suppression (GCS)** function (refer to 5.1.1.3.2). According to the range selected on ND, the relevant information is extracted from the database for display.

Figure 5-23: Multiscan processing

- In weather mode

  The weather radar alternatively scans for the upper beam (e.g. clockwise) and the lower beam (e.g. counterclockwise). With this scan pattern, the weather radar refreshes the weather display every 8 s.

- In PWS mode

  The weather radar alternatively scans for weather and wind shears, and for the upper beam and for the lower beam.

  illustrates the alternation of weather radar scans. With this scan pattern, the weather radar refreshes the weather display every 11.2 s.

Figure 5-24: Multiscan scans in PWS mode

• 3D Buffer (Honeywell RDR-4000 series)

OPS+

The AESS and RDR-4000 Weather Radar function introduces a new concept: **the weather radar stores the weather information in a 3D buffer and extracts data as selected by the Flight crew for display.** The 3D buffer allows new weather capabilities (i.e. on/off path weather, elevation mode, vertical view, Earth curvature correction, automatic ground mapping, weather displayed behind the aircraft) and improves the weather awareness.

Manual radars directly update the weather display according to the radar antenna position. The AESS and RDR-4000 radar antenna continuously scans the envelope ahead of the aircraft and stores weather returns in a 3D buffer. Then, the system uses weather information stored in the 3D buffer for display on ND and VD (A350/A380). With the 3D buffer, the weather display is no more correlated with the radar antenna position.

At the first activation of the weather radar (e.g. on runway before take-off or when switching from WXR system 1 to system 2, a minimum number of scanning is required to completely fill the 3D buffer in. It could take up to 30 seconds to get a full weather picture on displays.

Figure 5-25: AESS/RDR-4000 3D buffer

NOTE:

A straight beam over a curved ground surface is equivalent to a curved beam over a plan ground surface. Refer to Figure 5-26.

Earth Curvature Correction

AESS and RDR-4000 applies a correction of the Earth curvature on weather information extracted from the 3D buffer. The effects of the Earth curvature are noticeable beyond 40 NM.

Figure 5-26: Effect of Earth curvature

The following figures illustrate the AESS/RDR-4000 corrections.

Figure 5-27: AESS/RDR-4000 correction of Earth curvature for tilt and elevation

5.1.1.3.2. ADDITIONAL FEATURE

5.1.1.3.2.1 GROUND CLUTTER SUPPRESSION – GCS (ROCKWELL COLLINS MULTISCAN)

The Ground Clutter Suppression function automatically removes ground returns for display. The GCS function is:

- Available in WX and WX+T modes
- Not active in MAP mode (ground returns are called for display) and manual operations.

In automatic Multiscan mode, the flight crew may manually and temporarily deactivate the GCS function at its discretion.

In manual mode, the GCS function is deactivated.

5.1.1.3.2.2 LONG RANGE COLOR ENHANCEMENT (ROCKWELL COLLINS MULTISCAN)

The Long Range Color Enhancement by Rockwell Collins compensates the beam attenuation beyond 80 NM. It emulates a red core bordered with yellow and green for a precipitation that would have appeared fully in green without the color enhancement. When the aircraft gets closer to the precipitation, the display gets more accurate.

Conventional radar **Radar with Long Range Color Enhancement**

Figure 5-28: Weather displays with and without Long Range Color Enhancement

5.1.1.3.2.3 ELEVATION MODE (HONEYWELL RDR-4000 AND AESS)

In elevation mode, weather radar:

- Makes a 360° horizontal laser cut at the selected altitude across the 3D buffer
- Displays the weather behind the aircraft in ND ROSE mode.

The selectable altitude range goes from the ground level to 63 000 ft or FL630.

Figure 5-29: Elevation mode

5.1.1.3.2.4 CONVENTIONAL INCREASE AND DECREASE OF RECEIVER SENSITIVITY (ROCKWELL COLLINS MULTISCAN)

This function manages the color variation for display when the gain is manually set. The MAX setting approximately represents an increase of one and half color level (+16 dB). The MIN setting approximately represents a decrease of one and half color level (-14 dB).

The CAL setting is the default setting that provides a color code as depicted in 5.1.1.1.5.

5.1.1.3.2.5 VARIABLE TEMPERATURE BASED GAIN(ROCKWELL COLLINS MULTISCAN)

The reflectivity of water changes according to its state (i.e. liquid or ice). Refer to 5.1.1.1.1. Therefore, the reflectivity changes according to the temperature.

- When the temperature is above 0°C, the gain is constant.
- When the temperature is below 0°C, the Variable Temperature Based Gain function increases the gain to compensate the reflectivity diminution.
- When the temperature is below –40°C (water exclusively in ice crystal form), the Variable Temperature Based Gain function increases the gain by approximately one color level.

5.1.1.3.2.6 PATH ATTENUATION COMPENSATION (PAC) ALERT (ROCKWELL COLLINS MULTISCAN)

OPS+

Figure 5-30: PAC alert

When the radar beam is attenuated (radar shadow, refer to 5.1.1.1.7), the Path Attenuation Compensation (PAC) alert provides a visual cue on ND: a yellow arc on the outermost range ring.

The PAC alert is available when the gain is set to CAL and the attenuation is within 80 NM.

NOTE:

Honeyweel developed a similar function called “REACT” part of the hazard package (refer to 5.1.1.3.2.1.2)

5.1.1.3.2.7 OVER-FLIGHT PROTECTION (ROCKWELL COLLINS MULTISCAN)

The Over-Flight Protection tracks thunderstorms in the aircraft flight path, and until the aircraft passes the thunderstorms. The Over-Flight Protection improves the weather awareness, and may prevent inadvertent penetration of thunderstorm tops.

With conventional weather radars, the wet part of a thunderstorm (that is the most visible on radar display) may get below the radar beam when the aircraft approaches the thunderstorm. Consequently, the thunderstorm may disappear from the display when the aircraft is getting closer to it.

Thanks to the pair of Multiscan radar beams, the Over-Flight Protection scans down to 6000 ft below the aircraft to keep the reflective part visible (step 2, Figure 5-31).

When the thunderstorm is within 15 NM from the aircraft, the Over-Flight Protection compares the image of the thunderstorm stored in the database with the image of the last scan. The Over-Flight Protection displays the image with the strongest returns.

Figure 5-31: Over-Flight Protection with Multiscan

Therefore, when a threatening thunderstorm gets below the radar beam (i.e. radar returns are weakening), the image of the thunderstorm stored in the database is displayed until the aircraft passes the thunderstorm.

The Over-Flight Protection operates **above 22 000 ft.** The 6000 ft clearance below the aircraft is a maximum. When the aircraft flies at 26 000 ft, the clearance is 4 000 ft (26 000 ft minus 22 000 ft).

Similarly, the pair of radar beams allows the detection of thunderstorm vault (refer to Appendix G – Aviation meteorology reminders / G.4.3 – Thunderstorm Vault) thanks to the upper beam. Indeed, the most reflective part of a vaulted thunderstorm is the intermediate part instead the bottom part.

Therefore, as the upper beam scans the intermediate part, the flight crew is able to correctly evaluate the thunderstorm threat.

Figure 5-32: Thunderstorm vaul

5.1.1.3.2.8 REGIONAL WEATHER REFLECTIVITY COMPENSATION (ROCKWELL COLLINS MULTISCAN)

The reflectivity of a cell varies according to the region where the cell develops (refer to Appendix G – Aviation meteorology reminders / G.2.5 – Oceanic Cell). A regional weather reflectivity compensation adjusts the gain and tilt for a more accurate representation of a cell in a given region. The regional weather reflectivity compensation activates when the aircraft is over a specific type of region. The weather radar detects the type of the flown region thanks to an internal data base. The internal data base includes oceanic, equatorial and polar regions. Based on the aircraft position, the Multiscan radar provides an optimum tilt adapted to the flown region.

5.1.1.3.2.9 ON-PATH AND OFF-PATH WEATHER CONCEPT (HONEYWELL RDR-4000 AND AESS)

An envelope is defined along the current flight path. The envelope expands 4000 ft above and below the flight path. In addition, the lower boundary is 25 000 ft at most, and the higher boundary is 10 000 ft at least.

OPS+

- The **on path weather** is the weather inside this envelope,
- The **off path weather** is the weather outside this envelope.

The **STANDARD WXR AUTO mode is** active when:

- The flight crew sets WXR AUTO on the control panel (or on the MFD SURV CONTROLS page),
- The FMS flight plan is available.

Figure 5-33: STANDARD WXR AUTO envelope

The **BASIC WXR AUTO mode is** active when:

- The flight crew sets WXR AUTO on the control panel (or on the MFD SURV CONTROLS page),
- The navigation mode is selected,
- The aircraft is converging to the selected FCU altitude.

Figure 5-34: BASIC WXR AUTO envelope in climb

Figure 5-35: BASIC WXR AUTO envelope in descent

The **DEFAULT WXR AUTO** mode is active when:

- The flight crew sets WXR AUTO on the control panel (or on the MFD SURV CONTROLS page),
- The FMS flight plan is not available,
- No FCU altitude is selected.

Figure 5-36: DEFAULT WXR AUTO envelope in climb

Figure 5-37: DEFAULT WXR AUTO envelope in descent

AESS or RDR-4000 use the On-path and Off-path weather concept to generate the horizontal weather view on ND. The ND displays **On-path weathers with solid colors and Off-path weathers with dashed colors.**

Figure 5-38: Generation of weather view on ND

Step 1: Weather radar draws the envelope of the On-path weather on the current aircraft flight path (see above).

Step 2: Weather radar rotates the On-path weather envelope around a vertical axis to form a 3D envelope.

Step 3: This 3D envelope defines a set of vertical laser cuts in the 3D buffer.

Step 4: For each vertical laser cut, AESS projects the On-Path weather of the highest reflectivity on the horizontal plane. If there is no On-Path weather, AESS projects the Off-Path weather of the highest reflectivity on that horizontal plane.

Step 5: Finally, the projections of vertical laser cuts on the horizontal plane form the horizontal weather view.

5.1.1.3.2.10 ENHANCED OF ON PATH DEFINITION (HONEYWELL AESS/RDR-4000 V2)

ON PATH envelope modulation has been updated thanks to the algorithm to be adapted depending of the presence of convective weather cells.

With previous definition of ON PATH envelope, in cruise, lower boundary of ON PATH envelope was always 25000 ft.

This lower boundary is still applied for convective weather in order to effectively display the cell as relevant; however, for stratiform weather (nonconvective or non-thunderstorm-like), this lower boundary will be heightened to 4000ft below A/C altitude in order to limit nuisance display due to vertical resolution decreasing with range.

Figure 5-39: Enhanced On Path Definition

Figure 5-40 describes new ON PATH envelopes determination according to A/C flight phases.

Climbing from Ground level

Figure 5-40: On-Path envelope per flight phase

5.1.1.3.2.11 WEATHER AHEAD (HONEYWELL AESS/RDR-4000 V2 AND ROCKWELL COLLINS MULTI SCAN WXR-2100A)

The purpose of this new function is to ensure that the flight crew is aware of severe weather area in the immediate vicinity of the A/C. This is also used to address inappropriate settings of WXR manual modes or display luminance preventing from data display on both NDs.

The function is active in both manual and automatic mode on AESS/RDR-4000, but only in Manual mode on WXR-2100A.

In case of red or yellow weather, or turbulence:

- At a distance of less than 3 minutes of flight
- Within a corridor width of 2 NM around the A/C track
- Within vertical limits of +/-4000 ft along current A/C path a “WEATHER AHEAD” alerting message is displayed on both ND regardless of WXR display settings. (Honeywell RDR-4000 only)

If none of the flight crew (CAPT, F/O) has selected WXR display (DISPLAY OFF or TERR ON ND selected), aircraft is above 2500ft AGL and the severe weather is confirmed for more than 10 seconds, an aural alert “Weather ahead, Weather ahead” will be emitted. This alert is inhibited by alerts with higher priority emitted meanwhile.

WEATHER AHEAD message is removed when there are no more yellow/red cells remaining in the corridor defined in Figure 5-41.

NOTE:

A350 WEATHER AHEAD audio reminder is triggered above 1500ft instead of above 2500ft on A320/A330/A340.

Figure 5-41: WEATHER AHEAD Detection Aarea

5.1.1.3.2.12 WEATHER HAZARD PREDICTIVE FUNCTION

5.1.1.3.2.12.1 HAIL AND LIGHTNING PREDICTION (HONEYWELL AESS/RDR-4000 V2 AND ROCKWELL COLLINS MULTI SCAN V2)

The weather radar can now predict hail and lightning areas. The hail and lightning risks are indicated on ND by icons until 160Nm.

On Honeywell AESS/RDR-4000 V2 some new icons have been introduced:

Predictive Hail – Icon: • Symbol – Based on ICAO standard for hail • Color – Yellow icon / magenta border circle / black background and black circle border • Icon is displayed only when HZD mode is active (including ELEVN mode but except MAP mode)	
Predictive Hail – Lightning: • Symbol –Unchanged, based on intuitive indication for lightning • Color – Yellow icon / magenta border circle / black background and black circle border • Icon is displayed only when HZD mode is active(including ELEVN mode but except MAP mode).	

On Rockwell-Collins multiscan V2 on there are no new icons, only the color is modified/intensified in case of hail or lightning

Figure 5-42: Rockwell Collins multiscan V2 hazard display

The following parts indicates the process of computation of the Hail and Lightning risk.

- **Hail risk assessment:** calculates probability of hail within a weather cell and displays associated icons on ND when an area contains a non-zero probability (risk) of producing hail
- **Lightning risk assessment:** calculates probability of lightning within a weather cell and displays associated icons on ND when an area contains a non-zero probability (risk) of producing lightning.

5.1.1.3.2.12.2 REACT FUNCTION (RAIN ECHO ATTENUATION COMPENSATION TECHNIQUE) (HONEYWELL AESS/RDR-4000 V2)

As the transmitted radar signal travels through heavy rain it loses power, or becomes attenuated. If this attenuation is severe enough, weather behind a storm cell may not be detectable, or it may be displayed as being less severe than it actually is (e.g. green instead of yellow). In this condition, those areas where the radar signal has been attenuated are automatically indicated by REACT (Rain Echo Attenuation Compensation Technique) HMI. These areas are shown as thin magenta arcs superimposed over the reflectivity in the areas where the signal attenuation is significant. These arcs indicate that there could be severe weather in that area, even though only mild or no reflectivity is shown.

This REACT HMI indicates regions of radar shadow where reflectivity levels cannot be fully assessed due to signal attenuation until 320Nm.

Figure 5-43: AESS/RDR-4000 Hazard display (Hail/Lightning/REACT)

5.1.1.3.2.12.3 LAAT/HAAT FUNCTION (LOW/HIGH ALTITUDE ASSOCIATED THREAT) (ROCKWELL-COLLINS MULTISCAN V2)

The associated threat assessment function provides analysis and display of threats which are associated with a weather cell but extend to the reflectivity region surrounding the cell. This function warns the crew that the weather threats are greater than would be normally indicated by the displayed reflectivity. This function also utilized horizontal and vertical scans and make a convective assessment in addition to temperature vs. reflectivity characteristics to evaluate the threat posed by the cell.

Associated threat is divided in:

- Low Altitude Associated threat (LAAT): identify electrified region that can mostly be encountered near freezing level. Example is a stratiform region that is present at lower altitudes after convection has passed, but may still be electrified and pose a threat for induced lightning strikes.
- High Altitude Associated Threat (HAAT): warn the crew for risks of hail or lightning outside cell's "radar visible" core. Example is a high altitude blow off region ("anvil") at the top of convective cell, caused by high altitude winds which spread the high altitude updrafts in a convective cell. Though these areas may have lower levels of reflectivity, they may contain lightning, hail and turbulence.

The inferred regions are depicted to the crew using a uniformly organized red speckled pattern. The density of this speckled pattern depends on selected range, so that the speckles are visible when overlaid on top of the depicted weather: denser speckle pattern for selected ranges less than 160 nautical miles and a less dense speckle pattern used for selected ranges greater than or equal to 160 nautical miles.

Associated threat assessment function is available up to 160 NM.

Figure 5-44: Associated threat HMI

Wind data not available

Aircraft is above 25000ft and wind speed is above 10

Figure 5-45: Wind impact

5.1.1.3.2.12.4 PREDICTIVE OVERFLIGHT (POF) (ROCKWELL-COLLINS MULTISCAN V2)

Figure 5-46: Predictive overflight principle

Inadvertent turbulence encounters may be caused by rapidly building thunderstorm cells that begin at low altitudes but rapidly grow into the aircraft flight path. These cells are difficult to detect since crews using manual radars are scanning far ahead of the aircraft for weather and are likely not looking down toward the building cell.

Predictive OverFlight (POF) function aims to indicate risk constituted by cell fastly growing underneath main radar beams.

The Predictive OverFlight feature commands dedicated horizontal and vertical antenna sweeps to identify and track cells below the aircraft. These cells are then analyzed to determine the cell storm top altitude and growth rate. The Predictive OverFlight feature also includes an estimation of possible clear air turbulence resulting from a turbulence "bow wave" over the rapidly building storm tops. If any of these cells are rapidly growing and will pose a threat to the aircraft, the crew will be alerted.

Figure 5-47: POF HMI

When a conflict is detected, the threat area is annunciated to the flight crew with a uniformly organized red speckles within a red boundary in the region of predicted weather threats.

POF icon size is 7*7 NM when range ≤ 160 NM is selected, 14*14 NM when range 320 NM is selected. The icon is firstly displayed "alone" over black when concerned cell is not displayable (meaning much lower than A/C flight level); then when cell reach A/C flight level, icon and reflectivity are displayed together. Finally icon is removed 1 minute after cell ceases to pose a threat or when relevant depiction (i.e. at least red core) for the cell is available on ND.

Predictive OverFlight function is active above 25000 ft and operates up to 60 NM, although the icon is not expected to appear further than 40NM.

5.1.1.3.2.12.5 "RIDE QUALITY" TURBULENCE (ROCKWELL-COLLINS MULTISCAN V2)

"Ride quality" turbulence detection alerts crews away from areas where uncomfortable levels of turbulence have been detected which may be lower than the severe turbulence level threshold required by the industry standard detection criteria.

Ride quality turbulence function complements severe (>0.3 Grms) turbulence detection (in plain magenta) with display of ride quality (> 0.1 Grms) turbulence area displayed on ND with magenta speckles.t

"Ride quality" turbulence function is available up to 40 NM, as the severe Turbulence.

Figure 5-48: 2 levels turbulence

5.1.1.3.3. SUMMARY OF RADAR CAPABILITIES PER MANUFACTURER

The following table summarized the different capabilities and functionnailities of Weather Radar systems installed on Airbus aircraft.

AIRCRAFT FAMILY		A318/A319/A320/A321/A330/A340										A380	A350
Supplier		ROCKWELL COLLINS						HONEYWELL					
WXR		622-5132-120	622-5132-620 to 623	WXR 701 622-5132-624	multiscanw-WXR-2100 822-1710-201/202/203/213	multiscan WXR-2100 V2 -401/-411	multiscan WXR-2100A -204/214	RTA-4A SperryPri-mus 2041217-0418	RTA-4B 066-50008-0407	RDR-4000V1 930-1005-001	RDR-4000V2 930-1005-002	AESS RDR-4000	AESS RDR-4000
Manual mode	Gain & Tilt									Elevation display mode	Elevation display mode	Elevation & Tilt display mode	Elevation & Tilt display mode
Automatic mode					multiscan	multiscan	multiscan		autotilt	3D buffer	3D buffer	3D buffer	3D buffer
WX													
TURB				Option 40NM	40 NM	40 NM	40 NM		40 NM	40 NM	60NM	40 NM	60NM
MAP	Ground map												
PWS					Option								
Ground clutter suppres-sion	Remove ground returns								Earth curvature + data-base	Earth cur-vature + database	Earth cur-vature + database	Earth curva-ture + data-base	Earth cur-vature + database
Long range color enhanced	Compen-sate beam attenuation								Sensitiv-ity Time Control (STC)	STC	STC	STC	STC

AIRCRAFT FAMILY		A318/A319/A320/A321/A330/A340										A380	A350
Supplier		ROCKWELL COLLINS						HONEYWELL					
WXR		622-5132-120	622-5132-620 to 623	WXR 701 622-5132-624	multiscanw-WXR-2100 822-1710-201/202/203/213	multiscan WXR-2100 V2 -401/-411	multiscan WXR-2100A -204/214	RTA-4A SperryPri-mus 2041217-0418	RTA-4B 066-50008-0407	RDR-4000V1 930-1005-001	RDR-4000V2 930-1005-002	AESS RDR-4000	AESS RDR-4000
Elevation mode	WX altitude cut												
+/- Receiver Sensitivity	Color varia-tion man-agement in manual gain									GAIN for display	GAIN for display	GAIN for display	GAIN for display
Variable Temp based gain	Increase gain in low temperature												
Attenuation compensa-tion					PAC	PAC	PAC				REACT	REACT	REACT
Overflight protection	Improve awareness of thunder-storm top												
Regional weather Reflectivity compen-sation	Gain/tilt based on regional database												
Weather ahead							Auto mode only				Manual/ Auto mode		Manual/ Auto mode
On path/ Off path													
Enhanced On-path	Envelope adapted if convective cell											Planned	Planned
WXR AUTO	Based on FPLN & FCU												
Vertical Display													
Hail / Lightning							Option					Planned	Planned
Low/high alt threat							Option						
Predictive OverFlight (POF)	Highly convective cell						Option						
Ride Quality turbulence	0.1 G turbulence												

Function not available
Function available

5.1.1.4. A350/A380 SPECIFICITIES

A350 and A380 Weather Radar introduces some specific designs compared to the RDR-4000 installed on A320/A330/A340 aircraft.

5.1.1.4.1. AUTOMATIC MODE – WXR AUTO

In automatic mode, the AESS Weather Radar displays the weather information according to the active navigation mode:

- **STANDARD WXR AUTO** based on FMS flight plan path and FCU altitude when the navigation mode is managed,
- **BASIC WXR AUTO** based on flight path along FPA up to FCU altitude when the navigation mode is selected,
- **DEFAULT WXR AUTO** based on flight path along FPA up to 60 NM when the navigation mode is manual.

5.1.1.4.2. ENHANCED TILT MODE

The 3D buffer eases the manual weather analysis with an enhanced tilt mode.

Tilt Mode

The enhancement of the tilt mode is triple:

- AESS applies **a correction of the Earth curvature on the tilt angle.**
- In tilt mode, AESS makes **a 360° laser cut around the aircraft** along the tilt angle across the 3D buffer. **In ND ROSE mode, the AESS displays the weather behind the aircraft.**
- The **ground de-cluttering is automatic.** Thanks to the terrain database, AESS removes terrain returns from the weather image. In addition, beyond the intersection of the laser cut and the ground, the weather is not displayed. Refer to Figure 5-50.

Figure 5-49: Tilt mode

Figure 5-50: Inhibition of weather display beyond the laser cut

5.1.1.4.3. VERTICAL DISPLAY

The Vertical Display (VD) is one of the novelties introduced by the A380 and then A350 cockpit that is capable to display Weather information.

The description of VD in this paragraph focuses on weather information. For more details, refer to your FCOM.

VD displays the aircraft symbol, the vertical flight plan, and horizontal and vertical scales. VD displays weather information as a background image. The horizontal scale equals the selected ND range up to 160 NM that is the maximum horizontal VD range (e.g. the horizontal VD range remains at 160 NM even if the ND range is greater than 160 NM in ARC mode). VD adapts the vertical scale to the horizontal scale in order to fit to the VD window.

- **VD image on aircraft track**

  When the VD image is on aircraft track and the aircraft is under specific conditions[3], the white indication VIEW ALONG ACFT TRK is displayed at the bottom of VD.

Figure 5-51: VD image on aircraft track

But the VD background image can run along the lateral flight path defined by the active navigation mode or a manually selected azimuth.

- **VD Background Image on the lateral flight path defined by the active navigation mode**

The VD background image runs along:

- The FMS flight plan when the navigation mode is managed, or
- The XLS approach course, or
- The current track when:
  - The navigation mode is managed and the aircraft significantly deviates from the FMS flight plan (see below) or from the XLS approach course, or
  - The navigation mode is selected (HDG or TRK).

Figure 5-52: VD image on FMS flight plan path

3 For instance, in managed mode, when the aircraft deviates from the flight plan or the XLS approach course. Refer to your FCOM for details.

When the VD background image is along the FMS flight plan, a vertical cut is made for each leg. The VD image along the FMS flight plan is a concatenation of all these vertical cuts.

When the aircraft significantly deviates from the FMS flight plan, the VD image returns on aircraft track. **The VD switches between "on track" mode and "on FMS flight plan path" mode with a threshold of 1 RNP approximately.** For instance, when RNP is 1 NM, the switch occurs at 1 NM from the FMS flight plan leg. Refer to Figure 5-53.

Figure 5-53: VD path reference

Figure 5-54: Track change and absence of terrain information on VD

If the track changes by more than 3° after the TO waypoint, the vertical view after the TO waypoint is shaded in grey. Refer to Figure 5-54.

When the terrain information is not available, the corresponding portion of the vertical view is shaded in magenta.

- **VD image on manually selected azimuth**

When the VD image is on manually selected azimuth, the cyan indication **VIEW ALONG AZIM NNN°** (NNN is the manually selected azimuth) is displayed at the bottom of VD. The eye icon highlights the manual setting.

The AESS also displays a white reference line on ND (also called "Lubber line") to illustrate the manually selected azimuth.

Figure 5-55: VD image on manual selected azimuth

When the flight crew does not select any new azimuth value during 30 seconds, the VD image automatically returns to a default VD path reference (i.e. along aircraft track or FMS flight plan path). Five seconds before the 30-second timer expires, the white reference line on ND flashes.

The selected azimuth for either terrain or weather analysis is not a fixed bearing. When the aircraft turns, the white reference line sticks to a heading. Practically, the white reference line moves with the compass rose on ND. When the white reference line reaches the +/- 60° limits, the white reference line sticks to the limit until the aircraft turns in the opposite direction.

Figure 5-56 illustrates the reference line behavior during a sequence of a 60° turn to the left followed by a 30° turn to the right. The sequence starts while the aircraft is heading to the North. The azimuth range is amber dashed and the reference line is black.

Figure 5-56: Behavior of the reference line during turns

The following table compares the weather data displayed on ND and VD.

	NAVIGATION DISPLAY ND	VERTICAL DISPLAY VD
WXR – Ground mapping	Yes	No
WXR – Weather	Yes	Yes
WXR – Wind shear (PWS)	Yes	No
WXR – Turbulence	Yes	No
WXR - Hazard	Yes	No

The vertical cut in the weather radar 3D buffer has no width. It is a “laser cut”.

• Image generation in automatic modes

Figure 5-57: Generation of vertical weather view along FMS flight plan

Figure 5-58: Generation of vertical weather view along track

Figure 5-59: Generation of vertical weather view along azimuth

• Image generation in manual modes

In tilt and elevation modes, the WXR function makes laser cut.

• Interpretation of Weather Elevation on VD

The aircraft altitude on VD is the barometric altitude. Atmospheric conditions (temperature and pressure) influence the barometric altitude. As a consequence:

- At the current aircraft position (i.e. where atmospheric conditions are known), terrain and weather elevation are reliable on VD.
- Ahead of the current aircraft position (i.e. where atmospheric conditions are unknown), terrain and weather elevations are not reliable on VD.

Figure 5-60 illustrates the case where the air ahead of the aircraft is getting colder. The aircraft is at 5 000 ft. The 5 000 ft isobar gets lower as the air temperature decreases. The terrain elevation below the aircraft is 2 000 ft (mark 1 in Figure 5-60) as atmospheric conditions are known. However, the weather elevation ahead of the aircraft is **not** 3 000 ft as AESS does not know the atmospheric conditions at that location.

Do not directly read weather elevations on VD as they depend on local atmospheric conditions.

Figure 5-60 – Interpretation of weather information on VD

5.1.1.5. WEATHER RADAR INDICATIONS

The weather radar display on ND is available in ROSE and ARC modes.

The weather radar displays weather information on ND according to the reflectivity of targets (i.e. green, yellow or red, refer to 5.1.1.1.5).

Instead of WXR MSG (rounded in dash red on Figure 5-61), indications from the weather radar about the operating modes or failures are displayed. Next section provides the list of these indications.

Figure 5-61: Weather display

Figure 5-62: Cell distortion

Figure 5-63: Steep reflectivity gradient

Figure 5-64: U-shape cell

SPECIFIC WEATHER SHAPES

The shape of a cell provides good cues about its activity:

- A distorted cell indicates turbulence. The distortion of the cell is due to wind shears inside the cell (Figure 5-62).
- A steep reflectivity gradient (variation of colors on a short distance) indicates strong convective movements and severe turbulence (Figure 5-63).
- U-shape cells, hooks, fingers, scalloped-edge cell indicate strong wind shears and turbulence (Figure 5-64 to Figure 5-67).

Shapes that change rapidly also indicate strong activity and turbulence. Intense and frequent lightning is also a good sign for severe turbulence.

Figure 5-65: Hook

Figure 5-66: Finger

Figure 5-67: Scalloped edge

USE DIFFERENT RANGES ON NDs

The PF should select a short range on his ND and the PNF should select a long range. Thanks to this method, the flight crew avoids being trapped by the Blind Alley effect. The Blind Alley effect is, when the aircraft flies a heading and this heading reveals a dead-end formed by active cells at a distance greater than the ND range.

Figure 5-68: Blind Alley effect – Right ND range = 40 NM, Left ND range = 80 NM

5.1.1.5.1. WEATHER RADAR MESSAGES

For weather radar standards before Honeywell RDR-4000 and Rockwell Collins multiscan, the following messages were displayed on ND:

CP SELECTION	EIS DISPLAY	ND DISPLAY
ON/AUTO	**WXR DU**[4]	Weather display lost DU overheating
	WXR R/T	Weather display lost WXR transceiver failure
	WXR ANT	Weather display lost WXR antenna failure
	WXR CTL	Weather display lost WXR control unit failure
	WXR RNG	Weather display lost Discrepancy between EFIS CP range selection and DMC range
	NO WXR	Weather display lost DU internal breakdown leading to cancellation of RADAR echoes

4 This message indicates an overheating of the display unit. It is not a weather radar message.

CP SELECTION	EIS DISPLAY	ND DISPLAY
	MAN GAIN	Manual gain
	MAN XX.X	Manual tilt
	PRED W/S	Weather display still available W/S failure
	WXR ATT	Weather display still available Attitude stabilization failure
	NO AUTOTILT[5]	Weather display still available Autotilt failure
	WXR STAB	Weather display still available Loss of antenna stabilization
ON (MCDU system test)	**WXR TEST**	Test image
OFF	**PWS SCAN**[6]	No echo displayed but windshear scan available

On Honeywell RDR-4000 series and Rockwell Collins multiscan series, a set of messages has been added on ND with EIS2 standard to reflect the weather radar mode selected (depending on available options):

CP SELECTION				EIS2 DISPLAY	RDR DISPLAY
SYSTEM SWITCH	DISPLAY MODE	TURB P/B	HZD P/B	MODE MES-SAGE	DATA DISPLAYED
OFF	**System OFF**			**WXR OFF**	Radar set to OFF No data displayed
ON/ AUTO (SYS1/ SYS2)	**OFF**[7]	X	X	**PWS SCAN**	Radar ON No echo displayed
	OFF [8]	X	X		Radar ON No echo displayed but Windshear scan available
	X	X	X	**MAN GAIN**	GAIN knob set to a position different from AUTO

5 With EIS1 display units, the message is displayed in the middle of ND.
6 This message is available with EIS 2 display units only.
7 PWS qualifiers are invalid
8 PWS qualifiers are valid,

CP SELECTION				EIS2 DISPLAY	RDR DISPLAY
SYSTEM SWITCH	DISPLAY MODE	TURB P/B	HZD P/B	MODE MES-SAGE	DATA DISPLAYED
	MAP	X	X	**MAP**	Only Ground echoes displayed (no TURB nor HZD data displayed)
	ALL WX	ON	OFF	**WX+T**	All WX echoes displayed (relevant in plein or not relevant in hashed) (reflectivity, REACT and TURB)
		ON	ON	**WX+T+H**	All WX echoes displayed (relevant in plein or not relevant in hashed) (reflectivity, REACT, HZD icons and TURB)
		OFF	OFF	**WX**	All WX echoes displayed (relevant in plein or not relevant in hashed) (reflectivity and REACT)
		OFF	ON	**WX+H**	All WX echoes displayed (relevant in plein or not relevant in hashed) (reflectivity, REACT and HZD icons)
	PATH WX (Hon-eywell only)	ON	OFF	**WX+T PATH**	Only relevant WX echoes displayed (reflectivity, REACT and TURB)
		ON	ON	**WX+T+H PATH**	Only relevant WX echoes displayed (reflectivity, REACT, HZD icons and TURB)

CP SELECTION				EIS2 DISPLAY	RDR DISPLAY
SYSTEM SWITCH	DISPLAY MODE	TURB P/B	HZD P/B	MODE MES-SAGE	DATA DISPLAYED
		OFF	OFF	**WX PATH**	Only relevant WX echoes displayed (reflectivity and REACT)
		OFF	ON	**WX+H PATH**	Only relevant WX echoes displayed (reflectivity, REACT and HZD icons)
	ELEVN (Hon-eywell only)	ON	OFF	**WX+T ELEV 12000FT or FL 120**	WX echoes at selected altitude displayed (reflectivity, REACT and TURB)
		ON	ON	**WX+T+H ELEV 12000FT or FL 120**	WX echoes at selected altitude displayed (reflectivity, REACT, HZD icons and TURB)
		OFF	OFF	**WX ELEV 12000FT or FL 120**	WX echoes at selected altitude displayed (reflectivity and REACT)
		OFF	ON	**WX+H ELEV 12000FT or FL 120**	WX echoes at selected altitude displayed (reflectivity, REACT and HZD icons)
	MCDU system test	X	X	**WXR TEST**	

NOTE:

Shaded cells above apply to Honeywell radar only.

5.1.1.5.2. PREDICTIVE WIND SHEAR INDICATIONS

PREDICTIVE WIND SHEAR CAUTION	PREDICTIVE WIND SHEAR WARNING
MONITOR RADAR DISPLAY	**Take-off:** WIND SHEAR AHEAD, WIND SHEAR AHEAD **Landing:** GO AROUND, WIND SHEAR AHEAD

The indications on PFD and ND are almost identical for Caution and Warning, except W/S AHEAD on PFD appears in red (refer to Figure 5-69 and Figure 5-70).

A yellow sector with red arcs indicates the location of detected wind shears on ND.

In case of a wind shear advisory (Refer to Figure 5-19), only the ND indication is provided (no indication on PFD).

Figure 5-69: Wind shear alert on PFD

Figure 5-70: Wind shear alert on ND

On A380/A350 aircraft, the symbols for wind shear depiction on ND slightly differ. In order to enhance awareness of wind shears, the WXR function displays sectors of wind shear in red doted circles and highlights sectors where wind shears occur in yellow for ND range greater than 10 NM.

Figure 5-71: A380/A350 Wind shear icons for ND range of 10 NM

Figure 5-72: A380/A350 Wind shear icons for ND range greater than 10 NM

5.1.1.6. WEATHER RADAR CONTROLS

5.1.1.6.1. A320/A330/A340

• EFIS Control Panel (EFIS CP)

The following EFIS Control Panel controls have an impact on WXR data display:

Figure 5-73: EFIS-CP controls

1/ A mode selector switch, made up of a rotary switch. It enables the selection of the ROSE or ARC function for display of weather radar image on the CAPT and F/O NDs. If weather data display selected and WXR system active, WXR image is displayed in the background of the navigation image.

2/ A scale selector switch, is common to EFIS, FMGES and RADAR system. It enables the display of the range selected for an optimum use of the WXR image on the corresponding ND

3/ A barometric setting knob, allows changing barometric altitude reference from STD (standard) to QFE/QNH. It impacts the Elevation altitude reference.

When STD reference is selected, then Elevation altitude indication is FLXX0.

When QFE/QNH reference is selected, then Elevation altitude is XX000 FT.

• Weather radar control panel

The flight crew is able to control four parameters in manual mode:

- The tilt angle: Angle between the beam center and the horizon,
- The gain: The sensitivity of the receiver,
- The ND range,
- The operating mode (WX, WX+T, WX/TURB, TURB, MAP, or PWS; manual or automatic if available).

NOTE 1:

The layout and the content of the control panel may change according to the installed options. Refer to your FCOM for the control panel installed on your aircraft.

NOTE 2:

A DEACT sticker in System 2 of 1/OFF/2 switch is added to indicate that only one WXR is available.

HONEYWELL RADAR

Figure 5-74: Honeywell control panel with Autotilt function

ROCKWELL COLLINS RADAR

Figure 5-75: Rockwell Collins control panel with Multiscan function

When tilting downward by 1°, the appearance of a cell at 80 NM means that the top of cell is located at 8 000 ft below the aircraft. Note that in the case of a cumulonimbus, it indicates the radar top.

USE THE TILT TO MEASURE VERTICAL EXTENSIONS

To measure the vertical extension of a cell or the vertical distance to the top or bottom of a cell at a given distance, the following formula can be used:

Height [feet] = Tilt (degrees) x (Distance [NM] + "00")

Figure 5-76: Vertical extension measurement with tilt

With the introduction of Honeywell RDR-4000 and possibility of the 3D buffer, the Control Panel has been modified to provide segregated display between Captain and First Officer, and manage the new elevation mode (similar to A350/A380 AESS features).

Figure 5-77: Basic Honeywell RDR-4000 Control panel

Additional modification was introduced on Honeywell RDR-4000 and Rockwell Collins multiscan V2 to manage the display of Hazard icons when the equipment is capable.

Figure 5-78: Honeywell RDR-4000 with Hazard function Control panel

Figure 5-79: Rockwell Collins multiscan V2 with Hazard (WX+T+HZD) function Control panel

5.1.1.6.2. A380/A350

All AESS controls are common to Captain and First Officer, except the following that are limited to onside displays:

- EFIS CP settings: display and range selection
- WXR SURV panel settings: elevation/tilt, gain, VD azimuth
- WXR MFD SURV CONTROLS settings: elevation/tilt, gain, mode (WX/MAP), WX ON ND.
- **EFIS Control Panel (EFIS CP)**

Figure 5-80: EFIS Control Panel

With the EFIS CP, in addition to the range/mode selection (refer to 5.1.1.6.1), the flight crew can select the information to be displayed on ND and VD (if available).

The flight crew cannot simultaneously select WX and TERR.

- **SURV Panel**

Figure 5-81: AESS Control Panel

With the SURV panel, the flight crew can manually set the WXR elevation/tilt[9], gain or VD azimuth (these settings for CAPT and F/O are independent) or activate the WXR AUTO mode[10]

• SURV Pages on MFD

Two pages relative to AESS are available on MFD:

- The SURV CONTROLS page
- The SURV STATUS & SWITCHING page.

The flight crew controls all the AESS functions (XPDR, TCAS, WXR, TAWS) through the MFD SURV CONTROLS page.

Figure 5-82:
A380 MFD SURV CONTROLS page

Figure 5-82b:
A350 MFD SURV CONTROLS page

Figure 5-83: A380 MFD SURV STATUS AND SWITCHING page

Figure 5-83b:
A350 MFD SURV STATUS & SWITCHING page

9 The flight crew uses the WXR ELEVN knob to manually set an elevation or tilt value. Refer to FCOM for more details.
10 The flight crew pushes the WXR ELEVN knob to activate the WXR AUTO mode.

At any time, the flight crew can reset the default settings (the ones shown in Figure 5-82 and Figure 5-82b) with the DEFAULT SETTINGS button in the bottom right corner. A dialog box pops up to confirm the reversion to default settings.

Figure 5-84: DEFAULT SETTINGS confirmation

5.1.2. OPERATIONAL RECOMMENDATIONS FOR WEATHER RADAR

This paragraph of operational recommendations is intentionally non-exhaustive. For more recommendations, please check your FCOM and/or FCTM as they are more frequently updated.

Recommendations are also available in pilot's guides from the weather radar manufacturers. See References.

5.1.2.1. WEATHER RADAR OPERATIONS

5.1.2.1.1. FOR THE AIRLINE

- **Inform your flight and maintenance personnel about radiation hazards from the weather radar antenna.**
- **Train your flight crews** to use the weather radar and to analysis and interpret weather returns properly and efficiently.
- Ensure a proper maintenance of weather radar components including the radome (e.g. check radome every C check). A faulty component may affect the sensitivity of the weather radar and then the weather indications on ND.

5.1.2.1.2. FOR THE FLIGHT CREW

- Periodically scan the weather vertically (tilt) and horizontally (ND range).
- **Always return to automatic modes (gain and tilt) when the manual control is no longer necessary**. The weather analysis should be done through a manual control, whereas the weather detection should be left to automatic modes.
- When Autotilt or Multiscan is not available, manually set the tilt so as to have ground returns at the top of the ND. This setting ensures an optimized scanning of the weather ahead of the aircraft.
- **Adjust gain, tilt and ND range to the flight phase.** Refer to FOBN quoted below.
- Pay attention when reading weather on ND with Autotilt. Ground returns could be confused with heavy rains.
- **Make the decision to avoid a large thunderstorm at least 40 NM away from the thunderstorm.**

- **Avoid cells laterally rather than vertically.** Severe turbulence may occur above the cell (i.e. turbulence dome) and below the cell (i.e. downdraft/updraft with heavy precipitations).
- **Avoid thunderstorms on the upwind side.** Hazards (hail, gust front, new cells) develop on the downwind side.
- **Avoid all cells with green or stronger (including turbulent areas – magenta) returns by at least 20 NM above FL 230 (10 NM below FL 230). This distance should be increased by 50% if the cell presents a specific shape** (see Figure 5-26 to Figure 5-67). Cumulonimbus should be cleared by at least 20 NM laterally and 5000 ft vertically.
- **Pay attention to cells with specific shapes** (finger, U-shape, hook, scalloped edges, etc) **or with fast changing shapes**. They usually indicate high turbulence, severe hail or strong vertical drafts.
- **PM: Monitor long-range weather (above 80 NM) for long-term avoidance strategy. PF: Monitor short-range weather (below 80 NM) for tactical weather avoidance.** Refer to Figure 5-68.
- **On A350/A380 aircraft, Be aware of the mechanism involved in the generation of the vertical terrain view** (e.g. along flight plan, along track, along selected azimuth, atmospheric influences on barometric elevations)
- Refer to FCTM "Aircraft systems/Weather Radar" for more recommendations.

5.1.2.2. WIND SHEAR

5.1.2.2.1. FOR THE AIRLINE

- **Operate the weather radar with PWS.** Wind shears were the root cause of several fatal accidents.
- **Develop Standard Operating Procedures (SOP) that emphasize awareness, recognition, avoidance and recovery of wind shears.**
- **Train your flight crews to recognize and avoid wind shears, and to apply recovery technique.** The Wind Shear Training Aid developed by the industry and other materials about wind shears are available at www.ntis.gov.

NOTE:

EASA published information on weather information for Pilots: refer to "Weather Information to Pilots" available on EASA website https://www.easa.europa.eu/easa-and-you/air-operations/weather-information-pilots

5.1.2.2.2. FOR THE FLIGHT CREW

- Report any encountered wind shear to ATC.

Take-off

- **Departure briefing:** consider most recent weather reports and forecast, visual observations, and crew experience on airport to build up your wind shear awareness.
- **Consider a delay of the take-off if wind shears are suspected.**
- If wind shears are suspected, adapt the aircraft configuration (minimum required slats/flaps configuration, maximum take-off thrust) to maximize the climb performances.
- Before the take-off run, check with the weather radar that the flight path is clear of meteorological hazards.
- **Monitor the airspeed and speed trend** during the take-off run to detect any occurrences of wind shear.
- **In case of wind shear, apply the recovery technique without delay.** Refer to your FCOM.
- Refer to FCTM "Aircraft systems/Weather Radar" for more recommendations.

Descent and approach

- **Approach briefing:** consider most recent weather reports and forecast, visual observations, and crew experience on airport to build up your wind shear awareness.
- **Consider a delay of the approach and landing** until conditions improve **or divert to a suitable airport** when wind shears are reported by other pilots from other aircraft or by ATC.
- During the approach, check with the weather radar that the flight path is clear of meteorological hazards.
- **Monitor the airspeed and speed trend** during the approach to detect any occurrences of wind shear.
- **In case of wind shear, abort the approach and apply the recovery technique without delay.** Refer to your FCOM.

5.1.3. REGULATIONS FOR WEATHER RADAR

The interpretation of regulations in this paragraph is limited to AIRBUS aircraft at the time of writing this brochure.

The carriage of weather radar is recommended in all ICAO member States as per **ICAO Annex 6 – Operation of Aircraft Part I**

"6.11 **Recommendation**.— Pressurized aeroplanes when carrying passengers should be equipped with operative weather radar whenever such aeroplanes are being operated in areas where thunderstorms or other potentially hazardous weather conditions, regarded as detectable with airborne weather radar, may be expected to exist along the route either at night or under instrument meteorological conditions."

The carriage of forward looking wind shear warning system is recommended in all ICAO member States as per **ICAO Annex 6 – Operation of Aircraft Part I:**

"6.21.1 Recommendation.— All turbo-jet aeroplanes of a maximum certificated take-off mass in excess of 5 700 kg or authorized to carry more than nine passengers should be equipped with a forward-looking wind shear warning system."

Weather radar

- **As per EASA AIR OPS ((EU) 965/2012) CAT.IDE.160:**

The following shall be equipped with airborne weather detecting equipment when operated at night or in IMC in areas where thunderstorms or other potentially hazardous weather conditions, regarded as detectable with airborne weather detecting equipment, may be expected to exist along the route:

(a) pressurised aeroplanes;

(b) non-pressurised aeroplanes with an MCTOM of more than 5 700 kg; and

(c) non-pressurised aeroplanes with an MOPSC of more than nine.

- **As per FAA FAR 121.357:** The weather radar is required for any transport aircraft, except during training, test, or ferry flight, and when the aircraft is solely operated in areas listed in FAR 121.357 (d) (e.g. Hawaii, Alaska).

Wind Shear

- **As per EASA AIR OPS ((EU) 965/2012),** no requirement has been found about wind shear warning and detection.
- **As per FAA FAR 121.358:** from 02 JAN 91, an approved airborne wind shear warning and flight guidance system (Reactive Wind Shear), an approved airborne wind shear detection and avoidance system (Predictive Wind Shear), or an approved combination of these systems is required for any aircraft.

All AIRBUS aircraft models (except the former aircraft from the A300/A310 family) are fitted with the Reactive Wind Shear from the production line. The very first aircraft from the A300/A310 family aircraft is the A300-B2 certified in 1974. The A310 was certified in 1983 and the A300-600 in 1984. Regulations about wind shear systems appeared in 1991. Consequently, only the most recent A300/A310 family aircraft are fitted with the Reactive Wind Shear from the production line.

The Predictive Wind Shear is proposed as an option on all types of weather radar installed on AIRBUS aircraft.

5.1.4. MANUFACTURERS FOR WEATHER RADAR

To fulfill the weather awareness function on A300/A310/A320/A330/A340 aircraft, AIRBUS proposes the following four systems:

- The Honeywell RDR-4B capable of predictive wind shear and Autotilt
- The Honeywell RDR-4000 and AESS capable of predictive wind shear and 3D buffer and Weather Ahead function
- The Rockwell Collins WXR 701X

NOTE:

Definitions as per AC 25-12

"Airborne Wind Shear Warning and Flight Guidance System: a device or system which identifies the presence of a severe wind shear phenomena and provides the pilot with timely warning and adequate flight guidance for the following:

- Approach/Missed Approach: To permit the aircraft to be flown using the maximum performance capability available without inadvertent loss of control, stall, and without ground contact.
- Take-off and Climb-out: To permit the aircraft to be flown during the initial or subsequent climb segments using the maximum performance capability available without inadvertent loss of control or ground contact with excess energy still available."

"Airborne Wind Shear Detection and Avoidance System: a device or system which detects a potentially severe wind shear phenomena far enough in advance of the encounter in both the take-off/climb-out profile and the approach/landing profile to allow the pilot to successfully avoid the phenomena and thereby alleviate a flight hazard."

- The Rockwell Collins WXR-2100 V1 and V2 capable of predictive wind shear and Multiscan.
- The Rockwell Collins WXR-2100A capable of Weather Ahead function.

Refer to § 1.1.5.2 for the details of additional function depending on the equipment standard.

Figure 5-85 provides a simplified view of the weather radar architecture.

Figure 5-85: Weather Radar architecture

5.1.5. WAY FORWARD

Two axis are studied to enhance the display of weather data. The detection of new elements, or the complement with additional source of information:

- In addition to lightning or hails, the aircraft may be affected by ice crystals. A high concentration of ice crystals could block probes or lead to engine power loss. Airbus in FCTM (refer to section Aircraft systems/weather radar/Ice crystals) provides information and operational recommendations to avoid Ice crystals area or detect icing of the airframe in flight. To go further Airbus and WXR suppliers studies the possibility to detect and display of area with high concentration of ice crystals.
- The other axis of improvement will be to complement and extend current on-board weather radar data with other source such as uplinked weather data.

PLEASE BEAR IN MIND…

DESCRIPTION

Operating in the X-band frequency (9.3 GHz), the weather radar detects any wet meteorological phenomena (clouds, precipitations, turbulence). Therefore, Clear Air Turbulence are not detected, and a weak reflectivity does not necessarily mean that the area is safe (e.g. dry hail).

For A300/A310/A320/A330/A340 aircraft, weather radars from two manufacturers are available: Honeywell and Rockwell Collins.

For A350/A380 aircraft, Honeywell AESS weather radar is installed with vertical display on ND.

Basically the weather radars equipments propose the detection of weather, turbulence and wind shear.

The Honeywell RDR-4000 and AESS, and Rockwell Collins multiscan products introduced new optional features such as hail and lightning detection, or anticipate convective cells, or propose new automatic modes to display pertinent weather information depending on the phase of flight.

OPERATIONAL RECOMMENDATIONS

The main recommendations (but non exhaustive) are:

- An appropriate maintenance of all weather radar components including the radome
- An appropriate and recurrent training on weather radar
- **A sharp knowledge on how to interpret weather radar indications**
- **An anticipation of the weather ahead the aircraft** (take-off, cruise, approach)
- **Use automatic mode per default**
- Use of manual mode for analysis purposes.
- **A good preparation to abort a procedure (take-off or approach) in case of wind shear**
- **Do not fly into a thunderstorm.** Avoid flying above or below a thunderstorm.
- On A350/A380 aircraft, Be aware of the mechanism involved in the generation of the vertical terrain view.

Refer to 5.1.2 – Operational Recommendations for Weather Radar.

REGULATIONS

The carriage of a weather radar is recommended as per ICAO Annex 6 – Operation of Aircraft – Part I. In most countries, the weather radar is required considering that significant weather may be experienced in most flights. Refer to local regulations.

WAY FORWARD

- Two axis are studied to enhance the display of weather data. The detection of new element (ice crystals), or the complement with additional source of information (uplinked weather data).

5.2. REACTIVE WIND SHEAR

The phenomenon and difference with predictive wind shear is detailed in 5.1.1.1.3.

According to the aircraft model, the Reactive Wind Shear is supported by:

- On A300/A310 family aircraft: FAC,
- On A320 family aircraft: FAC,
- On A330/A340 family aircraft: FE part of FMGEC,
- On A340-500/600 aircraft: FE part of FMGEC,
- On A380 aircraft: PRIM,
- On A350 aircraft: PRIM.

The Severity Factor (SF) determines the severity of a wind shear.

$\mathbf{SF} = \mathbf{SF}_{\text{LONGITUNAL}} + \mathbf{SF}_{\text{VERTICAL}}$ with

$\mathbf{SF}_{\text{LONGITUNAL}}$ for longitudinal tail wind gradient

$\mathbf{SF}_{\text{VERTICAL}}$ for downward wind.

The Reactive Wind Shear triggers alerts when the estimated SF reaches a threshold. This threshold depends on the real aircraft energy. The lower the aircraft energy (or the higher the angle of attack), the lower the threshold for alerts.

The Reactive Wind Shear alerts are available in high lift configuration between 50 ft and 1300 ft RA.

WIND SHEAR, WIND SHEAR, WIND SHEAR

The red WIND SHEAR indication on PFD flashes.

Figure 5 86: Reactive Wind Shear warning on PFD

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APPENDIX A – WORLDWIDE ADS-B/TCAS IMPLEMENTATION

The deployment of operational mandates on surveillance topics is constantly progressing. Airbus developed a website to gather all known information from ICAO and local authorities' regulations. The CNS|ATM website is available on www.airbusworld.com in Flight operations section.

FIGURE A-1: Homepage of CNS|ATM website

The operational mandates and implementations are depicted in the "Implementation World Map" section with interactive links to the applicable regulations.

FIGURE A-2: implementation section of CNS|ATM website

This database is provided for information only, based on Airbus experience, enriched with customers feedbacks.

For more details, please refer to:

https://w3.airbus.com/crs/A233_Flight_Ops_GN60_Inst_Supp/CNS-ATM/eSite/index.html

NOTE:

The implementation of ADS-B operations may locally change. Refer to AIP for specific regional procedures.

APPENDIX B – ADS-B PHRASEOLOGY

The following table provides an overview of the ADS-B phraseology as per the ICAO Doc 4444 – PANS ATM chapter 12 (see References)

CIRCUMSTANCES	RADAR	ADS-B
12.4.1.10. Termination or Radar or ADS-B service	**RADAR SERVICE TERMINATED [DUE (reason)]** (instructions)	**IDENTIFICATION TERMINATED [DUE (reason)]** (instructions)
12.4.1.11. Radar or ADS-B equipment degradation	**SECONDARY RADAR OUT OF SERVICE** (appropriate information as necessary) **PRIMARY RADAR OUT OF SERVICE** (appropriate information as necessary)	**ADS-B OUT OF SERVICE** (appropriate information as necessary)
12.4.3.1. & 12.4.3.2. To request the capability of the SSR or ADS-B equipment	**ADVISE TRANSPONDER CAPABILITY**	**ADVISE ADS-B CAPABILITY**
To advise the capability of the SSR or ADS-B equipment	**TRANSPONDER (ALPHA, CHARLIE or SIERRA as shown in the flight plan) NEGATIVE TRANSPONDER**	**ADS-B TRANSMITTER (data link*);** **ADS-B RECEIVER (data link*)** * As AIRBUS aircraft use the 1090 ES data link, TEN NINETY DATA LINK should be announced. **NEGATIVE ADS-B**
12.4.3.4. & 12.4.3.5. To request the pilot to reselect the assigned mode and code or the aircraft identification Read back	**RESET SQUAWK [(mode)] (code)** RESETTING (mode) (code)	**RE-ENTER [ADS-B or MODE S] AIRCRAFT IDENTIFICATION** **Note:** Not able to comply with some FMS standards. Refer to AIP for alternative procedures. Not defined
12.4.3.7. To request the operation of the IDENT feature	**SQUAWK [(code)] [AND] IDENT**	**TRANSMIT ADS-B IDENT** **Note:** Transponder and ADS-B transmitter are coupled on AIRBUS aircraft. Activate the IDENT function as in radar coverage.
12.4.3.10. To request the termination of transponder or ADS-B transmitter operation	**STOP SQUAWK [TRANSMIT ADS-B ONLY]**	STOP ADS-B TRANSMISSION [SQUAWK (code) ONLY]
	Note: Not able to comply with on AIRBUS aircraft. Refer to AIP for alternative procedures.	

CIRCUMSTANCES	RADAR	ADS-B
12.4.3.11. To request transmission of pressure-altitude	SQUAWK CHARLIE	**TRANSMIT ADS-B ALTITUDE** **Note:** Transponder and ADS-B transmitter are coupled on AIRBUS aircraft. Activate the altitude reporting as in radar coverage.
12.4.3.13. To request termination of pressure-altitude transmission because of faulty operation	**STOP SQUAWK CHARLIE WRONG INDICATION**	**STOP ADS-B ALTITUDE TRANSMISSION [(WRONG INDICATION, or reason)]** **Note:** Transponder and ADS-B transmitter are coupled on AIRBUS aircraft.

APPENDIX C – ATSAW IN TRAIL PROCEDURE (ITP)

This appendix provides details on ITP with the use of ATSAW. This appendix:

- Gives the definitions of terms commonly used for ITP
- Describes the ITP procedure in details
- Gives a practical example with cockpit interfaces.

The ITP description is compliant with standards published at the time of writing the brochure. The readers must ensure to take into account any updates of ITP standards.

C.1. DEFINITIONS

Ground Speed Differential	Difference of ground speed between the ITP aircraft and the Reference Aircraft. The ground speed differential is positive when aircraft are getting closer.
ITP Aircraft	Aircraft: - Fully qualified in terms of equipment, operator, and flight crew qualification to conduct an ITP That considers a flight level change.
ITP Criteria	Refer to C.2.6 – ITP Criteria.
ITP Distance	Refer to C.2.5 – ITP Distance.
ITP Volume	Refer to C.2.3 – ITP Volume.
Other Aircraft	Aircraft that are not either the ITP aircraft or the Reference Aircraft.
Qualified ADS-B data	ADS-B data that meet accuracy and integrity requirements for ITP.

Reference Aircraft	One or two aircraft in the ITP volume but not at the desired flight level: - With qualified ADS-B data - That meet the ITP criteria - That will be identified to ATC by the ITP Aircraft in the ITP clearance request.
Same Direction	Refer toC.2.2 – Aircraft on the Same Direction.

C.2. PROCEDURE

C.2.1. ITP SEQUENCE

1. **To initiate an ITP maneuver,** the flight crew must check that the **ITP criteria** (refer to C.2.6 – ITP Criteria) are met. The ITP criteria ensure that the ITP Aircraft and the Reference Aircraft do not get closer than the **ITP separation minimum** (10 NM).

Figure C-1: ITP separation minimum

2. **When the ITP criteria are met,** the flight crew may request an ITP clearance. The ITP request contains the identification of the Reference Aircraft and the range to these aircraft. The ATC controller checks that conditions are met to maintain safe separations between ITP and Reference Aircraft.
3. When these conditions are met, the ATC controller may deliver the clearance.
4. **When the ATC clearance is received**, the flight crew must re-check that the ITP speed/distance criteria are still met before initiating the ITP maneuver.

The ATC controller remains responsible for the aircraft separations. Therefore, the flight crew is not required to monitor the separations with the Reference Aircraft during the ITP maneuver.

Figure C-2: Same direction

C.2.2. AIRCRAFT ON THE SAME DIRECTION

The definition of the term Same Direction is derived from the term Same Track given in ICAO PANS-ATM, Doc 4444 (see References).

Aircraft are on a same direction when the difference of track angles is:

- Less than 45°, or
- More than 315°.

Refer to Figure C - 2.

C.2.3. ITP VOLUME

The ITP criteria apply to aircraft that are in the ITP volume. The ITP volume is centered on the ITP Aircraft and defined as follows:

- **Height: 4 000 ft** above the aircraft in climb or below the aircraft in descent.
- **Length: 160 NM**. It is equal to procedural longitudinal separations (10 min or 80 NM) behind and ahead of the aircraft.
- **Width: 40 NM**. This width ensures that aircraft on parallel tracks are excluded of the ITP process (e.g. when lateral separations of 30 NM are applied).

Figure C-3: ITP volume

Figure C-3 illustrates the ITP volume for an ITP climb.

The ITP maneuver is vertically limited to 4 000 ft (+ 4 000 ft in climb, - 4 000 ft in descent). Therefore, Reference Aircraft may be between 1 000 and 3 000 ft above (in climb) or below (in descent) the cruise flight level. Refer to Figure C - 4.

Figure C-4: Side view of ITP volume

C.2.4. ITP GEOMETRIES

The maximum number of Reference Aircraft is limited to two. Reference Aircraft are at any flight levels between the initial and the desired flight levels. The following illustrations describe some ITP geometries. Other geometries refer to two Reference Aircraft that are both behind or both ahead of the ITP Aircraft.

Figure C-5: ITP geometries

C.2.5. ITP DISTANCE

The **ITP distance** is the difference of distance to a common point along tracks of ITP and Reference Aircraft. Refer to Figure C - 6. Figure C - 7 provides the calculation methods of the ITP distance for different geometries. For more details, refer to ICAO PANS-ATM, Doc 4444, Chapter 5 – Separations Methods and Minima (see References).

The **ADS-B distance** computed thanks to ADS-B information is the distance between the GPS positions of both aircraft.

The **TCAS range** is the distance computed by TCAS between the current aircraft positions.

Figure C-6: ITP distance

Figure C-7: ITP distances with different geometries

C.2.6. ITP CRITERIA

To ensure that the ITP Aircraft and the Reference Aircraft do not get closer than the ITP separation minimum (10 NM), the following conditions must be met.

CRITERIA	CHECKED BY
1. **A maximum of two Reference Aircraft** are in the ITP volume.	ATSAW
2. Reference Aircraft must send qualified **ADS-B data** (refer to 2.2.1.4.3 – Combination of TCAS and ADS-B Information).	ATSAW
3. **The requested flight level must be within 4 000 ft** from the initial flight level.	ATSAW
4.The ITP distance and the positive ground speed differential must meet the criterion 4.a) or 4.b) below.	ATSAW

	ITP distance	Positive GS differential
4.a)	Greater than 15 NM	Less than 20 kt
4.b)	Greater than 20 NM	Less than 30 kt

5. The ITP Aircraft must be climb or descent at **300 ft/min minimum** or any higher rate as required by the appropriate authority.	Flight crew
6. The ITP Aircraft must be capable to **maintain its assigned Mach number** during the ITP maneuver.	Flight crew
7. The ITP and Reference Aircraft must be **on the same direction.**	ATSAW and ATC controller
8. The ITP Aircraft must not be a Reference Aircraft in another ITP clearance.	ATC controller
9.The **positive Mach differential is less than 0.04.**	ATC controller
10. **Procedural separations are met with Other Aircraft** at all flight levels between the CRZ FL and the desired FL (inclusive).	ATC controller
11. **Reference Aircraft must not maneuver** (i.e. change of speed, flight level or direction) during the ITP maneuver. A change of heading to remain on the same route as the ITP Aircraft is not considered as a maneuver. A change of Reference Aircraft speed that does not increase the positive Mach differential is not considered as a maneuver.	ATC controller

In Figure C-4, the ITP Aircraft is:

- Able to make a climb AHEAD OF. The ITP distance exceeds the minimum
- Not able to make a descent BEHIND. The ITP distance is less than required.

C.3. EXAMPLE

The following sections describe the ITP step by step from a cockpit perspective. In any cases, refer to AIP.

C.3.1. PF: CHECK THE AIRCRAFT PERFORMANCES

When the flight crew decides a FL change, PF checks the aircraft performances on MCDU FMS PROG page.

When the aircraft is below the REC MAX FL, the aircraft is able to:

- Climb at 300 ft/min minimum
- Maintain its speed during the climb.

Figure C-8: MCDU PROG page

C.3.2. PF: INITIATE THE ITP

In the MCDU MENU, PF selects TRAF (LSK 5R in Figure C – 9) to display the TRAFFIC LIST page. In the TRAFFIC LIST page, PF selects IN TRAIL PROCEDURE (LSK 5R in Figure C – 10) to display the ITP TRAFFIC LIST page.

In the ITP TRAFFIC LIST, PF enters the desired FL in the DESIRED FL field (LSK 1L in Figure C - 11).

Figure C-9: Select TRAF in MCDU MENU

Figure C-10: Select IN TRAIL PROCEDURE

Figure C-11: Enter desired FL in LSK 1L

C.3.3. PF: CHECK THE ITP OPPORTUNITY AND IDENTIFY REFERENCE AIRCRAFT

When PF entered the desired FL, the ATSAW function (refer to Figure C - 12):

- Checks that the ITP criteria are met as in C.2.6 – ITP Criteria
- Indicates if the ITP is possible or not (LSK 1R).
- Displays the aircraft in the ITP volume.

PF checks the ITP opportunity (possible or not and time) and identifies the Reference Aircraft in the ITP Traffic List (ITP distance, relative position, and flight number).

Figure C-12: Check the ITP opportunity and identify Reference Aircraft

C.3.4. PM: REQUEST THE ATC CLEARANCE

PF informs PM that ITP is possible and indicates the Reference Aircraft (ITP distance, position, and flight number).

PM requests an ITP clearance to ATC by CPDLC. PNF applies a specific phraseology in the CPDLC message.

Figure C-13: Enter desired FL in the CPDLC vertical request

It is recommended to edit the free text as follows (refer to Figure C - 15):

- **LSK 1L:** ITP
- **LSK 2L:** The ITP distance/relative position/flight number of the first Reference Aircraft
- **LSK 3L:** The ITP distance/relative position/flight number of the second Reference Aircraft (if any).

This method provides a clear view of entered data and permits the flight crew to rapidly check and/or correct one line.

Figure C-14: Go directly to the 2nd TEXT page with the SLEW keys (←→)

Figure C-15: Enter ITP data and transfer the message to DCDU

Figure C-16: Send the message from DCDU

The flight crew applies the usual procedures relative to CPDLC (e.g. cross-check, efficient management of DCDU). **For more details on CPDLC, refer to Getting to Grips with FANS** (see Airbus References.).

NOTE 1:

following CRISTAL ITP evaluations ICAO published guidelines for ITP phraseologie in Circular 325. Figure C-16 uses the suggested ITP phraseology. Note that the ITP Traffic list displays the information in the same sequence as in the suggested ITP phraseology (i.e. ITP distance/relative position/flight number, see Figure C-12 and Figure C-16).

NOTE 2:

The CRISTAL ITP consortium(refer to C.5 – CRISTAL ITP) considers CPDLC as more efficient than HF voice to request an ITP clearance for the following reasons:

- CPDLC is faster than HF voice in terms of transmission time.
- CPDLC prevents errors that could occur with the poor transmission quality of HF voice, especially for the transmission of flight numbers.
- CPDLC is a Direct Controller-Pilot Communication (DCPC) media.

C.3.5. PF: PERFORM THE ITP

When the flight crew receives the ITP clearance (refer to Figure C-17), PF must re-check that the ITP is still possible in the ITP TRAFFIC LIST page (refer to Figure C-12). PF re-checks:

- Aircraft performances
- Green ITP POSSIBLE in the ITP TRAFFIC LIST page.

If ITP is still possible, PM accepts (i.e. WILCO) the ITP clearance by CPDLC. If a report level instruction is included in the ITP clearance, the ATSU monitors the aircraft FL (refer to Figure C-18).

Then, PF starts the ITP maneuver without delay. The aircraft must:

- Climb at 300 ft/min minimum or any higher rate as required by the appropriate authority
- Maintain its assigned Mach number.

Figure C-17: ITP clearance

Figure C-18: Accept the clearance

When the aircraft engages the ITP maneuver and is more than 300 ft from the initial FL, the ATSAW function displays the message VERTICAL MANEUVER IN PROGRESS in the ITP TRAFFIC LIST page (refer to Figure C - 19). The ATSU triggers a report level message when the FL in the report level instruction is reached (refer to Figure C - 20).

Figure C-19: ITP TRAFFIC LIST page during the ITP maneuver

Figure C-20: Report level

NOTE 1:

If ITP is no more possible when the flight crew receives the ITP clearance, the flight crew must refuse the ITP clearance.

NOTE 2:

If a problem occurs during the ITP maneuver, the flight crew must apply the regional contingency procedures as required.

C.3.6. SPECIFIC CASES

When there is no Reference Aircraft in the ITP volume (refer to Figure C-21), the ATSAW function indicates that:

- The ITP is not applicable
- The flight crew should request a standard clearance.

The ATSAW function displays in the MCDU scratchpad the flight level and the range of:

- An aircraft (ADS-B or not) that is at the desired FL in the ITP volume, or
- An ADS-B aircraft that is not on the same direction in the ITP volume..

However, the ATSAW function may display “ITP POSSIBLE” despite the non-ADS-B aircraft. Indeed, the ATSAW function considers only ADS-B traffic to declare the ITP possible or not possible.

The ATC controller remains responsible for the aircraft separation during an ITP maneuver, for the following reasons:

- Some aircraft may not be equipped with an ADS-B OUT transmitter. Therefore, the ATSAW function is not able to detect all surrounding aircraft. Consequently, only the ATC controller has the knowledge of the entire traffic.
- The initial ATSAW function is not designed for self-separation.

Figure C-21: ITP not applicable

Figure C-22: Non-ADS-B aircraft in the ITP volume

C.4. OPERATIONAL ENVIRONMENT

ITP can be applied in theory in any RVSM / Non-RVSM airspace where procedural control is used. Conditions for operational approval include controller training to ITP. For the procedure to provide the expected benefits, a non exhaustive list of conditions are provided below:

- Separation standards with minima greater than 15 NM,
- Sufficient number of ADS-B OUT equipped aircraft
- Aircraft usually following similar routes (e.g. North Atlantic Organized Track System).

C.5. CRISTAL ITP

CRISTAL ITP is a consortium with AIRBUS, Alticode, Eurocontrol, ISAVIA (Icelandic ANSP) and NATS (UK ANSP). The objective of CRISTAL ITP is to validate ITP. In March 2008, CRISTAL ITP performed a successful flight test with an SAS commercial flight and an AIRBUS test aircraft. During the flight test, the AIRBUS test aircraft performed different ITP maneuvers around the SAS aircraft. The flight test occurred in the Reykjavik airspace under radar coverage to ensure safe separations.

Based on CRISTAL ITP and ICAO SASP group feedback, ICAO issued the "Circular on In-Trail Procedure (ITP) using Automatic Dependent Surveillance -Broadcast (ADS-B) (Cir 325) to amend PANS-ATM (ICAO Doc 4444).

APPENDIX D - ATSAW VISUAL SEPARATION ON APPROACH (VSA)

D.1. PROCEDURE

With the introduction of ATSAW in the VSA procedure, the distinction is made between three types of VSA procedure:

- **The current VSA procedure without ATSAW**
- **The basic VSA procedure with ATSAW** slightly modifies the flight crew procedure. The ATC controller does not distinguish aircraft equipped with ATSAW from aircraft not equipped with ATSAW. Therefore, the ATC controller procedure is not modified. The flight crew uses ATSAW to visually acquire the preceding aircraft and to maintain the visual separation.
- **The advanced VSA procedure with ATSAW** modifies the flight crew and ATC controller procedures. With a new phraseology, the flight crew informs the ATC controller that the preceding aircraft is identified with ATSAW but not yet visually acquired out the window. Consequently, the ATC controller is not required to update the traffic information until the visual contact by the flight crew.

ATSAW significantly improves the VSA procedure by providing the following parameters:

- The position and orientation of surrounding aircraft
- The flight identification of surrounding aircraft that can be correlated with ATC transmissions
- The ground speed of surrounding aircraft that help anticipating sudden deceleration of the preceding aircraft.

The following sections describe the VSA procedure as per the three types above.

The VSA procedure contains three steps:

1. The visual acquisition of the preceding aircraft
2. The clearance for maintaining the visual separation with the preceding aircraft
3. The maintenance of visual separation on approach with the preceding aircraft.

D.1.1. VISUAL ACQUISITION OF THE PRECEDING AIRCRAFT

CURRENT VSA PROCEDURE **BASIC VSA PROCEDURE** *(Green italic is specific to the basic procedure)*	**ADVANCED VSA PROCEDURE** *(Blue italic is specific to the enhanced procedure)*
(Amber italic is specific to the basic and advanced procedure)	
INITIATION BY THE ATC CONTROLLER	
• The ATC controller provides the flight crew with traffic information on the preceding aircraft. • The flight crew looks out the window to visually acquire the preceding aircraft. • *The flight crew looks at the ND with the traffic display enabled (refer to 3.6.5.1.1 – TRAF ON/OFF) to detect the preceding aircraft.* **Visual contact** • *The flight crew checks the consistency between the visual contact, the ATSAW traffic information, and the ATC traffic information.*	
• The flight crew informs the ATC controller that the preceding aircraft is in sight (i.e. TRAFFIC IN SIGHT). Go to the next step.	*The flight crew informs the ATC controller that the preceding aircraft with its flight number displayed on ND is in sight (e.g. TRAFFIC AIB1234 IN SIGHT[1]).* *The ATC controller checks the consistency between the flight number of the preceding aircraft provided by the flight crew and the one on the surveillance display.* • *If the flight numbers are consistent, **go to the next step.*** • *If the flight numbers are not consistent, the ATC controller informs the flight crew that the flight number is not correct and provides the traffic information again.*

1 It means that the traffic is identified on ND thanks to ATSAW but the visual contact is not established. At the time of writing the brochure, this new phraseology was not yet validated. ICAO recommendations on this new phraseology will be published in the ICAO PANS-ATM, Doc 4444 (see References).

CURRENT VSA PROCEDURE BASIC VSA PROCEDURE *(Green italic is specific to the basic procedure)*	ADVANCED VSA PROCEDURE *(Blue italic is specific to the enhanced procedure)*
(Amber italic is specific to the basic and advanced procedure)	
• **No visual contact** - The flight crew reports to the ATC controller that they continue to search the preceding aircraft (i.e. LOOKING OUT) - The flight crew asks the ATC controller for traffic information updates if the visual contact is not quickly achieved *- When the preceding is finally in sight, the flight crew checks the consistency between the visual contact, the ATSAW traffic information, and the ATC traffic information.*	*• If the preceding aircraft is on ND, the flight crew* *- Informs the ATC controller that the preceding aircraft is identified on ND (e.g. LOOKING OUT AIB1234[2])* *- Continues to search the preceding aircraft with the support of the ATSAW traffic information.* *• The ATC controller checks the consistency between the flight number of the preceding aircraft provided by the flight crew and the one on the surveillance display:* *- If the flight numbers are consistent, the ATC controller waits the flight crew reports the traffic in sight.* *- If the flight numbers are not consistent, the ATC controller informs the flight crew that the flight number is not correct and provides the traffic information again.*
• The flight crew informs the ATC controller that the preceding aircraft is finally in sight. **Go to the next step.**	
INITIATION BY THE FLIGHT CREW	
The flight crew achieves a visual contact with the preceding aircraft with visual information, *ATSAW traffic information,* and party line (transmissions from the controller and other flight crews on the frequency). • *When the preceding is in sight, the flight crew checks the consistency between the visual contact and the ATSAW traffic information.* • If the visual contact can be maintained, the flight crew: - Informs the ATC controller that the preceding aircraft *with its flight number displayed on ND* is in sight *(e.g. PRECEDING TRAFFIC AIB1234 IN SIGHT).* - Requests a clearance for VSA procedure. Go to the next step.	

2 At the time of writing the brochure, this new phraseology was not yet validated. ICAO recommendations on this new phraseology will be published in the ICAO PANS-ATM, Doc 4444 (see References).

D.1.2. CLEARANCE FOR THE MAINTENANCE OF THE VISUAL SEPARATION WITH THE PRECEDING AIRCRAFT

CURRENT VSA PROCEDURE **BASIC VSA PROCEDURE** *(Green italic is specific to the basic procedure)*	**ADVANCED VSA PROCEDURE** *(Blue italic is specific to the enhanced procedure)*
(Amber italic is specific to the basic and advanced procedure)	
• The ATC controller clears the flight crew: - To maintain a visual separation with the preceding aircraft - If needed, to continue on a visual approach. •The flight crew accepts or refuses the clearance. *The flight crew can better assess the ATC clearance with ATSAW.* • If the flight crew accepts the clearance, **go to the next step**.	

D.1.3. MAINTENANCE OF VISUAL SEPARATION ON APPROACH

CURRENT VSA PROCEDURE **BASIC VSA PROCEDURE** *(Green italic is specific to the basic procedure)*	**ADVANCED VSA PROCEDURE** *(Blue italic is specific to the enhanced procedure)*
(Amber italic is specific to the basic and advanced procedure)	
• The flight crew: - Flies the approach *- Looks at the preceding aircraft on ND with the traffic display enabled.* - Looks at the preceding aircraft out the window - Decides if a maneuver is required based on visual information *or ATSAW traffic information* - Maneuvers the aircraft if required to maintain the visual separation. • The VSA procedures ends when the preceding aircraft lands. • If the visual contact is lost or the flight crew considers that the situation becomes unsafe; the flight crew: - Interrupts the approach - Executes a missed approach - Informs the ATC controller.	

When a maneuver is required, the flight crew may adjust the speed or heading to maintain an appropriate distance behind the preceding aircraft.

D.2. OPERATIONAL ENVIRONMENT

- Approach under radar surveillance down to the ground
- Ground surveillance with one SSR and one PSR
- Communication between the flight crews and controllers via VHF voice
- Traffic density from low to high
- All types of runway configuration (e.g. single, independent parallel, dependent parallel, etc)
- Approach in VMC only
- Preceding aircraft capable of ADS-B OUT.

APPENDIX E – NUC, NAC, NIC, SIL

The following table provides an overview of NUC/NAC/NIC/SIL values used in ADS-B transmissions. **It must be seen as for information only.** For specification purposes, refer to appropriate documents.

NUC_P	INTEGRITY	ACCURACY
0	--	--
1	HPL < 20 NM	HFOM < 10 NM
2	HPL < 10 NM	HFOM < 5 NM
3	HPL < 2 NM	HFOM < 1 NM
4	HPL < 1 NM	HFOM < 0.5 NM
5	HPL < 0.5 NM	HFOM < 0.25 NM
6	HPL < 0.2 NM	HFOM < 0.1 NM
7	HPL < 0.1 NM	HFOM < 0.05 NM
8		HFOM < 10 m, VFOM < 15 m
9		HFOM < 3 m, VFOM < 4 m

SIL	PROBABILITY OF EXCEEDING CONTAINMENT BOUNDS FOR NIC WITHOUT BEING NOTIFIED
0	(No Integrity)
1	< 10-3 per flight hour
2	< 10-5 per flight hour
3	< 10-7 per flight hour

NIC	INTEGRITY CONTAINMENT LIMITS
0	--
1	RC < 20 NM
2	RC < 8 NM
3	RC < 4 NM
4	RC < 2 NM
5	RC < 1 NM
6	RC < 0.6 NM
7	RC < 0.2 NM
8	RC < 0.1 NM
9	RC < 75 m
10	RC < 25 m
11	RC < 7.5 m

NAC_P	ACCURACY
0	--
1	EPU < 10 NM
2	EPU < 4 NM
3	EPU < 2 NM
4	EPU < 1 NM
5	EPU < 0.5 NM
6	EPU < 0.3 NM
7	EPU < 0.1 NM
8	EPU < 0.05 NM
9	EPU < 30 m, VFOM < 45 m
10	EPU < 10 m, VFOM < 15 m
11	EPU < 3 m, VFOM < 4 m

MESSAGE TYPE CODES	NUCP	NAC	NIC	SIL
0	0	0 HFOM>=10NM	0 RC < 20 NM	0
5	9	11 HFOM<3m	11 RC < 7.5m	2
6	8	10 HFOM<10m	10 RC < 25m	2
7	7	8 HFOM<0.05NM	8 RC < 0.1NM	2
8	6	0 HFOM>=0.05NM	0 RC >= 0.1NM	0
9	9	11 HFOM<3m	11 RC < 7.5m	2
10	8	10 HFOM<10m	10 RC < 25m	2
11	7	8 HFOM<0.05NM	8 RC < 0.1NM	2
12	6	7 HFOM<0.1NM	7 RC < 0.2NM	2
13	5	6 HFOM<0.3NM	11 RC < 0.5NM	2
14	4	5 HFOM<0.5NM	10 RC < 1NM	2
15	3	4 HFOM<1NM	8 RC < 2NM	2
16	2	1 HFOM<10NM	1 RC < 8NM	2

MESSAGE TYPE CODES	NUCP	NAC	NIC	SIL
17	1	1 HFOM<10NM	1 RC < 20NM	2
18	0	0 HFOM>=10NM	0 RC >= 2NM	0
20	9	11 HFOM<3m VFOM<4m	11 RC < 7.5m	2
21	8	10 HFOM<10m VFOM<15m	10 RC < 25m	2

Figure E-1: correspondence table between version zero transmitting system (NUCp) and version one or above receiving system (NIC/NAC/SIL)

APPENDIX F – IDENTIFICATION OF AN AIRCRAFT

The following table lists the designation of the different codes used for the identification of an aircraft in the ICAO literature and in AIRBUS cockpit.

ICAO	AIRBUS	EXAMPLES
Aircraft Identification Up to 7 characters, it is: • The registration marking of the aircraft when: - In radiotelephony the call sign used by the aircraft will consist of this identification alone or preceded by the ICAO telephony designator for the aircraft operating agency; - The aircraft is not equipped with radio. • The ICAO designator for the aircraft operating agency followed by the flight identification when in radiotelephony the call sign used by the aircraft will consist of the ICAO telephony designator for the operating agency followed by the flight identification.	Flight Number entered into the FM INIT A page.	F-OHAP AIB1234
Flight identification	Numerical part of the flight number (up to 4 characters).	1234
	Airline ID is the IATA 2-letter code. Used for data link.	AU

ICAO	AIRBUS	EXAMPLES
	Flight ID Airline ID followed by the flight identification (up to 6 characters). Used for data link.	AU1234
Registration Marking It is the tail number.	Aircraft Registration Number (ARN) Used for data link.	F-WWOW
Aircraft Address A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.	ICAO Code (data link) or Mode S address (transponder)	380338 (hexadecimal format)
Call Sign ICAO telephony designator for the operating agency followed by the flight identification.		"AIRBUS ONE TWO THREE FOUR" for AIB1234
ICAO telephony designator for the operating agency Designator defined in ICAO Doc 8585.		"AIRBUS" for AIRBUS

Recommendations for the use of radiotelephony call signs are provided in ICAO Annex 10, Volume II, Chapter 5 (see References). ICAO designators and telephony designators for aircraft operating agencies are listed in ICAO Doc 8585 — Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services (see References).

APPENDIX G – AVIATION METEOROLOGY REMINDERS

This appendix provides some reminders about aviation meteorology. For further details, please refer to typical aviation meteorology courses.

G.1. STANDARD ATMOSPHERE

The figure below illustrates the different layers of the atmosphere and the variation of standard temperature with altitude. Interesting clouds for transport aviation are in the Troposphere.

However, specific clouds may form in the Stratosphere (nacreous clouds also called mother-of-pearl clouds), and in the Ionosphere (noctilucent clouds or NLC). Auroras also appear in the Ionosphere. The top of a cumulonimbus may penetrate the Tropopause due to the inertia of a rapid expansion.

Figure G-1: Standard atmosphere

Below 0°C, super-cooled water may coexist with ice crystals. Below -40°C, there are only ice crystals.

G.2. THUNDERSTORMS

G.2.1. FORMATION

The thunderstorm is a cumulonimbus that develops up to a stage with an anvil top. However, a cumulonimbus may have all the dangerous characteristics of a thunderstorm (i.e. lightnings, hail, turbulence).

The development of a thunderstorm results from the conjunction of two conditions:

- **A global shearing of the atmosphere**, as wind speed generally increases with altitude. That wind gradient is enhanced by earth friction, but less by sea friction
- **An airmass of high humidity at lower levels.** It is a fact of physics that humid air is more unstable than dry air. Note that the maximum water content of an airmass increases very rapidly with temperature.

When those two conditions are met, vertical instability develops. Thunderstorm activity is enhanced by very small changes in the conditions surrounding the system:

- A colder airmass arriving at high altitude
- The system passes over an area gradually heated by the sunshine
- Some orographic effect.

Under such conditions, the development of a thunderstorm may be extremely rapid, even at a visible pace. One may have blue sky in the morning, a severe thunderstorm in the afternoon and dissipating clouds at sunset, which makes the weather forecast difficult to interpretate. A thunderstorm often develops up to the tropopause altitude, sometimes above.

Other characteristics:

- Most thunderstorms have a life cycle associated with the duration of sun radiation.
- Sea thunderstorms are less severe (less wind gradient and lower surface temperature).
- Winter thunderstorms often top at altitudes lower than the summer ones (colder airmass, therefore less water, hence less instability).

G.2.2. SINGLE CELL

A single cell thunderstorm is the result of a single updraft. This kind of thunderstorms is rare. A single cell may have a life cycle above one hour, because of its high instability.

G.2.3. MULTI-CELL THUNDERSTORMS

Multi-cell thunderstorms are more common. Each thunderstorm is at different formation stage. The downdraft of one cell creates a gust front. This gust front provides the lifting mechanism for new cells. New cells will tend to form on the downwind side of existing cells.

RECOMMENDATION

As a general rule, Aircraft en route should avoid thunderstorms on the upwind side, if it can be detected.

In a regular atmosphere, the upwind side at the opposite of the anvil. The shape of the anvil is due to flattening of the cloud and normal wind increase at its altitude. Under such conditions, the upwind side is free from precipitations and turbulence at a relatively short distance from the cloud body side. But it may happen that wind direction changes at the level of the anvil, or the cell is stationary. Under those conditions, the recommended distance to fly from the cloud must be respected. But in all cases, avoid flying under the anvil. Severe precipitations, hail, icing, etc may exist, even at an FL supposed to be under -40°C.

G.2.4. SUPER CELL

The super cell is an example of diverging mechanism in atmospheric dynamics. If the airmass is very unstable up to a large altitude, vertical speeds are high. A very active convection cycle is triggered inside the cloud, which activates condensation and icing (step 1 of Figure G - 2). This puts dry air in contact with precipitations. Dry air is rapidly cooled. This super cold air is the origin of massive air falls, called downdraft and downbursts (step 2 of Figure G - 2).

A super cell thunderstorm can grow up to 10 NM horizontally and 60 000 ft vertically. Due to the powerful updraft, the top of the thunderstorm may deploy above the Tropopause (step 3 of Figure G - 2).

Figure G-2: Super cell development

The resulting anvil top deploys downwind and commonly produces hail. It can produce powerful updraft (more than 90 kt – 9 100 ft/min), surface winds (more than 70 kt), large hailstones (10 cm – 4 in), and tornadoes.

G.2.5. OCEANIC CELL

Oceanic cells contain less water than continental cells. Consequently, for equivalent height, oceanic cells are less massive and less reflective than continental cells.

G.2.6. SQUALL LINE

A squall line is a line of thunderstorms that form approximately 150 NM ahead of a cold front. It may extend on several hundred miles. Typical thunderstorm weather (heavy rain, hail, lightning, strong winds, tornadoes) may occur on a large area.

G.3. HAIL ENCOUNTER

Figure G-3 provides a rough order of magnitude of hail encounter probability with a mature thunderstorm. The probabilities may vary according to the current weather conditions.

The thunderstorm is vertically split into three thirds:

- The top third (ice crystals only) and the mid third present a high probability of hail encounter,
- The bottom third is the area of medium probability.

Figure G-3: Probability of hail encounter

Hail may also be encountered on the downwind side. This is the reason why aircraft should avoid thunderstorm on the upwind side.

G.4. TURBULENCE

The present paragraph briefly references the different kind of turbulence.

G.4.1. CLEAR AIR TURBULENCE (CAT)

CATs occur at any altitudes:

- At high altitudes in the shear of jet streams, or
- Any altitudes downstream of mountains, or
- Near areas with high vertical wind gradient.

Weather radars do not detect CATs because CATs do not contain water.

G.4.2. TURBULENCE DOME

Several thousand feet above the visible top of a thunderstorm, severe turbulence occurs.

G.4.3. THUNDERSTORM VAULT

The thunderstorm vault occurs when the airmass is unstable at high level only and the lower air is too dry to feed the convection. Most of the unstability is trapped in the upper part of the thunderstorm. Consequently, there are very little precipitations. Contrary to a common thunderstorm structure, the bottom part of the thunderstorm is less reflective than the upper part, or even not visible on radar display. Refer to Error! Reference source not found..

G.4.4. DOWNDRAFT

The downdraft is a movement of cool air induced by the precipitation of water droplets. When the downdraft hits the ground, it spreads out in all directions.

If the thunderstorm is stationary, the resulting gust front will be more or less circular, centered on the downdraft.

If the thunderstorm moves, the resulting gust front precedes the thunderstorm: the gust front is downwind. Refer to G.4.6 – Gust Front.

Figure G-4: Downdraft development

G.4.5. DOWNBURST

The downburst is a powerful downdraft that can induce significant damages on the ground (e.g. felled trees). Horizontal winds from downburst may be as high as 100 kt.

- The **macroburst** is a downburst on a horizontal extent of more than 4 km.
- The **microburst** is a powerful downburst on a horizontal extent of less than 4 km. It can be either dry or wet:
  - A dry microburst occurs with little or no precipitation when reaching the ground. The dry microburst is the result of an evaporation of rain in a dry air. The rain that evaporates cools the air. The cool air descends and accelerates as it approaches the ground. The visible signs of a dry microburst are:

- A cumulus or cumulonimbus with virga (precipitation that evaporates before reaching the ground),
- A ring of blowing dust on the ground, beneath the virga.

- A wet microburst occurs with moderate or heavy precipitation on the ground. The wet microburst forms with the drag of precipitations. The visible sign of wet microburst is a “rain foot” (prominence of precipitation) forming near the ground.

RECOMMENDATIONS

As a general rule, when flying at low altitude near airports, pay a lot of care in presence of thunderstorms. The risk of downdraft or downburst is present all around the cloud, but especially in the direction the cell moves (approaching thunderstorm). The onset of associated turbulence may be extremely abrupt. Windshear procedures must be applied without delay. At ground level, the gust front may appear in a fraction of a second and have enough energy to damage an aircraft sitting on ground.

G.4.6. GUST FRONT

A gust front is the result of a thunderstorm downdraft hitting the ground and spreading out on the ground surface. Gust fronts may produce severe turbulence, and generally spread out downwind.

G.4.7. WIND SHEAR

The wind shear is a variation of wind in speed and/or direction on a short distance. It is a well-known cause of fatal accidents during take-off or landing. However, there are several types of wind shears with different levels of danger.

There are several causes for wind shears. The main ones are the following:

- Downburst: It causes the most dangerous wind shear for aircraft as the wind shear presents a significant wind speed difference, and occurs at low levels during take-off and landing.
- Wind around obstacles: A steady wind that blows on obstacles (buildings, mountain ranges, extensive forests, etc) becomes turbulent and induces wind shears.
- Wind associated with frontal surfaces: When a cold air mass slips beneath a warmer air mass (clod air is denser than warm air), the contact of air masses defines the frontal surface. At frontal surfaces, there are wind velocity discontinuities (i.e. wind shears) due to the dynamics of the frontal system (different air densities, temperatures, displacement of air masses).
- Front of sea breezes: Sea breeze appears due to the different temperatures over the land and sea. The front of the sea breeze induces wind shears when it encounters average surface winds.
- Wake vortices: Wake vortices are a kind of wind shear. They may induce severe turbulence when the encounter occurs at a certain distance behind the generating aircraft.
- Radiation inversion and low-level jet streams: At night with fair weather conditions, the land may cool down faster than the air above. There is a heat transfer from the warm air to the cool ground. A radiation inversion occurs: the temperature increases with height. The height of a radiation inversion is approximately 100 m and goes up to 1 km. Surface winds tend to be light or calm. When a low level jet stream passes over a radiation inversion area, wind shears appear.

G.4.8. NON-REFLECTIVE WEATHER

Small cumulus clouds may not content enough water. Weather radars may not detect them due to their weak reflectivity. Nevertheless, this kind of clouds may produce light to moderate turbulence.

The turbulence is due to the alternation of updrafts that form the clouds and downdrafts between the clouds.

Figure G-5: Turbulence due to cumulus

APPENDIX H – LOW LEVEL WIND SHEAR EFFECTS ON AIRCRAFT PERFORMANCES

This appendix provides a summary of wind shear effects on aircraft performances at low level. For a more detailed analysis of these effects, refer to the ICAO Manual on Low Level Wind Shear and Turbulence, Doc 9817 (see References).

H.1. HORIZONTAL WIND SHEARS

There are two kinds of horizontal wind shears: longitudinal wind shears and crosswind shears. As runways are aligned on dominant winds, the most frequent wind shears encountered at low levels are longitudinal. Nevertheless, crosswind shears have some significant effects on the aircraft flight path.

Wind shears affect the aircraft in a transient way. They affect the airspeed, the altitude, the angle of attack or the drift depending on their direction (longitudinal, lateral, or vertical). The initial effects of wind shear are the ones that mostly affect aircraft performances.

H.1.1. LONGITUDINAL WIND SHEARS

Figure H-1: Equilibrium of aerodynamic forces

The equilibrium of aerodynamic forces illustrated in Figure H- 1 assumes that:

- The flight is straight (no turn) and is not accelerating
- The thrust is along the flight path.

γ is the angle of climb/descent.

Figure H-2: Resultant flight path vector – Decreasing headwind/Increasing tailwind

Figure H-2 illustrates the initial effect (resultant flight path vector R) due to the transient decrease of airspeed following a decreasing headwind or an increasing tailwind, until the aircraft reaches a new equilibrium.

Figure H-3: Resultant flight path vector – Increasing headwind/Decreasing tailwind

Figure H-3 illustrates the initial effect (resultant flight path vector R) due to the transient increase of airspeed following an increasing headwind or a decreasing tailwind, until the aircraft reaches a new equilibrium.

Considering the transient effect of wind shears on airspeed, an increasing headwind is equivalent to a decreasing tailwind, and vice-versa.

When the aircraft passes the wind shear, the aircraft naturally returns to equilibrium thanks to its longitudinal stability. However, the flight crew must often take the controls to avoid the aircraft starting phugoid oscillations (airspeed and height oscillations with a period of approximately 40 seconds).

Figure H-4 illustrates the effects of longitudinal wind shears on the flight path at take-off and landing.

H.1.2. CROSSWIND SHEARS

The initial effect of a crosswind shear affects the drift and the sideslip angles, without any initial effects about airspeed and altitude. When the aircraft encounters a crosswind shear, the aircraft:

- Yaws towards the shear
- Rolls away from the shear
- Drifts away from the nominal flight path (see Figure H-5).

Figure H-4: Effects of longitudinal wind shears on flight path

Figure H-5: Effect of crosswind shears on flight path

H.2. VERTICAL WIND SHEARS

H.2.1. EFFECT ON ANGLE OF ATTACK

Figure H-6: Wing aerofoil view – Vertical wind shear effect

In a level flight, the airflow hits the wing horizontally. When the aircraft flies in a downdraft or updraft, the resultant airflow (i.e. nominal airflow + downdraft/updraft) hits the wing with an angle to the horizontal. This angle depends of the airspeed and the velocity of the downdraft or updraft. The pitch attitude remains unchanged.

The initial effect of a downdraft is then a transient reduction of the Angle Of Attack (AOA) that leads to a transient lift reduction. On the contrary, the initial effect of an updraft is a transient increase of the AOA that leads to a transient lift increase.

As a consequence, the initial effect of a downdraft on the flight path is the same as the one with a decreasing headwind or increasing tailwind (see Figure I - 4). And the initial effect of an updraft is the same as the one with an increasing headwind or decreasing tailwind.

When the aircraft passes the vertical wind shear, the aircraft naturally returns to equilibrium thanks to its longitudinal stability. Without any pilot actions, pitch oscillations may occur with a period of approximately 5 seconds.

H.2.2. DOWNBURST EFFECTS

A downburst is a powerful downdraft produced by a thunderstorm. As it approaches the ground, the downburst splits in all directions.

Figure H-7: Downburst effect

Figure H-8: Downburst side view

Figure H - 7 and Figure H - 8 illustrate the effects of downburst on the flight path assuming that the downburst is centered on the glide path. Effects of vertical wind shears on AOA and of longitudinal wind shears are combined.

When the downburst is centered on the glide path, the effects of the downburst are sequenced in three steps:

1. The aircraft encounters an increasing headwind. The aircraft flies above the glide path (See Figure H - 4).
2. The aircraft comes into the center of the downburst and encounters a vertical wind shear. In a downburst, the AOA and then the lift are reduced. The aircraft passes below the glide path (See Figure H - 4).
3. The aircraft encounters an increasing tailwind. The lift increases; the aircraft may regain or overshoot the glide path according to the magnitude of the tailwind (See Figure H - 4).

A downburst centered on the glide path is the worst wind shear case when ap-

proaching the runway. Indeed, the aircraft encounters wind shears in opposite directions along the flight path plus a downdraft.

When the downburst is not centered on the glide path, the aircraft encounters less critical but non-negligible effects: airspeed, drift, and descent rate vary. See situations 1 and 2 of Figure H - 9.

Figure H - 9: Downburst effect – Top view

EFFECTS	DOWNBURST POSITION VS. AIRCRAFT			SITUATION
Airspeed	Increasing		Decreasing	1
Drift	Increasing Left	Increasing Left	Decreasing Left	
Descent rate	Decreasing		Increasing	
Airspeed	Increasing		Decreasing	2
Drift	N/A		N/A	
Descent rate	Decreasing		Increasing	
Airspeed	Increasing		Decreasing	3
Drift	Increasing Right	Increasing Right	Decreasing Right	
Descent rate	Decreasing		Increasing	

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