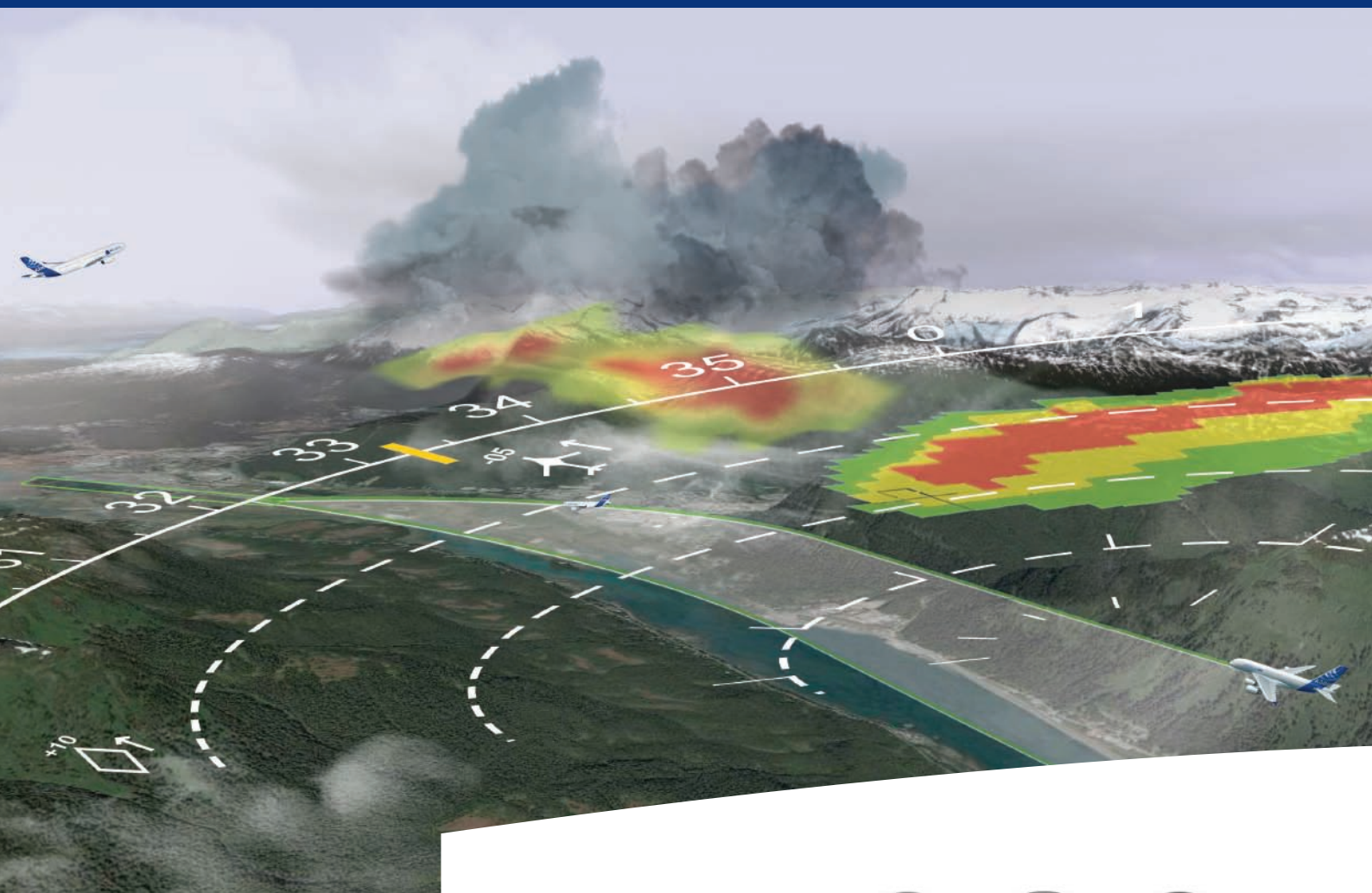




getting to grips with surveillance

Issue I - May 2009



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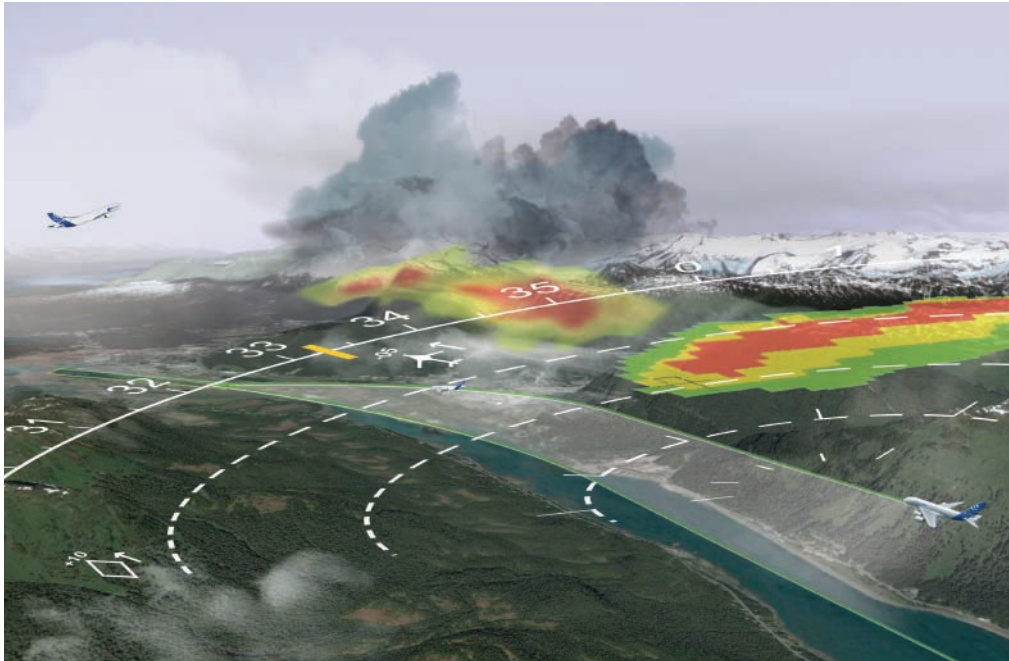
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FOREWORD

The present brochure describes the surveillance in the broad sense of the term, from an airborne system perspective. It covers existing systems (e.g. transponder, TCAS, TAWS, etc) as well as emerging systems (e.g. AESS, ATSAW, etc) and new technologies (e.g. ADS-B).

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

The contents of this Getting to Grips brochure are not subject to Airworthiness Authority approval. Therefore, this brochure neither supersedes the requirements mandated by the State in which the operator's aircraft is registered, nor does it supersede the contents of other approved documentation (e.g. AFM, MEL, etc). If any contradiction exists between this brochure and local/national authority regulations (or other approved documentation), the latter applies.

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EXECUTIVE SUMMARY

1. INTRODUCTION

Safety of air transportation relies on three pillars: Communication, Navigation and Surveillance. Surveillance provides the flight crew with awareness and alerts regarding external hazards (traffic, terrain, weather). With the air transportation increase, Surveillance became of prime importance. The definition of Surveillance is a question of perspective: flight crew's perspective or air traffic controller's perspective. From the flight crew's perspective, Surveillance has been distributed among several systems (transponder, TCAS, TAWS, etc). From the air traffic controller's perspective, Surveillance mainly relies on ground receivers (e.g. radar) and on aircraft transponders.

The goals of this brochure are 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.

To these ends, the brochure is split into 5 main chapters that describe the main surveillance functions:

1. **The Aircraft Identification and Position Reporting**
2. **The Traffic Surveillance**
3. **The Terrain Surveillance**
4. **The Weather Surveillance**
5. **The Runway Surveillance**

The chapter "Aircraft Identification and Position Reporting" focuses on Surveillance from an air traffic controller's perspective. Other chapters focus on Surveillance from the flight crew's perspective.

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

- T2CAS combines Traffic Surveillance and Terrain Surveillance.
- AESS combines all the functions above except the Runway Surveillance.

In each chapter, the reader will find:

- **A 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.
- **Future systems** expected in the near future to improve the fulfillment of the function.

2. AIRCRAFT IDENTIFICATION AND POSITION REPORTING

Transponder

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: the **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):

- **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.

Transponders proposed on AIRBUS aircraft are all capable of Mode A/C/S, ELS/EHS, and ADS-B NRA. At the time of writing the brochure, definitions of standards for ADS-B RAD and 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**, even there are no impacts in the cockpit for the flight crew
- 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 **2.5 – 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.

Future Systems

At the time of writing the brochure, no new transponder is expected on a short term.

3. TRAFFIC SURVEILLANCE

Aircraft Collision Avoidance System – ACAS

Description

ACAS (or commonly named Traffic alert and Collision Avoidance System – **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 comply with TCAS II Change 7.0: ACSS TCAS 2000 or T2CAS, Rockwell Collins TTR 921, Honeywell TPA 100A. (P/N 940-0300-001). ACSS T3CAS and Honeywell TPA 100A (P/N 940-0351-001) complies 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 **3.2 – Operational Recommendations for TCAS**.

Regulations

The carriage of TCAS II is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I.

Future Systems

At the time of writing the brochure, no new TCAS is expected on a short term.

Airborne Traffic Situational Awareness – ATSAW

Description

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

ATSAW applications are: **ATSA AIRB**, **ATSA VSA**, **ATSA ITP**, ATSA SURF (not yet available).

TCAS computer capable of ATSAW on AIRBUS aircraft are: new version of **Honeywell TPA 100B** (early 2010) and **ACSS T3CAS** (early 2010).

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 **3.7 – Operational Recommendations for ATSAW**.

Regulations

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

Future Systems

To improve the Traffic Surveillance during taxi, AIRBUS is currently developing the integration of the ATSA SURF application in the OANS for all AIRBUS aircraft.

4. TERRAIN SURVEILLANCE

Enhanced Ground Proximity Warning System (EGPWS) or Terrain Awareness and Warning System (TAWS) of T2CAS

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 and Terrain Clearance Floor – TCF ,and Runway Field Clearance Floor (RFCF).
- **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.

Refer to **4.1.3.3 – EGPWS/T2CAS Comparison** to compare both 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.

Refer to **4.2 – Operational Recommendations for TAWS**.

Regulations

The carriage of TAWS is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I.

Future Systems

At the time of writing the brochure, no new TAWS computer is expected on a short term.

5. RUNWAY SURVEILLANCE

On-board Airport Navigation System – OANS

Description

The **On-board Airport Navigation System (OANS)** is a new system introduced by the A380. It improves the flight crew situational awareness during taxi by **locating the aircraft on an airport map**.

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.

Operational Recommendations

The main recommendations (but non exhaustive) are:

- **OANS is not a guidance tool**
- A regular update of OANS Airport Data Base (ADB)
- **The check of NOTAM before taxiing**
- **The correlation of OANS indications with outside visual references.**

Refer to **5.2 – Operational Recommendations for OANS**.

Regulations

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

Future Systems

The future evolutions of OANS are expected to be the integration of:

- The ADS-B data for Traffic Surveillance
- Data link applications to display NOTAM and ATC ground clearances.

Runway end Overrun Warning and Protection (ROW/ROP)

Description

The ROW and ROP functions help the flight crew anticipating an overrun of the runway end at landing. During the final approach, ROW provides aural and visual indications that invite the flight crew to consider a go around. On the runway, ROP provides aural and visual indications for the settings of thrust reversers. ROW/ROP improves the flight crew awareness regarding risks of runway end overrun.

ROW and ROP are optional functions and used in conjunction with OANS.

Operational Recommendations

The main recommendations (but non exhaustive) are:

- The correct understanding of ROW and ROP indications
- The proper disconnection of the auto brake.

Refer to 5.7 – Operational recommendations for ROW/ROP.

Regulations

At the time of writing the present brochure, no country has required the carriage of the ROW/ROP functions.

Future Systems

AIRBUS studies the extension of ROW/ROP to the manual braking mode.

Runway Awareness and Advisory System – RAAS

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 unable 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.

Future Systems

At the time of writing the present brochure, no evolutions are expected, from an AIRBUS perspective, for RAAS in terms on new functions.

6. WEATHER SURVEILLANCE

Weather Radar

Description

Operating in the X-band frequency (9.3 GHz), the weather radar detects any wet meteorological phenomena (clouds, precipitations, turbulence). Hence, **Clear Air Turbulence is 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, two manufacturers are proposed: **Honeywell (RDR-4B)** and **Rockwell Collins (WXR701X/2100)**. The automatic function (Autotilt for RDR-4B or Multiscan for WXR 2100) is optional.

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)
- Regular manual scans
- **Use of automatic mode** (Autotilt or Multiscan) when manual control is not necessary
- **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.

Refer to [6.2 – 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.

Future Systems

The Honeywell RDR 4000, already available on A380 aircraft, will introduce the benefits of the 3D weather scanning on A320/A330/A340 aircraft in 2010 such as:

- The automatic correction of the Earth curvature
- Automatic modes to display on-path and off-path weather
- The elevation mode.

7. AIRCRAFT ENVIRONMENT SURVEILLANCE

Aircraft Environment Surveillance System – AEES

Description

The AEES is an integrated surveillance system on A380 aircraft that includes the following: transponder, TCAS, TAWS and weather radar with PWS. The TAWS and the weather radar use the **Vertical Display (VD)** at best to enhance the flight crew awareness on terrain and weather.

Thus, the AEES is also able to display on VD the terrain and weather along the path followed by the aircraft (flight plan, track) or the azimuth selected by the flight crew. The weather radar also introduces, thanks to the 3D buffer, the **on-path and off-path weather concept**, the weather view at a selected altitude (elevation mode).

The AEES controls are distributed on the AEES Control Panel, the EFIS CP, the MFD SURV page and the RMP SQWK page.

Operational Recommendations

Operational recommendations regarding the AEES functions are the same as the ones provided for the elementary systems (i.e. XPDR, TCAS, TAWS, WXR). The VD introduces new logics and features. Therefore, **a special attention should be paid to mechanisms introduced by the VD.**

Refer to **7.2 – Operational Recommendations for AEES.**

Regulations

Regulations for the integrated AEES are the same as for elementary systems (i.e. XPDR, TCAS, TAWS, WXR).

Future Systems

To keep pace with the deployment of the ADS-B technology, the AEES is expected to implement the ATSAW application for an enhanced traffic awareness.

ABBREVIATIONS

A/C	Aircraft	AMI	Airline Modifiable Information
A/THR	Auto Thrust	AMM	Aircraft Maintenance Manual
ABV	Above	ANSP	Air Navigation Service Provider
AC	Advisory Circular	AOA	Angle Of Attack
ACAS	Aircraft Collision Avoidance System	AOC	Airline Operations Control
ACSS	Aviation Communication & Surveillance Systems	AP	Auto Pilot
ADB	Airport Data Base	ARN	Aircraft Registration Number
ADIRU	Air Data and Inertial Reference Unit	ASAS	Airborne Separation Assistance System
ADR	Air Data Reference	A-SMGCS	Advanced – Surface Movement Guidance and Control Systems
ADS	Automatic Dependent Surveillance	ATC	Air Traffic Control
ADS-B	Automatic Dependent Surveillance – Broadcast	ATCRBS	Air Traffic Control Radar Beacon System
ADS-C	Automatic Dependent Surveillance – Contract	ATS	Air Traffic Service
AESS	Aircraft Environment Surveillance System	ATSA or ATSAW	Airborne Traffic Situational Awareness
AESU	Aircraft Environment Surveillance Unit	ATSU	Air Traffic Service Unit
AFM	Aircraft Flight Manual	BCS	Braking Control System
AFS	Automatic Flight System	BLW	Below
AGL	Above Ground Level	BTV	Brake To Vacate
AIC	Aeronautical Information Circular	CAA	Civil Aviation Authority
AIP	Aeronautical Information Publication	CASA	Australian Civil Aviation Safety Authority
AIRB	Airborne	CASCADE	Co-operative ATS through Surveillance and Communication Applications Deployed in ECAC
ALA	Approach and Landing Accident	CAT	Clear Air Turbulence
ALAR	Approach and Landing Accident Reduction	CDTI	Cockpit Display of Traffic Information
ALT RPTG	Altitude Reporting	CFIT	Controlled Flight Into
AMC	Acceptable Means of Compliance		
AMDB	Airport Mapping Data Base		

	Terrain	ELS	Mode S Elementary Surveillance
CMV	Concentrator and Multiplexer for Video	EMMA2	European airport Movement and Management by A-SMGCS
CNS / ATM	Communication Navigation Surveillance / Air Traffic Management	EPE	Estimated Position Error
CPA	Closest Point of Approach (ACAS)	EPU	Estimated Position Uncertainty
CPA	Collision Prediction and Alerting (TAWS)	EWD	Engine and Warning Display
CPDLC	Controller Pilot Data Link Communication	FAA	Federal Aviation Administration
CRISTAL	Co-operative Validation of Surveillance Techniques and Applications	FAC	Flight Augmentation Computer
CSD	Customer Service Director	FANS	Future Air Navigation Systems
DCDU	Datalink Control and Display Unit	FC	Flight Crew
DCPC	Direct Controller-Pilot Communication	FCOM	Flight Crew Operating Manual
DMC	Display Management Computer	FCU	Flight Control Unit
DME	Distance Measuring Equipment	FD	Flight Director
DSNA	Direction des Services de la Navigation Aérienne	FDE	Fault Detection and Exclusion
DU	Display Unit	FE	Flight Envelope
EASA	European Aviation Safety Agency	FLS	FMS Landing System
ECAC	European Civil Aviation Conference	FM	Flight Management
ECAM	Electronic Centralized Aircraft Monitoring	FMA	Flight Mode Annunciator
EFIS	Electronic Flight Instrument System	FMGEC	Flight Management Guidance and Envelope Computer
EFIS CP	EFIS Control Panel	FMS	Flight Management System
EGPWM	Enhanced Ground Proximity Warning Module	FOBN	Flight Operations Briefing Note
EGPWS	Enhanced Ground Proximity Warning System	FPA	Flight Path Angle
EHS	Mode S Enhanced Surveillance	FSF	Flight Safety Foundation
EIS	Electronic Instrument System	FWS	Flight Warning System
		G/S	Glide Slope
		GCAS	Ground Collision Avoidance System
		GCS	Ground Clutter

	Suppression		
GPIRS	Global Positioning and Inertial Reference System	MTCD	Minimum Terrain Clearance Distance
GPS	Global Positioning System	MTOW	Maximum Take Off Weight
GPS-SU	GPS Single Unit	NAC	Navigational Accuracy Category
GPWC	Ground Proximity Warning Computer	NAS	National Airspace System
GPWS	Ground Proximity Warning System	NASA	USA National Aeronautics and Space Administration
GS	Ground Speed	NATOTS	North Atlantic Organized Track System
HFOM	Horizontal Figure Of Merit	NATS	National Air Traffic Services (UK)
HIL	Horizontal Integrity Limit	ND	Navigation Display
HPL	Horizontal Protection Limit	NGATS or NextGen	Next Generation Air Transportation System (USA)
IAS	Indicated Air Speed	NIC	Navigational Integrity Category
ICAO	International Civil Aviation Organization	NLC	Noctilucent Cloud
ID	Identification	NOTAM	Notice To Air Men
IMC	Instrument Meteorological Conditions	NPRM	Notice of Proposed Rule Making
IR	Inertial Reference	NUC	Navigational Uncertainty Category
ITP	In Trail Procedure	OANS	On-board Airport Navigation System
KCCU	Keyboard and Cursor Control Unit	OIT	Operator Information Telex
LAHSO	Land And Hold Short Operations	OTS	Organized Track System
LDA	Landing Distance Available	P/N	Part Number
LDG	Landing	PAC	Path Attenuation Compensation
LGERS	Landing Gear Extension and Retraction System	PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management
LSK	Line Select Key	PANS-OPS	Procedures for Air Navigation Services – Operations
MAC	Mean Aerodynamic Chord	PANS-RAC	Procedures for Air Navigation Services – Rules of the Air and Air Traffic Services
MCDU	Multipurpose Control & Display Unit	PDA	Premature Descent Alert
MFD	Multi Function Display		
MMO	Maximum Operating Mach		
MMR	Multi-Mode Receiver		
MNPS	Minimum Navigation Performance Specification		
MSL	Mean Sea Level		

PF	Pilot Flying	SCP	Soft Control Panel
PFD	Primary Flight Display	SF	Severity Factor
PNF	Pilot Non Flying	SIL	Service Information Letter
PPOS	Present Position	SIL	Surveillance Integrity Level
PRIM	Primary Flight Control and Guidance Computer	SMR	Surface Movement Radar
PSR	Primary Surveillance Radar	SOP	Standard Operating Procedure
PWS	Predictive Wind Shear	SPI	Special Position Identification
R/T	Receiver / Transmitter	SPP	Soft Pin Programming
RA	Radio Altitude	SQWK	Squawk
RA	Resolution Advisory (ACAS)	SSR	Secondary Surveillance Radar
RAAS	Runway Awareness and Advisory System	STBY	Stand-By
RADAR	Radio Detection And Ranging	STC	Sensitivity Time Control
RAIM	Receiver Autonomous Integrity Monitoring	SURF	Surface
RCD	RAAS Configuration Database	T/TISS	Traffic and Terrain Integrated Surveillance System
RFCE	Runway Field Clearance Floor	T2CAS	Traffic and Terrain Collision Avoidance System
RMP	Radio Management Panel	TA	Traffic Advisory
RNP AR	Required Navigation Performance Authorization Required	TAAATS	The Australian Advanced Air Traffic System
ROP	Runway end Overrun Protection	TAU	<i>It is not an acronym but the Greek letter τ.</i>
ROT	Runway Occupancy Time	TAWS	Terrain Awareness and Warning System
ROW	Runway end Overrun Warning	TCAS	Traffic alert and Collision Avoidance System
RTO	Rejected Take Off	TCF	Terrain Clearance Floor
RVSM	Reduced Vertical Separation Minima	THD	Terrain Hazard Display
RWY	Runway	THRT	Threat
S&M	Sequencing and Merging	TIBA	Traffic Information Broadcasts by Aircraft
SA	Selective Availability	UAP	Upper Airspace Program (Australia)
SARPs	Standards And Recommended Practices	UAT	Universal Access Transceiver
SAT	Static Air Temperature		

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
WAM	Wide Area Multi-lateration
WGS84	World Geodetic System revised in 1984
WX	Weather
WXR	Weather Radar
XLS	Landing System (ILS, FLS, GLS)
XPDR	Transponder

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¹ Thanks to AIRBUS flight test campaign about wake vortices with modern measuring instruments, international standards about wake vortices are being reviewed.

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 - Edition #4, June 2007:
 - o **Do you know your ATC/TCAS panel?**
 - o **Managing hailstorms,**
 - o **Terrain Awareness and Warning Systems operations based on GPS data.**
 - Edition #7, February 2009: **Airbus AP/FD TCAS mode: a new step towards safety improvement.**
- REF 23 **AIRBUS Flight Operations Briefing Notes (FOBN)** on Airbus World at https://w3.airbus.com/crs/A233_Flight_Ops_GN60_Inst_Supp/FOBN/index01.htm via Flight Operations Community:
- **Human Performance:**
 - o **Effective Pilot/Controller Communications**, Rev 3, September 2004,
 - o **Enhancing Situational Awareness**, Rev 1, July 2007,
 - o **Visual Illusion Awareness**, Rev 2, September 2005.
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 - o **Optimum Use of the Weather Radar**, Rev 2, February 2007,
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 - **Supplementary Techniques:**
 - o **Use of Radio Altimeter**, Rev 3, December 2005,
 - o **Preventing Altitude Deviations/Level Busts**, Rev 2, May 2005.
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 - **Approach Techniques:**
 - o **Flying Stabilized Approaches**, Rev 2, October 2006,
 - o **Aircraft Energy Management during Approach**, Rev 2, October 2005.

- REF 24 **Service Information Letter (SIL)** on Airbus World at <https://services.airbus.com/ym01/SIL/firstscreenlayout.htm>:
- **Map Shift Events and EGPWS False Warning Associated**, 22-043, Rev 0, January 2005.
 - **"Terrain Awareness and Warning System" (TAWS) on AIRBUS Aircraft**, 34-080, Rev 8, December 2008.
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- **AIRBUS Policy Concerning The Use Of GPS Position For Terrain Awareness And Warning System (TAWS) Operations**, OIT 999.0015/04/VHR, February 2004.
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 - **Automatic Dependent Surveillance - Broadcast OUT (ADS-B OUT) via ATC Transponders on AIRBUS Aircraft**, OIT 999.0057/08/BB, June 2008.
- REF 26 **ADS-B OUT Capability Declaration** as referenced in your AFM. Contact your Customer Service Director (CSD) to get a copy.
- REF 27 **Getting to grips with FANS**, Issue III – April 2007 on Airbus World at https://w3.airbus.com/crs/A233_Flight_Ops_GN60_Inst_Supp/Portlet/safety_OED.htm via Flight Operations Community.

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1. 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 surveillance 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. This is the purpose of **Automatic Dependent Surveillance – Broadcast (ADS-B)**, **Airborne Traffic Situational Awareness (ATSAW)** applications, **Runway Awareness and Advisory System (RAAS)** and **On-board Airport Navigation System (OANS)**. 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.

1.1. WHAT IS SURVEILLANCE?

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

1.1.1. 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.

1.1.2. 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 **2 – Aircraft identification and position reporting** for more details.

1.2. 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, CBT). 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.

1.2.1. 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 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.

5. **The Runway Surveillance:** OANS displays the aircraft position on an airport map to improve the flight crew situational awareness. The ROW/ROP functions in conjunction with OANS provide warnings (visual and aural) and protection against runway end overruns. RAAS is a module of EGPWS and provides aural messages regarding the aircraft position on or out the runway.

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

- T2CAS combines Traffic Surveillance and Terrain Surveillance.
- T3CAS combines Aircraft Identification and Position Reporting, Traffic Surveillance, and Terrain Surveillance.
- AECS combines all the function above except the Runway Surveillance.

1.2.2. CHAPTER STRUCTURE

Each of the following chapters describes one of the six 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.
- **Future systems** 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.

1.2.3. CAPTIONS

Grey frames highlight summaries ***“Please bear in mind...”*** and important remarks.

Light brown frames highlight very important remarks.



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

Tips

Turquoise frames highlight operational tips.

Grey highlights identify interactive cross-references.

1.3. SYSTEM SUMMARY

The following table gives the functions and the related systems. The reader can click on the table to directly go to the corresponding page.

Click on a function or system name to jump to the appropriate page.

	Air-to-Ground	Air-to-Air			
Function	A/C Identification and Position Reporting	Traffic Surveillance	Terrain Surveillance	Weather Surveillance	Runway Surveillance
Existing systems	XPDR with Mode A, C or S	ACAS	TAWS	WX Radar ¹	RAAS
	XPDR with ADS-B			WX Radar with 3D buffer ²	
New systems		AP / FD TCAS			OANS
		ATSAW ³			ROW / ROP ⁴

Note: Some systems (i.e. T2CAS, T3CAS, AESS) combine different functions. Refer to [1.2.1 – Surveillance Systems and Functions](#).

¹ WX Radar takes into account Rockwell Collins Multiscan and Honeywell Autotilt.

² The Rockwell Collins Multiscan weather radar and the AESS use a 3D buffer.

³ ATSAW is a module of some TCAS computer.

⁴ ROW/ROP is used in conjunction with OANS.



2. AIRCRAFT IDENTIFICATION AND POSITION REPORTING

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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.

2.1. DESCRIPTION OF TRANSPONDER

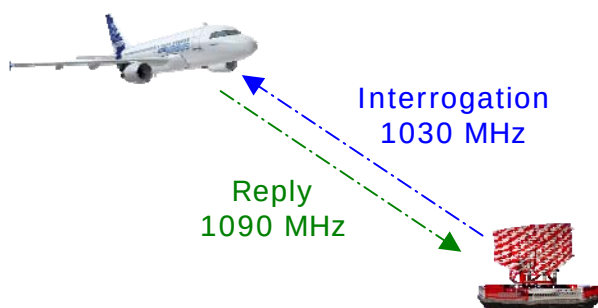


Figure 2-1: SSR interrogation and transponder reply

The aircraft identification and position reporting function requires a transponder onboard where a **Secondary Surveillance Radar (SSR¹)** 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 2-1). 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

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

- **Independent** as the SSR calculates the horizontal² 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.

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.

2.1.1. 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**.

2.1.2. MODE C

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

2.1.3. MODE S

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.

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

3. **Selective³ 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 **2.1.3.6 – 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)**:

- **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.

The Mode S lexicon

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

2.1.3.1. MODE S DATA LINK

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.

2.1.3.2. 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. |

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

³ Mode S stands for Selective.

2.1.3.4. GROUND INITIATED COMM B (GCIB)

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 2.1.3.8 – Extended Squitter) that transmit data without solicitation.

2.1.3.5. 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.

2.1.3.6. 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).

2.1.3.7. AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B)

ADS-B is a 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 2.4 – Aircraft identification and Position Reporting with FANS), ADS-B transmits surveillance data to the ATC ground station, without specific connection between the aircraft and the ATC ground station.

• ADS-B OUT

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 2.2 – 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.

- **ADS-B IN**

From the own aircraft perspective, ADS-B IN refers to the capability to acquire and to process 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 **3.6 – Description of ATSAW**.

2.1.3.8. 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.
- Aircraft identification, flight number, aircraft category, etc.
- GPS velocity, vertical rate, etc.

Notes:

- Refer to **2.2.4 – Generic Emergency Indicator** for details on the **surveillance status**.
- The **aircraft category** identifies several types of category: From “no reporting” to surface vehicle or space vehicle.

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 **3.1.2 – TCAS Principle**.

2.1.3.9. 1090 EXTENDED SQUITTER

The **1090 MHz Extended Squitter (1090 ES)** is the medium used to transmit ADS-B data. The reader may find other media to transmit ADS-B data:

- **Universal Access Transceiver (UAT):** FAA supports it for general aviation.
- **VHF Data Link Mode 4 (VDL 4):** The Swedish CAA supports VDL 4. However, as VDL 4 causes interferences with other onboard radio transmitters, AIRBUS does not support this medium.

2.1.4. 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 are still active.

Tips: 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, no TCAS information⁴ 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 3.1.4 – Collision Threat Evaluation.

For more details, please refer to your FCOM.

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 2-2 gives an example of ATC/TCAS panel. Other ATC/TCAS panels are illustrated at <http://www.gableseng.com/platform.asp>.

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 MODESTBY).



Figure 2-2: Example of ATC/TCAS panel

2.2. 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.

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

- 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 position⁵ 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 3.6 – 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.



Figure 2-3: Secondary Radar (left) and Primary Radar (right)



Figure 2-4: ADS-B ground receiver

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**. These new services are part of the European CASCADE program and will be deployed progressively over the European airspaces (refer to Appendix A – Worldwide ADS-B implementation). Similar programs are in progress in USA and Australia. The following sections describe the ADS-B services as per the European CASCADE program.

2.2.1. 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/pilotcentre/projects/adsb/adsbuap.asp>).

⁵ As a dependent surveillance method, ADS-B transmits the aircraft GPS position to the ground.

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.

For more details, please refer to

http://www.eurocontrol.int/cascade/public/standard_page/ads_b_nra.html.

EASA certified A320/A330/A340 aircraft at the beginning of 2008 and A380 aircraft at the end of 2007 eligible for ADS-B NRA operations. However, operators must obtain an operational approval from their Authorities before starting ADS-B NRA operations. Refer to **2.6.2 – Operational Approval of ADS-B OUT**.

2.2.2. 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.

Note: The European CASCADE program defines the ADS-B RAD service areas with high traffic density and the ADS-B NRA service for areas with low traffic density. Therefore, for the ADS-B RAD service, ATC ground stations will still use a minimum number of SSR as backup. The use of ADS-B ground receivers combined with a minimum number of SSR is more cost-effective than an exclusive set of SSR.

For more details, please refer to

http://www.eurocontrol.int/cascade/public/standard_page/RAD.html

At the time of writing the brochure, Eurocontrol and industrial partners work on standards for the provision of the ADS-B RAD service.

2.2.3. 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).

At the time of writing the brochure, Eurocontrol and industrial partners work on standards for the provision of the ADS-B APT service.

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.

2.2.4. 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.

2.2.5. 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:
 - o General emergency
 - o Communication failure
 - o Unlawful interference
- Urgency modes:
 - o Minimum fuel
 - o Medical.

Note: At the time of writing this brochure, only the ACSS XS 950 (P/N 751-7800-10100) and T3CAS are able to transmit the Discrete Emergency Code.

2.2.6. DO-260 AND DO-260A

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.

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. Appendix E – NUC, NAC, NIC, SIL provides the ranges of these values.

2.2.7. 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.

2.2.8. 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 and Version Number 1 to DO-260A. Version Number 2 is expected for DO-260B.

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

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.

2.2.10. 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)**⁶.

2.2.11. 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 2-5 illustrates a satellite geometry with:

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

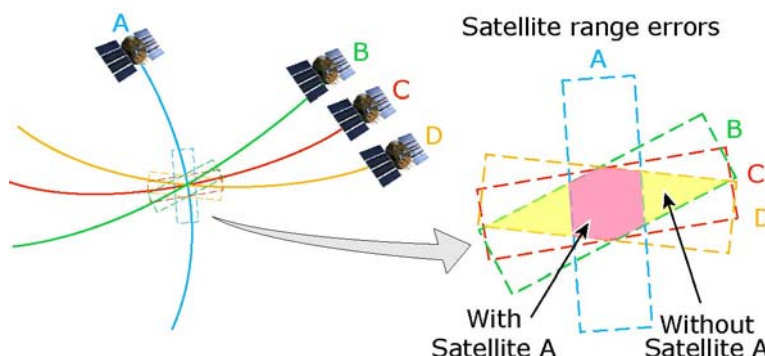


Figure 2-5: Accuracy (HFOM) vs. integrity (HPL)

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).

2.2.12. 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 after an announcement of the US president Bill Clinton.

⁶ It is different from the Estimated Position Error (EPE) calculated by FM computers. EPE is the drift of the FM position.

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. At the time of writing the brochure, Thalès MMR only is capable of SA Awareness function. Other GPS sensors installed on AIRBUS aircraft assume that SA is always on: the accuracy of the GPS position is always downgraded on a conservative basis.

2.2.13. NAVIGATIONAL UNCERTAINTY CATEGORY (NUC)

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

NUC_p may be derived from HFOM or HPL as per DO-260. However, as illustrated in Figure 2-5, it is preferable to derive NUC_p from HPL to take into account a potential satellite failure (as HFOM assumes there is no satellite failure). Transponders proposed on AIRBUS aircraft derive NUC_p from HPL first, then from HFOM if HPL is not available.

2.2.14. NAVIGATION INTEGRITY CATEGORY (NIC)

DO-260A 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.

2.2.15. NAVIGATIONAL ACCURACY CATEGORY (NAC)

The DO-260A 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.

NAC_p is relative to the position and NAC_v to the velocity.

2.2.16. SURVEILLANCE INTEGRITY LEVEL (SIL)

SIL is the probability that the current position is outside the circle defined by NIC.

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

Figure 2-6 illustrates the differences between HFOM, HPL, NIC, NAC, and SIL.

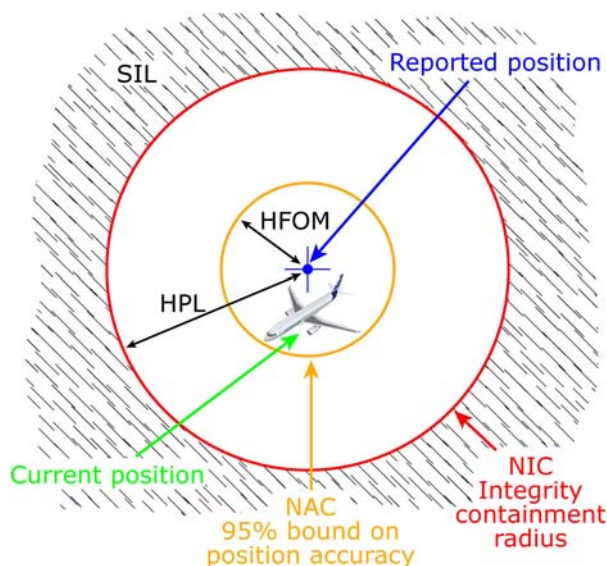


Figure 2-6: NIC, NAC, SIL

2.2.17. 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, 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.

In ADS-B operations, the flight crew uses the same controls of the ATC/TCAS panel for the transmission of the SQWK code⁷, IDENT (SPI), and the barometric altitude as in SSR operations (see Figure 2-2).

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.

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).

2.3. AIRCRAFT IDENTIFICATION AND POSITION REPORTING WITH WIDE AREA MULTILATERATION

As more and more new systems derived from the CNS/ATM concept⁸ 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

⁷ Only some transponders capable of ADS-B are capable to transmit the SQWK code. Refer to 2.2.6 – DO-260 and DO-260A.

⁸ Refer to Part I of the Getting to Grips with FANS, issue III, April 2007 for a description of the CNS/ATM concept.

antennas calculates the aircraft position from the **Time Difference Of Arrival (TDOA)** of the signal at the different ground antennas.

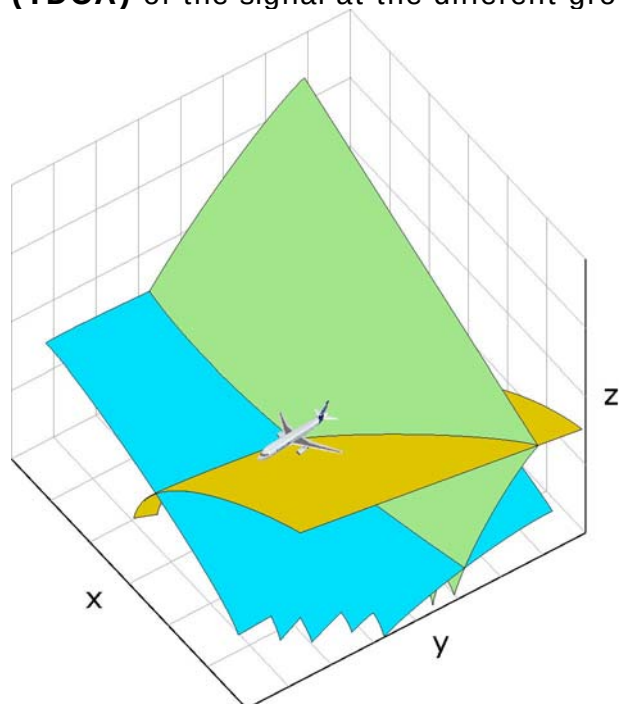


Figure 2-7: Intersection of hyperboloids

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.

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

http://www.eurocontrol.int/surveillance/public/standard_page/sur_WAMevent.htm | or to the **Wide Area Multi-lateration Report from the Dutch National Aerospace Laboratory (NLR)** (see **References**).

2.4. AIRCRAFT IDENTIFICATION AND POSITION REPORTING WITH FANS

FANS A/A+ systems (namely ATSU for A320/A330/A340 aircraft and ATC applications for A380 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 15 and 30 minutes. Therefore, the ATC controller cannot use ADS-C to provide the same separation as with SSR.



Nevertheless, ADS-C removes the requirement for tiring HF 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**).

2.5. OPERATIONAL RECOMMENDATIONS FOR TRANSPONDER

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.

2.5.1. CONVENTIONAL TRANSPONDER OPERATIONS

2.5.1.1. FOR THE AIRLINE

Refer to **3.2 – Operational Recommendations for TCAS**.

2.5.1.2. 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](#)).

2.5.2. ADS-B OPERATIONS

2.5.2.1. FOR THE AIRLINE

- **Make sure that your flight crews are familiar with ADS-B** (e.g. technology, phraseology, routine and emergency procedures as published in AIP, etc). 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.**
- **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 [2.6.2 – Operational Approval of ADS-B OUT](#).
- Refer to OIT 999.0057/08/BB (See [AIRBUS References](#)).

2.5.2.2. FOR THE FLIGHT CREW

- **Make sure that the flight number in the FMS INIT A page matches the flight number filled in the item 7 of the ICAO flight plan. Use ICAO format (i.e. three-letter code),** do not use IATA format (i.e. two-letter code). 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

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airborne. The capable FMS standard are the **Honeywell FMS2 P2** onwards and the **Thalès FMS2 Rev2** onwards.

- **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 “/D” in item 10.** “/D” designates the ADS capability (either ADS-C or ADS-B). Local Authorities may require the insertion of “RMK/ADS-B” in item 18 to clearly identify the ADS-B capability. Please refer to AIP.

Note: At the time of writing the brochure, ICAO has been reviewing the coding of equipment carried on-board, including ADS-B. The new codes are expected to be in force in 2012.

- **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. See also **2.2.5 – Discrete Emergency Codes** and **2.2.6 – DO-260 and DO-260A**.
- **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 **2.2.17 – 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.**

2.6. REGULATIONS FOR TRANSPONDER

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

2.6.1. 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 EU OPS 1.866, a transponder capable of Mode C is mandatory and other transponder capabilities may be required for the route being flown. At the time of writing this brochure, the carriage of **Mode S ELS transponder** is mandatory in the entire European airspace, and the carriage of **Mode S EHS transponder** is mandatory in the core area of Europe (i.e. Belgium, France, Germany, Luxembourg, The Netherlands, Switzerland and the United Kingdom) as per the **Eurocontrol Specimen AIC – Carriage and Operation of SSR Mode S Airborne Equipment in European Airspace** (see [References](#)). The mandate will be extended to the whole European airspace later on.

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

Note: TCAS compliant with TCAS II Change 7 requires a Mode S transponder for its functioning. Therefore, the mandatory carriage of TCAS (refer to [3.3 – Regulations for TCAS](#)) implies a mandatory carriage of a Mode S transponder.

2.6.2. 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 and the A380 aircraft. The AFM states the ADS-B NRA capability. At the time of writing the brochure, four circulars on ADS-B NRA airworthiness approval were identified (see [References](#)):

- The **European AMC 20-24** – Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application
- The **Australian AC 21-45** – Airworthiness Approval of Airborne Automatic Dependent Surveillance Broadcast Equipment
- The **Canadian AC 700-009** – Automatic Dependent Surveillance - Broadcast
- The **US NPRM** Automatic Dependent Surveillance—Broadcast (ADS-B) Out Performance Requirements to Support Air Traffic Control (ATC) Service.

Agreements between EASA, CASA Australia, Transport Canada 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. Consequently, A320/A330/A340/A380 aircraft, 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.

The FAA expects to release the final rule based on its NRPM by the end of 2009. It encompasses demanding ADS-B performance requirements for the 2020 milestone of the Surveillance and Broadcast Services program (refer to **Appendix A – Worldwide ADS-B implementation**). The NPRM aims at ADS-B RAD services. At the time of writing the brochure, a lot of discussions about the NPRM were in progress. Updated information will be provided in a timely manner.

Operators must obtain an operational approval before starting ADS-B NRA operations. Eurocontrol outlines some guidelines for the operational approval process at

http://www.eurocontrol.int/cascade/public/standard_page/guidelines.html

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 your Customer Service Director (CSD) to get a copy of this document.

2.7. MANUFACTURERS FOR TRANSPONDER

At the time of writing the brochure, three models of transponders are available on AIRBUS aircraft:

- ACSS XS 950, or
- Rockwell Collins TPR 901, or
- Honeywell TRA 67A.

Figure 2-8 provides a simplified view of the transponder architecture.

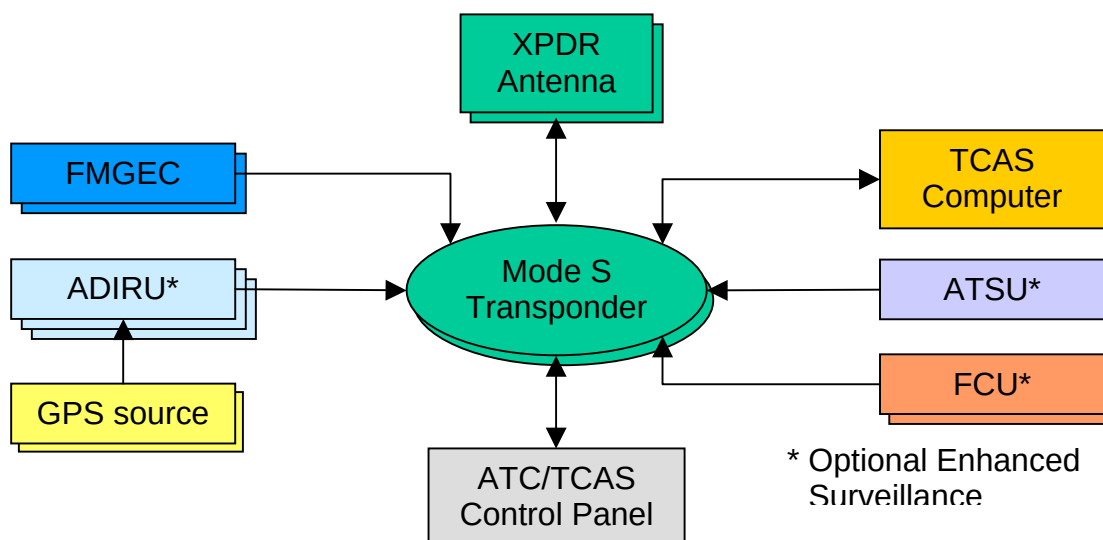


Figure 2-8: Transponder architecture

Note 1: The Mode S transponder must receive GPS data in order to broadcast ADS-B data. The GPS source is either a MMR or a GPS-SU. All MMRs installed on AIRBUS aircraft and Honeywell GPS-SU are compliant with ADS-B OUT requirements.

Note 2: The Mode S transponder gets pure 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).

2.7.1. ACSS XS 950

The ACSS XS 950 transponder (P/N 751-7800-10005) is compliant with DO-260 and the European AMC 20-24. The latest version of XS 950 (P/N 751-7800-10100) is compliant with DO-260A Change 2 and the European AMC 20-24. This latter transponder is directly linked to the GPS source in order to improve the ADS-B OUT performances (e.g. latency).

More information is available at <http://www.acssonboard.com/>.

2.7.2. TRANSPONDER PART OF ACSS T3CAS

The ACSS T3CAS is a further step of integration including:

- A Mode S transponder capable of ADS-B NRA as per DO-260A Change 2
- A TCAS II compliant with TCAS II Change 7.1
- An enhanced TAWS module derived from T2CAS TAWS module.

The advantages of this integration are the same as for T2CAS, a step further: reduced weight, volume, wiring, and power consumption.

The TCAS module and the Mode S transponder module share the same set of antennas, reducing weight and wirings.

The certification of the T3CAS is expected by end 2009. More information is available at <http://www.acssonboard.com/media/brochures/T3CAS.pdf>.

2.7.3. ROCKWELL COLLINS TPR 901

The Rockwell Collins TPR 901 is capable of ADS-B NRA as per DO-260.

More information is available at

<http://www.rockwellcollins.com/products/cs/at/avionics-systems/legacy-products/index.html>.

2.7.4. HONEYWELL TRA 67A

The Honeywell TRA 67 A is capable of ADS-B NRA as per DO-260.

More information is available at <http://www.honeywell.com/sites/aero/TCAS.htm>.

2.8. FUTURE SYSTEMS

At the time of writing the brochure, no new transponder is expected on a short term.

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, and ADS-B NRA. At the time of writing the brochure, definitions of standards for ADS-B RAD and 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).

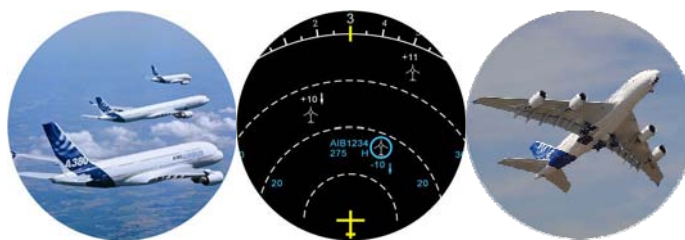
Refer to **2.5 – Operational Recommendations for Transponder**.

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.

Future systems

At the time of writing the brochure, no new transponder is expected on a short term.



3. 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.

Aircraft Collision Avoidance System - ACAS

3.1. 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 is a tool that assists the flight crew for the visual acquisition of surrounding aircraft. The flight crew must not use the TCAS for self-separation.

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.

3.1.1. 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.
- **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 7.0 since 2003 (since 2000 in Europe). At the time of writing the brochure, the TCAS II Change 7.1 was released. ICAO intends to mandate the TCAS II Change 7.1 from 2012 (refer to 3.1.6 – TCAS II Change 7.1).
- **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. Therefore, **TCAS refers to equipment compliant with TCAS II Change 7.0 for the remainder of the document, except when specified.**

3.1.2. 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.

¹¹ Both aircraft must be equipped with Mode S transponders for coordinated maneuvers.

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

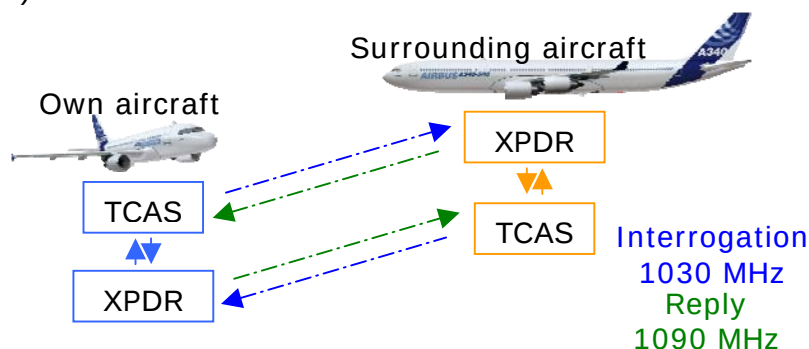


Figure 3-1: TCAS interrogation and transponder reply

- **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.**

3.1.2.1. 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:

1. Mode C interrogations to get altitudes of non-Mode S aircraft
2. Mode S interrogations to get altitudes of Mode S aircraft via selective calls
3. 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:

4. 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,
5. 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 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.

3.1.2.2. 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 TCAS function) simultaneously and displays the 8 most threatening aircraft.**

3.1.3. 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.

3.1.3.1. 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.

3.1.3.2. 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.

3.1.4. 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.

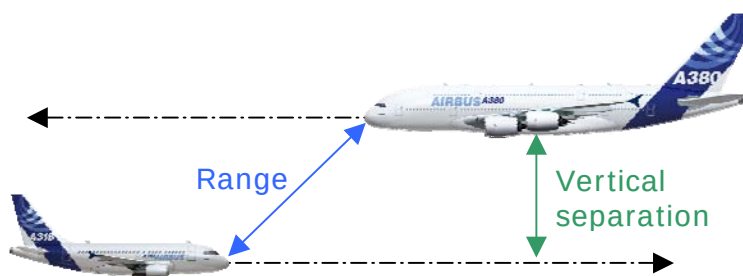


Figure 3-2: Vertical separation and range

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**.

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 3-3). The two criteria are:

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

3.1.4.1. 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.

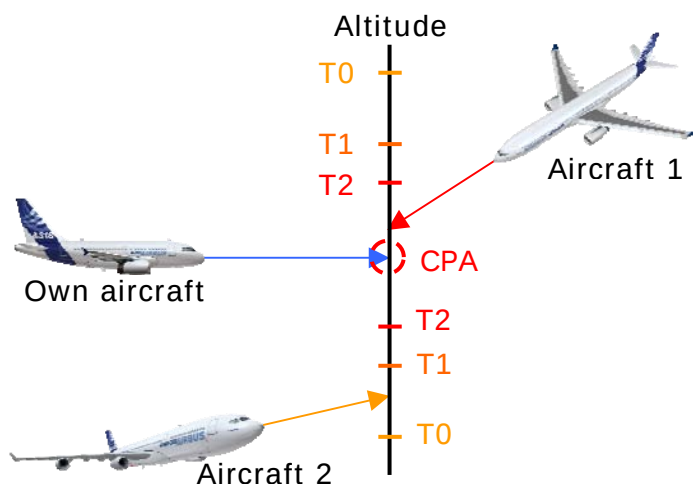


Figure 3-3: Closest Point of Approach (CPA)

Values of T0, T1 and T2 vary according to TAU values (refer to 3.1.4.2 – Time to Intercept (TAU)) and the sensitivity level (refer to 3.1.5 – TCAS Envelope).

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

3.1.4.2. 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.

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

³ TAU refers to the Greek letter τ .

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 3-4).

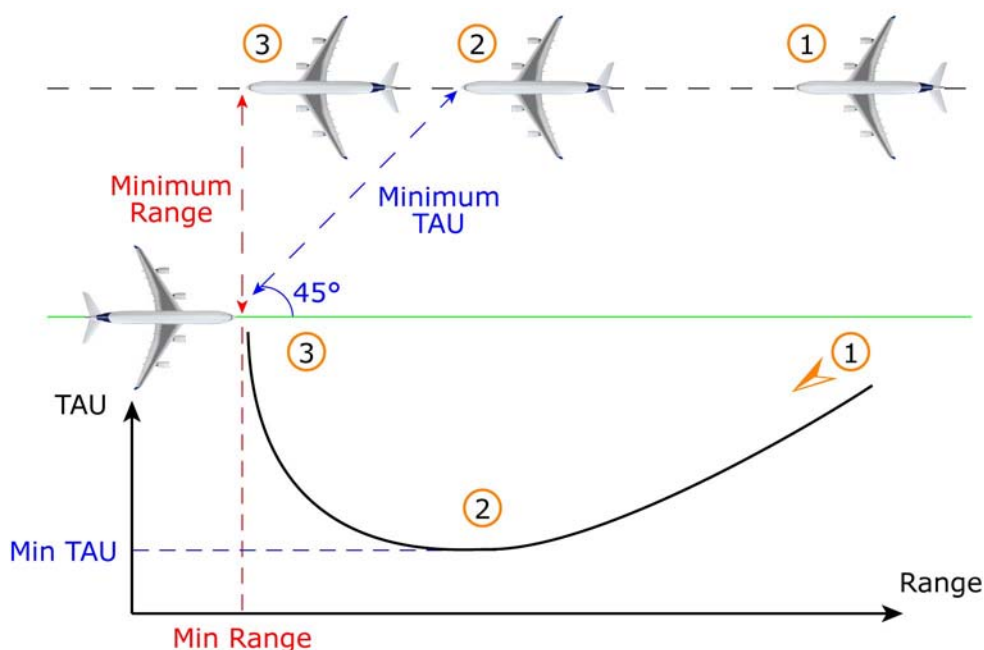


Figure 3-4 : TAU variation with range

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.

3.1.5. 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.

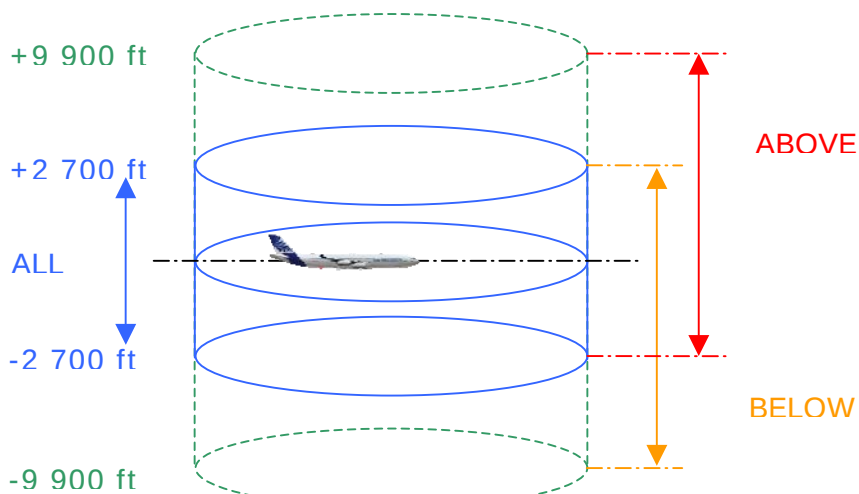


Figure 3-5: TCAS surveillance envelopes

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 3-5.

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 3-8.

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).

3.1.6. 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”.

3.1.6.1. 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).

3.1.6.2. 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.

3.1.7. 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.

3.1.7.1. TCAS DISPLAY

3.1.7.1.1. 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**, 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 3-7](#).

3.1.7.1.2. Primary Flight Display – PFD



Figure 3-6: TCAS display on 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**.

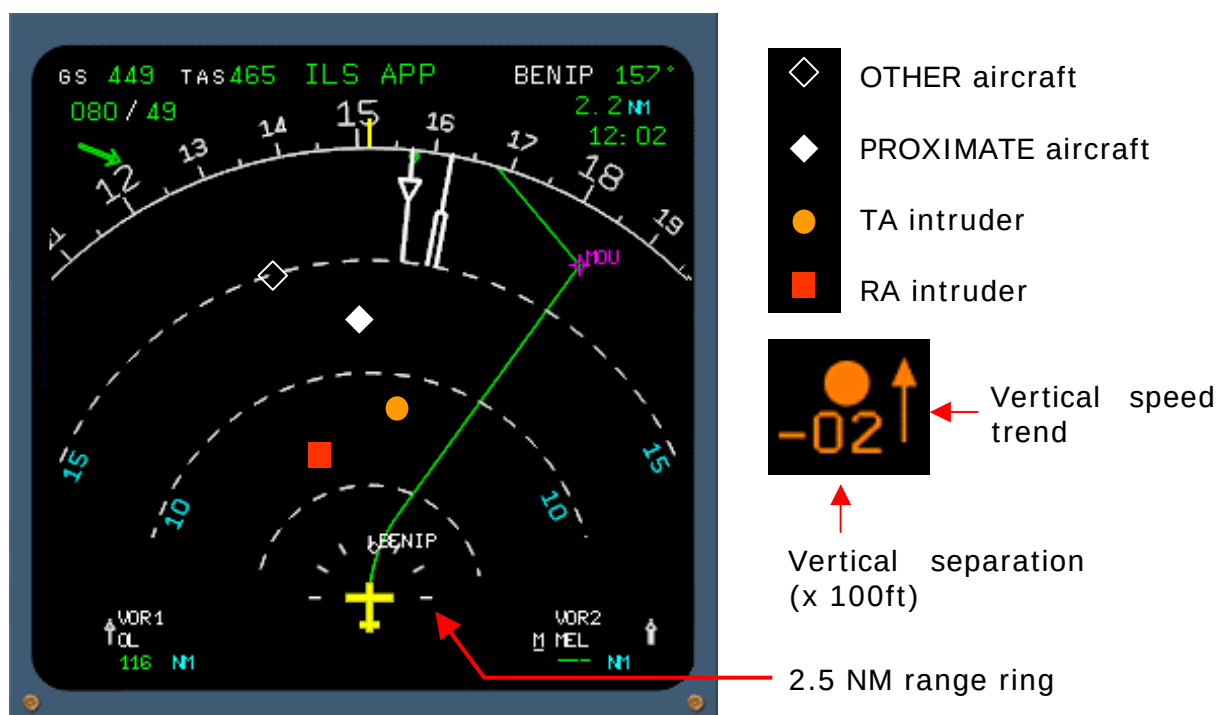


Figure 3-7: TCAS display on ND

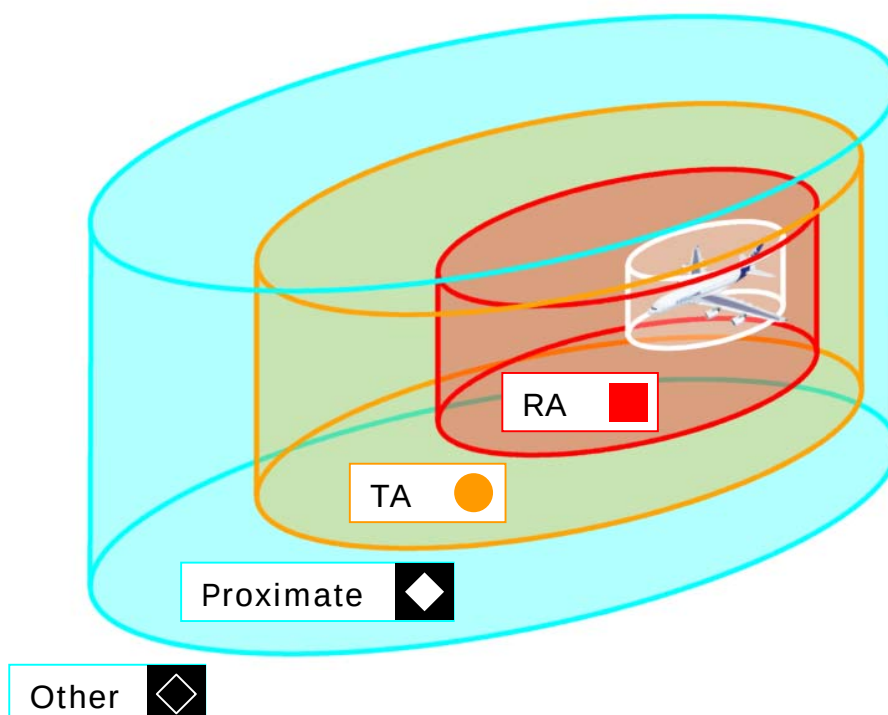
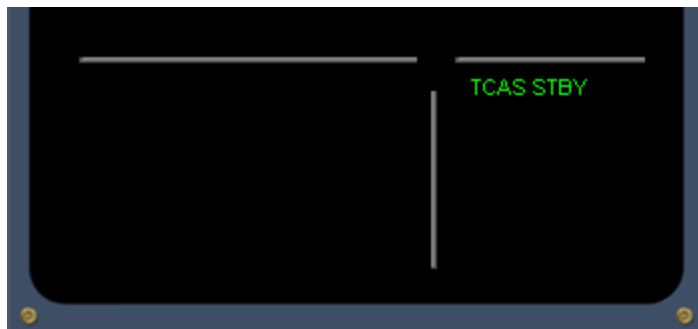


Figure 3-8: TCAS protection envelopes

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

3.1.7.1.3. 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.



3.1.7.2. 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.

3.1.7.2.1. Traffic Advisory

Aural alerts	Meaning
TRAFFIC TRAFFIC	TCAS detects a TA aircraft.

3.1.7.2.2. 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	+1 500

Aural Alerts	Meaning	Required V/S (ft/min)
	separation from a maneuvering intruder.	
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
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 3.1.6.2 – CP115 – Solution to the “ADJUST VERTICAL SPEED, ADJUST” Issue.	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

Aural Alerts	Meaning	Required V/S (ft/min)
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.	

3.1.7.2.3. 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.

3.1.7.2.4. Advisory Inhibition

When the own aircraft is below an altitude limit $\pm$ 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.

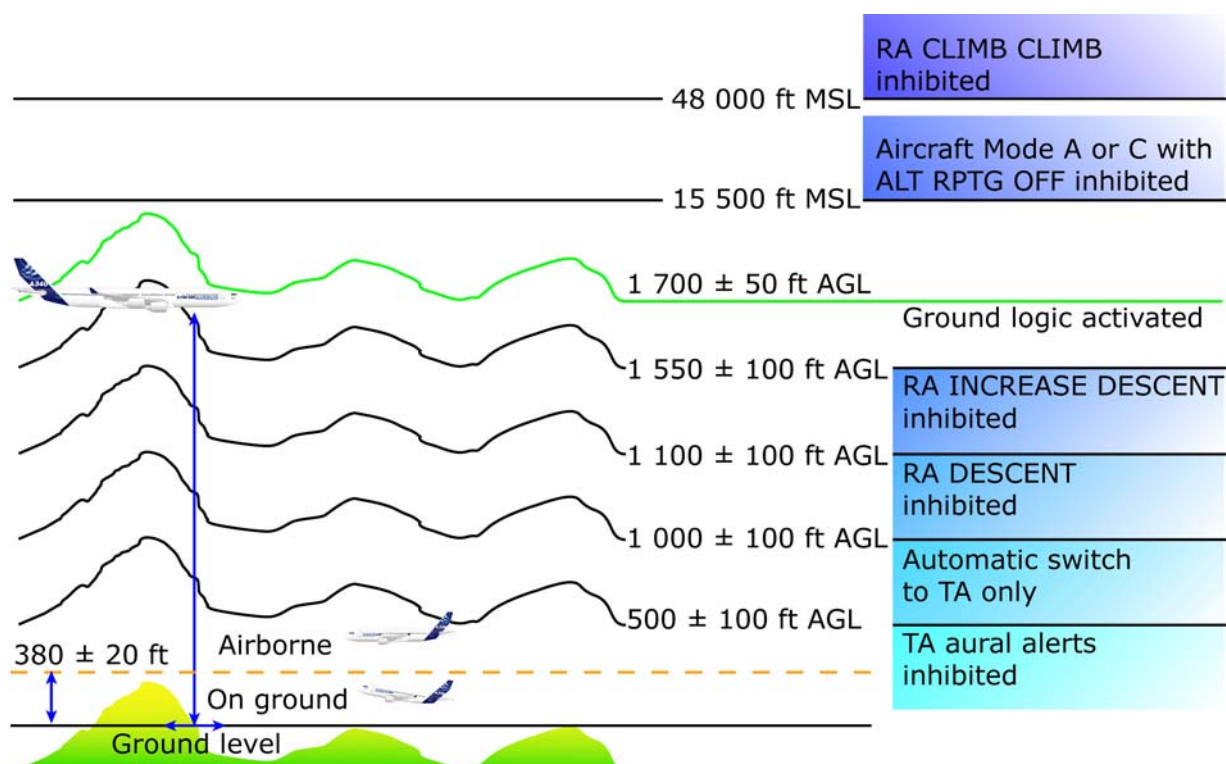


Figure 3-9: TCAS inhibitions

3.1.8. 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 3-5).
- **ABV:** TCAS displays surrounding aircraft in the surveillance envelope between -2 700 ft and +9 900 ft (refer to Figure 3-5).
- **BLW:** TCAS displays surrounding aircraft in the surveillance envelope between -9 900 ft and +2 700 ft (refer to Figure 3-5).

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

Tips: 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 **3.1.4 – Collision Threat Evaluation**.

For more details, please refer to your FCOM.

3.2. 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/msa/public/standard_page/ACAS_ACAS_Safety.html.

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.

3.2.1. 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 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.

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

3.2.2. FOR THE FLIGHT CREW

- **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.
- **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).**

3.3. 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**:

“6.18.1 From 1 January 2003, 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 an airborne collision avoidance system (ACAS II).”

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

As per EASA EU OPS 1.668, ACAS II is mandatory.

As per FAA FAR 121.356, ACAS II is mandatory.

3.4. MANUFACTURERS FOR TCAS

At the time of writing the brochure, three models of TCAS II are available on AIRBUS aircraft:

- ACSS TCAS 2000 or the T2CAS with TCAS module, or
- Rockwell Collins TTR 921, or
- Honeywell TPA 100A.

Figure 3-10 provides a simplified view of the TCAS architecture.

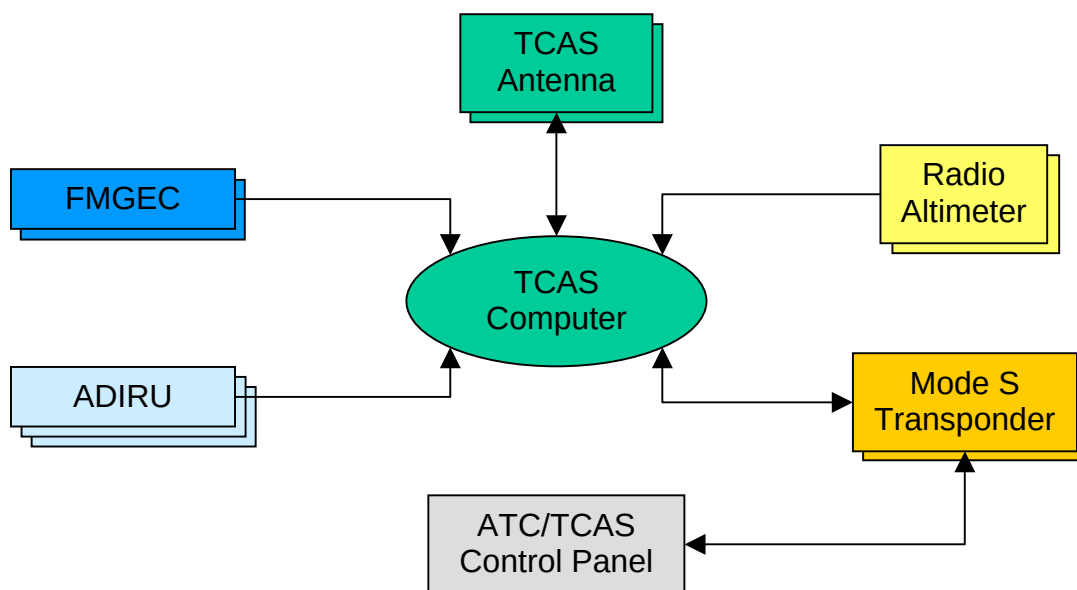


Figure 3-10: TCAS architecture

3.4.1. ACSS TCAS 2000 AND T2CAS

From ACSS, the TCAS 2000 and the T2CAS are available on AIRBUS aircraft to fulfill the traffic awareness function. The TCAS part of the T2CAS is almost identical to the ACSS TCAS 2000. The minor differences only affect the maintenance functions.

More information is available at <http://www.acssonboard.com/>.

3.4.2. TCAS PART OF ACSS T3CAS

The ACSS T3CAS is a further step of integration including:

- A Mode S transponder capable of ADS-B OUT as per DO-260A Change 2
- A TCAS II compliant with TCAS II Change 7.1
- An enhanced TAWS module derived from T2CAS TAWS module.

The advantages of this integration are the same as for T2CAS, a step further: reduced weight, volume, wiring, and power consumption.

The TCAS module and the Mode S transponder module share the same set of antennas, reducing weight and wirings.

The certification of the T3CAS is expected by end 2009. More information is available at <http://www.acssonboard.com/media/brochures/T3CAS.pdf>.

3.4.3. ROCKWELL COLLINS TTR 921

From Rockwell Collins, the TTR 921 is available on AIRBUS aircraft. It is a component of the Rockwell Collins ACAS 900 suite.

More information is available at

<http://www.rockwellcollins.com/products/cs/at/avionics-systems/legacy-products/index.html>.

3.4.4. HONEYWELL TPA 100A

From Honeywell, the TPA 100A is available on AIRBUS aircraft. The latest version of TPA 100A (P/N 940-0351-001) is compliant with TCAS II Change 7.1.

More information is available at <http://www.honeywell.com/sites/aero/TCAS.htm>.

3.5. FUTURE SYSTEMS

At the time of writing the brochure, no new TCAS is expected on a short term.

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 comply with TCAS II Change 7.0: ACSS TCAS 2000 or T2CAS, Rockwell Collins TTR 921, Honeywell TPA 100A (P/N 940-0300-001). ACSS T3CAS and Honeywell TPA 100A (P/N 940-0351-001) complies 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 **3.2 – Operational Recommendations for TCAS**.

Regulations

The carriage of TCAS II is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I.

Future systems

At the time of writing the brochure, no new TCAS is expected on a short term.

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 a new 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 includes several applications that are optimized for each flight phase (on ground or airborne). AIRBUS already proposes systems capable of airborne ATSAW applications (refer to 3.6.2 – ATSAW Applications) and plans to cover all applications. Manufacturers that propose TCAS computer capable of ATSAW are:

- **Honeywell with a new version of TPA 100A:** At the time of writing the brochure, the certification is expected very shortly (mid 2009)
- **ACSS with its T3CAS:** The certification of ACSS T3CAS is planned for the end 2009.

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.

3.6. DESCRIPTION OF ATSAW

The **Airborne Traffic Situational Awareness (ATSAW⁵)** 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 3-11 and 2.1.3.7 – Automatic Dependent Surveillance – Broadcast (ADS-B)). 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 3.6.1 – Enriched Traffic Information).
- **The ATSAW function do not provide any alerts.** For collision avoidance purposes, the flight crew must refer to TCAS indications.

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

The 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.

A new TCAS computer supports the ATSAW function. Therefore, TCAS and ATSAW information are seamlessly integrated (refer to 3.6.4.2.4 – Combination of TCAS and ADS-B Information).

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.

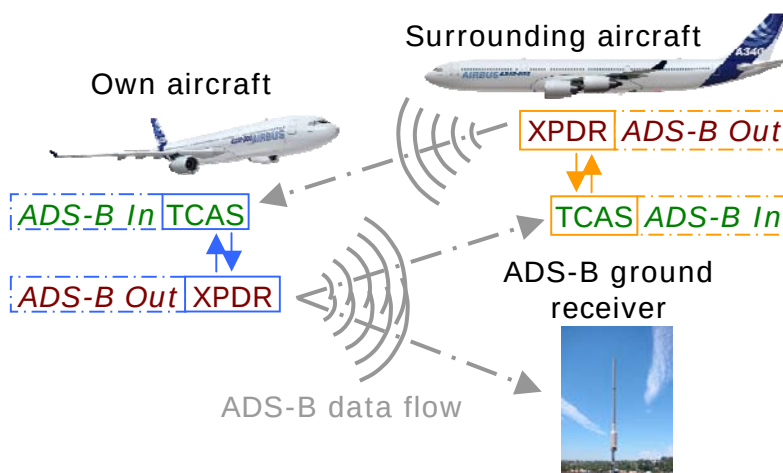


Figure 3-11: ADS-B data broadcast and collection

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 computer capable of ATSAW is compliant with TCAS II Change 7.1**. Refer to 3.1.6 – TCAS II Change 7.1 for more details.

ACAS and ATSAW software are fully segregated inside the TCAS computer.

3.6.1. 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 3.1 – Description of ACAS – TCAS). 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 2.1.3.8 – Extended Squitter), the ATSAW function provides for any surrounding aircraft capable of ADS-B OUT:

- The flight number⁶
- The position
- The relative altitude
- The vertical tendency
- The distance
- The heading
- The ground speed
- The indicated air speed
- The wake vortex category.

⁶ Refer to Appendix F for details.

3.6.2. ATSAW APPLICATIONS

The following sections describe the different ATSAW 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 ATSAW applications can also be found at

http://www.eurocontrol.int/cascade/public/standard_page/service_descriptions.html.

3.6.2.1. ON GROUND: ATSA SURFACE (ATSA SURF)

ATSA SURF provides the flight crew with information regarding the surrounding traffic during taxi and runway operations. ATSA SURF is expected to improve safety and to reduce taxi time during low visibility conditions and by night.

3.6.2.2. 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. In particular, the flight crew uses ATSA AIRB to enhance existing procedures:

- Construction of traffic awareness
- Visual acquisition for See-and-Avoid
- Traffic Information Broadcasts by Aircraft (TIBA).

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 **3.2 – Operational Recommendations for TCAS**.
- **Early detection of developing dangerous situations.** With a better knowledge of the traffic situation, the flight crew can identify dangerous situations with other aircraft and contact the ATC controller to get confirmation.

- **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.

3.6.2.2.1. Construction of Traffic Awareness

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:

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

3.6.2.2.2. Visual Acquisition for See-and-Avoid

The See-and-Avoid procedure mainly relies on the visual acquisition of surrounding aircraft. However, the flight crew hardly achieves the visual acquisition of an aircraft because:

- o Aircraft that fly VFR are often small, and aircraft that fly IFR are bigger but faster.
- o An aircraft on a collision course remains on a constant bearing. The flight crew hardly detects the threat due to the lack of apparent relative movement.
- o In busy flight phases (e.g. approach), the flight crew may inadvertently reduce the time for visual scans due to the workload increase.
- o The windshield limits the visual scans. Some dead angles appear in specific aircraft attitude (e.g. during a turn).
- o The flight crew may wrongly identify an aircraft through visual scans.

ATSAW AIRB improves the visual acquisition for See-and-Avoid as:

- It provides a precise location of surrounding aircraft.
- It provides the flight number (when available) of each aircraft.

3.6.2.2.3. Traffic Information Broadcasts by Aircraft (TIBA)

The Traffic Information Broadcasts by Aircraft (TIBA) is applied in areas where:

- Radar surveillance is low or absent, or
- Communications are not reliable, or
- Air Traffic Services are not reliable.

The TIBA objective is the collision avoidance instead of separation provision. Therefore, in TIBA airspaces, a flight crew may perform a collision avoidance maneuver based on TIBA reports listened on the radio frequency. In this context, the flight crew makes again a significant mental effort to construct the traffic picture. In addition, in TIBA airspaces, it is for collision avoidance purposes. Refer to Attachment C of ICAO Annex 11 (see References) for details about the TIBA procedure.

Collision avoidance with TIBA

The collision avoidance with TIBA occurs far beyond the threshold of a TCAS RA. The time scale for the collision avoidance with TIBA is some minutes. The time scale for the collision avoidance with TCAS is less than 1 minute.

In TIBA airspaces, the flight crew considers there is a collision risk when another aircraft is:

- o At the same flight level or is going to climb/descent through the flight level of the own aircraft
- o Converging on the same route or estimating to pass a point at almost the same time as the own aircraft.

ATSA AIRB improves the TIBA procedure as:

- o It reduces the mental effort of the flight crew to construct the traffic picture.
- o It permits the flight crew to anticipate any maneuvers for collision avoidance.
- o Some flight crews do not broadcast traffic information on the TIBA frequency.

3.6.2.3. 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 improvement of the flight safety** by avoiding flight levels with turbulence
- **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.

Note: 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.

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

3.6.2.4. 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 - ATSAW Visual Separation on Approach (VSA).

3.6.3. ATSAW ENVELOPES AND FILTERING LOGIC

3.6.3.1. ATSAW ENVELOPES

- **Vertical extension:**
 - o **For ACSS T3CAS:** The ATSAW envelopes have the same vertical extension as the TCAS envelopes (refer to Figure 3-5). They depend on the settings of the TCAS control panel (ALL, ABOVE, or BELOW).
 - o **For Honeywell TCAS TPA 100A:** The ATSAW envelope goes from – 10 000 ft to + 10 000 ft, regardless of the settings of the TCAS control panel.
- **Horizontal range:** 100 NM longitudinally, 30 NM on either sides of the aircraft..

3.6.3.2. FILTERING LOGIC

The TCAS computer limits the display of traffic (ADS-B and/or TCAS – refer to 3.6.4.1.1 – TCAS and ATSAW Symbols) that are in the ATSAW envelopes:

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

3.6.4. ATSAW INDICATIONS

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

3.6.4.1. 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).

3.6.4.1.1. 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. Refer to 3.6.4.2.4 – Combination of TCAS and ADS-B Information.

<div>Traffic</div> <div>Symbol</div>	Other	Proximate	TA	RA
TCAS Only	<div>+ 10</div> <div></div>	<div>+ 10</div> <div></div>	<div></div> <div>- 08</div>	<div></div> <div>- 05</div>
ADS-B Only	<div>+ 10</div> <div></div>	<div>+ 10</div> <div></div>	<div></div> <div>- 08</div>	<div></div> <div>- 05</div>
TCAS+ADS-B	<div>+ 10</div> <div></div>	<div>+ 10</div> <div></div>	<div></div> <div>- 08</div>	<div></div> <div>- 05</div>

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

Thanks to the different ATSAW controls (refer to 3.6.5 – ATSAW Controls), the ATSAW symbols get different states (refer to Figure 3-12).

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).

Basic	Extended	Full
<div>+11↓</div> <div></div>	<div>AIB1234</div> <div>+11↓</div> <div></div>	<div>AIB1234</div> <div>323</div> <div>M</div> <div></div>

Figure 3-12: ATSAW symbol labels

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.

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 3.6.4.2.4 – Combination of TCAS and ADS-B Information 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 3.6.5.2 – Traffic Selector.

When a flight crewmember highlights or selects an ATSAW symbol, the TCAS computer displays the ATSAW symbol with its full label. Refer to Figure 3-13.

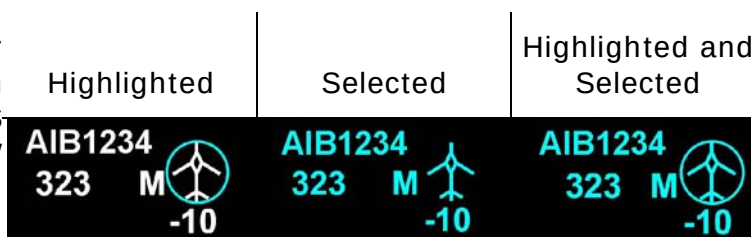


Figure 3-13: Highlight and selection of an ATSAW symbol

Note 1: The TCAS computer displays:

- **When it triggers a TA:**
 - o All non-TA aircraft with basic labels (refer to Figure 3-12). 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 3-14).
 - o The TA aircraft using one of the symbols illustrated in Figure 3-15 depending the flight crew setting (selected and/or highlighted, or not).



Figure 3-14: Non-TA aircraft selected and/or highlighted



Figure 3-15: ATSAW symbols for TA aircraft

- **When it triggers an RA:**
 - o Removes the labels for all aircraft (RA and non-RA aircraft). Therefore, the flight crew can easily identify the intruder.
 - o Keeps the highlight circle when the highlighted aircraft becomes an RA aircraft.
- **When Clear of Conflict:**
 - o Reverts all aircraft to their previous state as before the TA or RA event.



Figure 3-16: ATSAW symbols for RA aircraft

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

Note 2: When an ATSAW symbol is:

- Highlighted and exits the ATSAW envelope and the ND range, the TCAS computer:
 - o Removes the highlight signs (cyan circle on ND and cyan brackets on MCDU)
 - o Displays the TRAFFIC LIST page on MCDU if the current MCDU page was the TRAFFIC INFORMATION page (refer to 3.6.4.2 – MCDU).
- Selected and exits the ATSAW envelope and the ND range, the TCAS computer:
 - o Maintains the highlight and selection signs (highlight: cyan circle on ND, cyan brackets on MCDU; selection: cyan labels)
 - o Maintains the TRAFFIC INFORMATION page on MCDU
 - o Displays a half ATSAW symbol on the edge of the ND display area (e.g. ND edge in ROSE NAV mode or outermost ring in ARC mode) with the correct bearing.

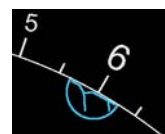


Figure 3-17: Half ATSAW symbol

3.6.4.2. MCDU

On 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.



Figure 3-18: MCDU MENU

3.6.4.2.1. Traffic List Page

The TRAFFIC LIST page displays **up to 90 aircraft** that are in the ATSAW envelopes (refer to 3.6.3.1 – ATSAW Envelopes). **Two sub-lists** compose the Traffic List:

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



Figure 3-19: Traffic List page

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 3.6.4.2.2 – 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 3.6.4.2.3 – ITP Traffic List Page)
- Provides two functions (TRAF ON and FLT ID ON, refer to 3.6.5.1 – MCDU controls).

3.6.4.2.2. 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 3.6.4.2.5 – Information sources for ADS-B traffic, 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 3-20, the TCAS computer used both ADS-B and TCAS information (see ADS-B/TCAS indication in the title line).



Figure 3-20: Traffic Information page

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

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 3-21: Traffic Information page with selected aircraft

3.6.4.2.3. 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 3.6.5.1 – MCDU controls).



Figure 3-22: ITP Traffic List page

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).



Figure 3-23: ITP possible



Figure 3-24: ITP possible with detected non-ADS-B aircraft

The TCAS computer displays the message TRAFFIC AT FLXXX RNGYY (refer to Figure 3-24) 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 3-25):
 - o DISTANCE when the distance criterion is not met, or
 - o REL SPEED when the relative speed criterion is not met, or
 - o 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 3-26.



Figure 3-25: ITP not possible due to the distance with one aircraft



Figure 3-26: ITP not possible due to the number of aircraft

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 3-27: Sorting of the ITP Traffic List

The TCAS computer also indicates when the ITP maneuver is in progress (refer to Figure 3-28), or when a standard procedure instead of ITP is sufficient to perform a climb or a descent (refer to Figure 3-29).



Figure 3-28: ITP in progress



Figure 3-29: ITP not applicable

3.6.4.2.4. Combination of TCAS and ADS-B Information

TCAS information is based on TCAS measurements (refer to 3.1.2 – TCAS Principle). 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
 - $\pm 30^\circ$ 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 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.

3.6.4.2.5. 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.

3.6.5. 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.

3.6.5.1. MCDU CONTROLS

3.6.5.1.1. TRAF ON/OFF

The TRAF ON/OFF function in the TRAFFIC LIST page (refer to [Figure 3-19](#)) displays or hides ATSAW symbols on ND.

When the TRAF 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 [3.6.4.1.1 – TCAS and ATSAW Symbols](#))
- Permits the display of the Traffic List on MCDU.

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

3.6.5.1.2. FLT ID ON/OFF

The FLT ID ON/OFF in the TRAFFIC LIST and the ITP TRAFFIC LIST pages (refer to [Figure 3-19](#) and [Figure 3-22](#)) displays or hides flight numbers of all ATSAW symbols on ND (refer to extended label in [Figure 3-12](#)). 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.

3.6.5.1.3. TRAFFIC SELECT/DESELECT

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 [3.6.5.2 – Traffic Selector](#)).

Note: 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 3-13](#), [Figure 3-19](#), [Figure 3-21](#), and [Figure 3-23](#).

3.6.5.2. TRAFFIC SELECTOR



Figure 3-30: Traffic Selector in the cockpit

The flight crew uses the Traffic Selector to highlight or select an ADS-B symbol on ND. There is one Traffic Selector on either side of the cockpit for each flight crew member.

3.6.5.2.1. Turn to highlight

The flight crew turns the Traffic Selector to highlight an ATSAW symbol on ND. The TCAS computer highlights aircraft as in [Figure 3-13](#). A flight crewmember can highlight only one aircraft at a time on his ND. A **quick turn** of the Traffic Selector removes the highlight.

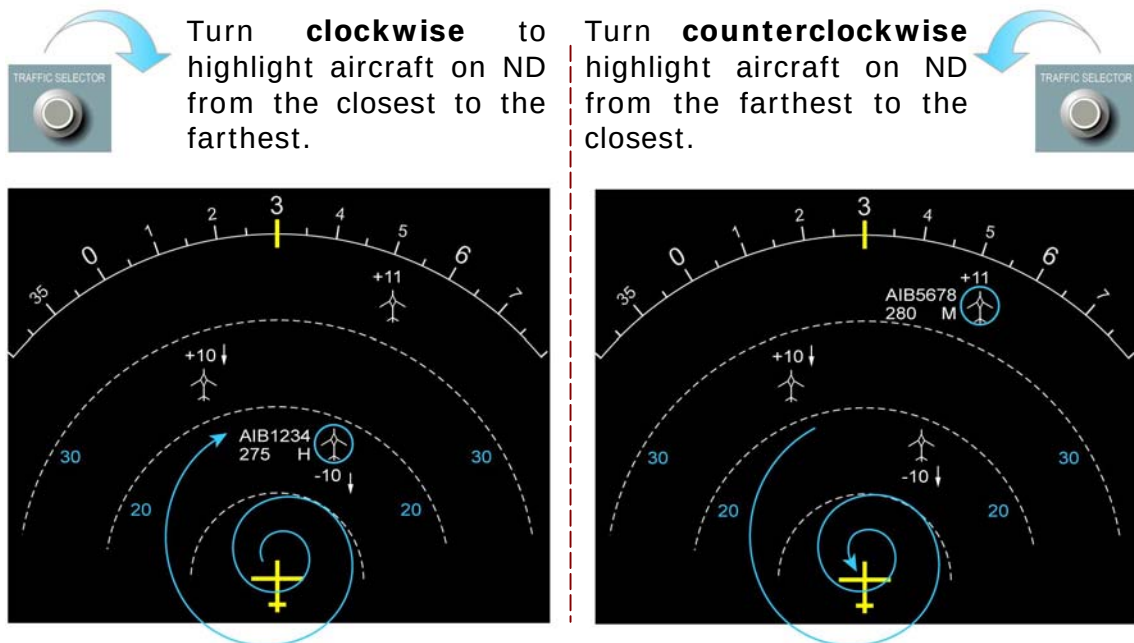


Figure 3-31: Turn Traffic Selector to highlight

3.6.5.2.2. Pull to select

The flight crew pulls the Traffic Selector to select an ATSAW symbol on ND. Refer to Figure 3-32. 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 3-32: Pull Traffic Selector to select

3.7. OPERATIONAL RECOMMENDATIONS FOR ATSAW

3.7.1. 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).

3.7.2. 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.

3.8. REGULATIONS FOR ATSAW

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 ATSAW function.

3.9. MANUFACTURER FOR ATSAW

To fulfill the Traffic Awareness function with ATSAW, AIRBUS proposes the following two systems: the Honeywell TPA 100B (available from early 2010) and the ACSS T3CAS (available from early 2010). These TCAS computer capable of ATSAW are also compliant with TCAS II Change 7.1 (refer to 3.1.6 – TCAS II Change 7.1).

ATSAW ITP is an option of ATSAW.

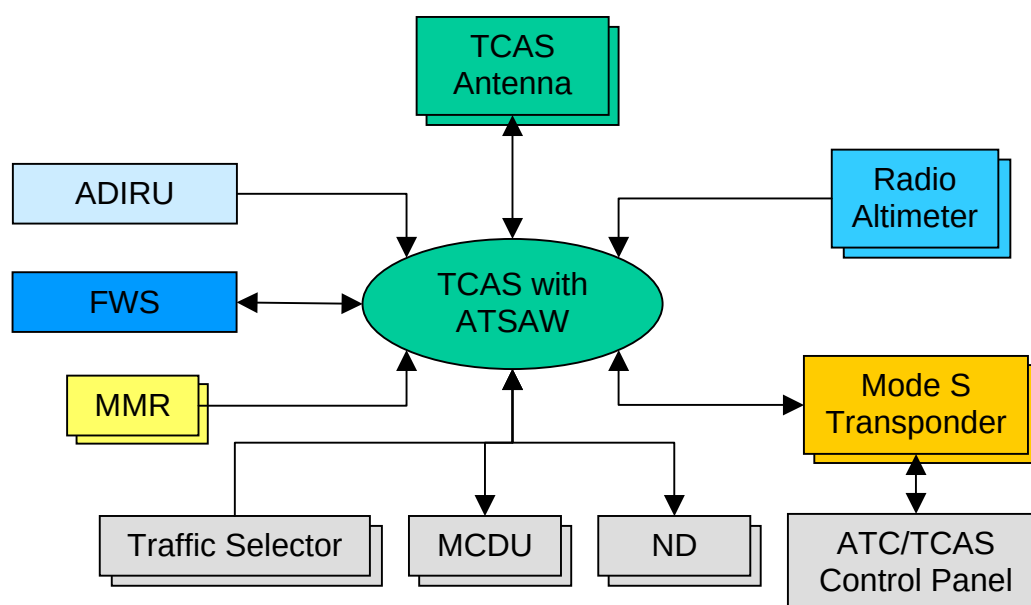


Figure 3-33: ATSAW architecture

Figure 3-33 provides a simplified view of the ATSAW architecture.

3.10. FUTURE APPLICATIONS

3.10.1. ATSA SURF WITH OANS

AIRBUS is currently developing the integration of the ATSA SURF application in the OANS (refer to 5.1 – Description of OANS) for all AIRBUS aircraft. The ATSA SURF application will provide the traffic around the aircraft on the OANS moving map. The ATSA SURF application will improve taxi operations (e.g. anticipation of aircraft queue for take-off) and safety on ground (i.e. traffic awareness during taxi with low visibility).

3.10.2. ENHANCED SEQUENCING AND MERGING OPERATIONS

AIRBUS actively participates to the development of new systems to assist the flight crew in Sequencing and Merging (S&M) operations. Those systems (Airborne Separation Assistance System – ASAS) will be able to merge the own aircraft behind a preceding aircraft and to maintain a separation behind this aircraft. On ATC instruction, the flight crew initiates the S&M procedure with the assistance of ASAS.

The objectives of ASAS are to:

- Enable flight crews to precisely meet ATC spacing instructions
- Reduce ATC workload
- Improve current safety level
- Increase airspace capacity.

Please bear in mind...**Description**

The ATSAW function 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**, ATSA SURF (not yet available).

TCAS computer capable of ATSAW on AIRBUS aircraft are: new version of **Honeywell TPA 100B** (early 2010) and **ACSS T3CAS** (early 2010).

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 **3.7 – Operational Recommendations for ATSAW**.

Regulations

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

Future systems

To improve the Traffic Surveillance during taxi, AIRBUS is currently developing the integration of the ATSA SURF application in the OANS for all AIRBUS aircraft.



4. 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 **Traffic and Terrain Collision Avoidance System (T2CAS)**. The TCAS part of T2CAS is identical to the stand-alone TCAS 2000. The TAWS part of T2CAS is also called Ground Collision Avoidance System (GCAS).

The present chapter describes the Terrain Awareness function as per (E)GPWS or T2CAS. These two systems are quite similar. The differences are highlighted when needed.

4.1. 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 **4.1.2.1 – EGPWS Mode 6: Excessive Bank Angle**)
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). Operational differences are highlighted when necessary.

Note 1: In this brochure, EGPWS refers to P/N 965-1676-002 and T2CAS refers to T2CAS standard 2.

Note 2: For the description of the EGPWS RAAS function, refer to **5.11 – Description of RAAS**.

4.1.1. TAWS PRINCIPLES

The TAWS processing may be depicted as in **Figure 4-1**. 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.

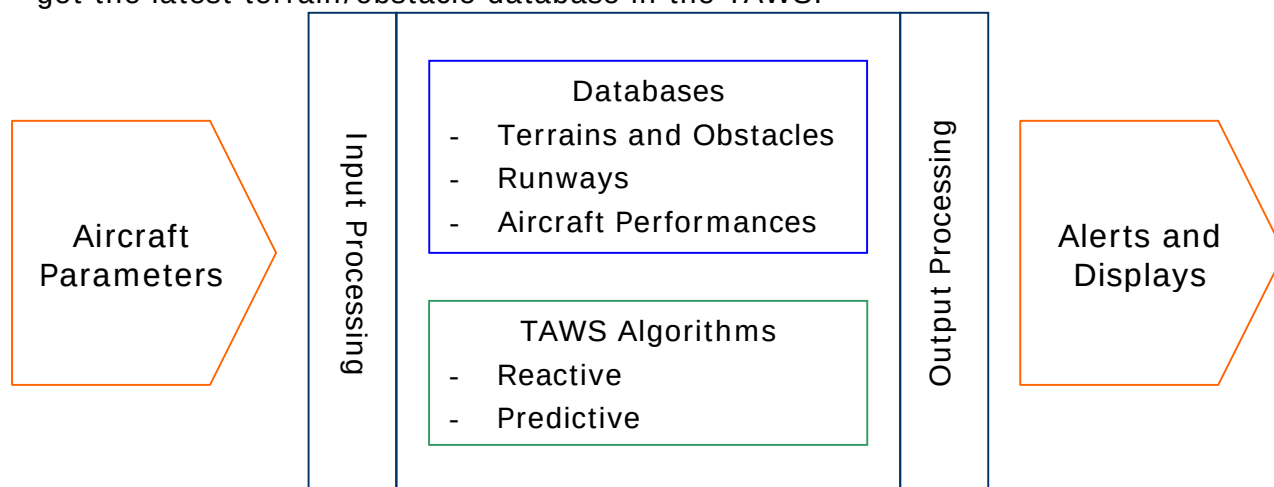


Figure 4-1: TAWS processing

Note: The Obstacle database is specific to EGPWS only. The Aircraft Performance database is specific to T2CAS only.

4.1.1.1. 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	T2CAS
<ul style="list-style-type: none"> - 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). 	<ul style="list-style-type: none"> - In en-route areas: 3.0 NM - In terminal areas within 22 NM from the airport: 0.5 NM - In final areas for mountainous airport (within 6 NM from airport if elevation is 2 000 ft or more): 0.25 NM.

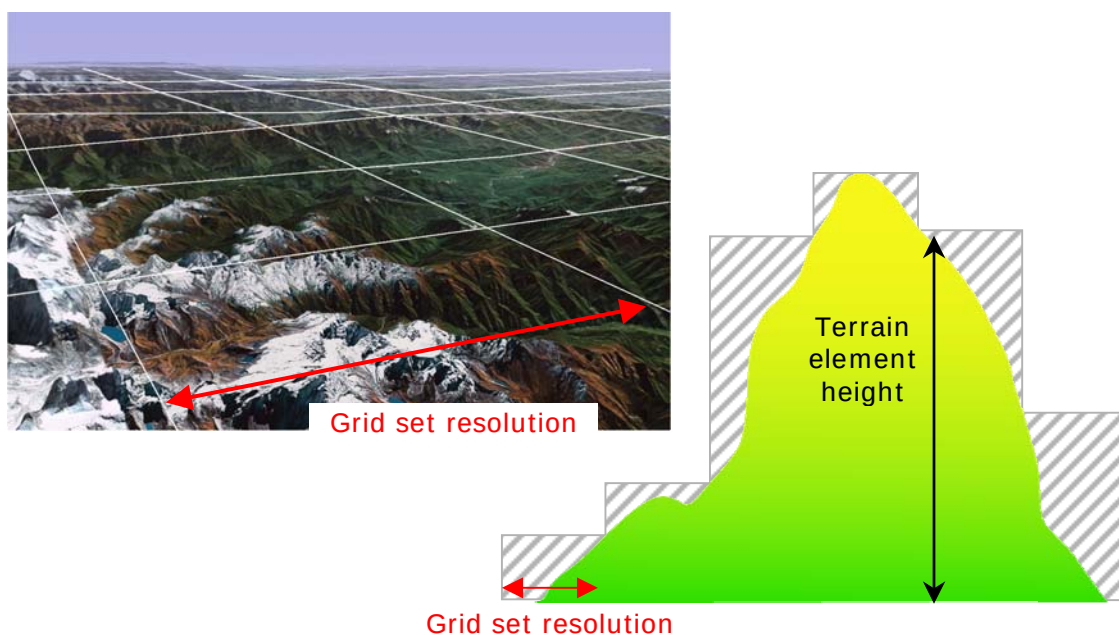


Figure 4-2: Terrain database encoding

4.1.1.2. OBSTACLE DATABASE

At the time of writing the brochure, only EGPWS contains an Obstacle database, which includes artificial obstacles worldwide. Thanks to this database, EGPWS displays obstacles on ND.

4.1.1.3. RUNWAY DATABASE

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

- EGPWS Terrain Clearance Floor (TCF)
- EGPWS Runway Field Clearance Floor (RFCF)
- EGPWS Runway Awareness and Advisory System (RAAS)
- T2CAS Collision Prediction and Alerting (CPA)
- T2CAS Premature Descent Alert (PDA).

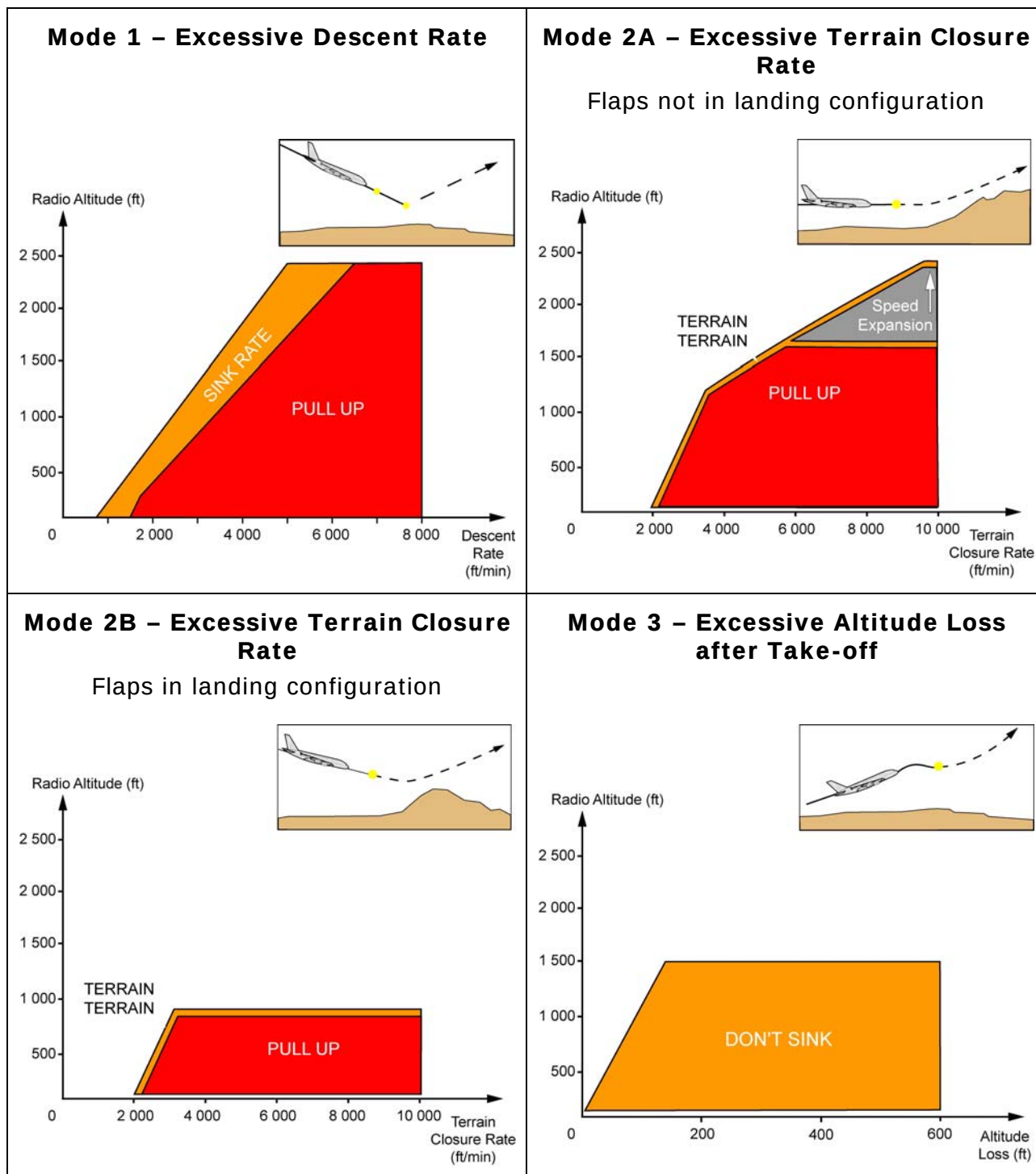
It includes runways longer than 3 500 ft (1 067 m) worldwide and runways longer than 2 000 ft (610 m) locally.

4.1.1.4. AIRCRAFT PERFORMANCE DATABASE

The **T2CAS** includes an Aircraft Performance database. The **T2CAS 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.

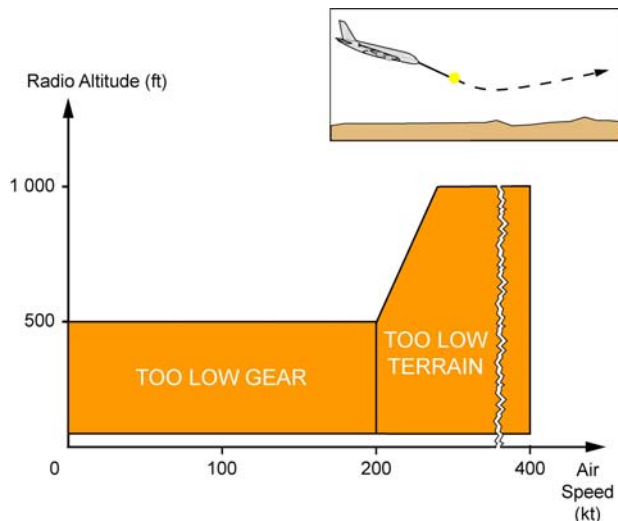
4.1.2. REACTIVE (BASIC) TAWS FUNCTIONS

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 (EGPWS or T2CAS).** However, principles remain the same. For more details, refer to your FCOM.

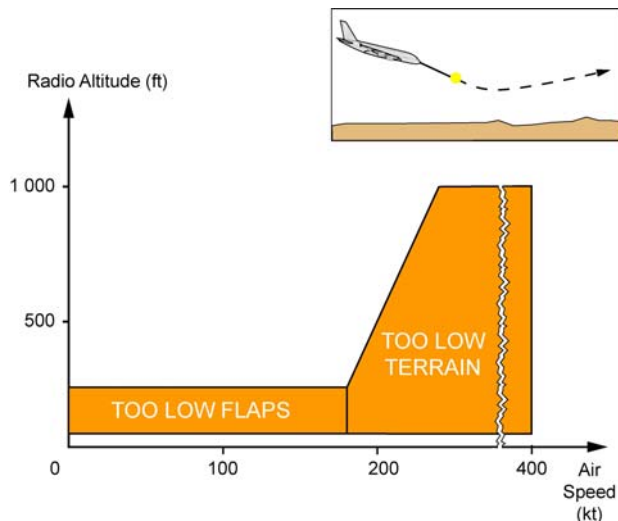


Mode 4A – Unsafe Terrain Clearance

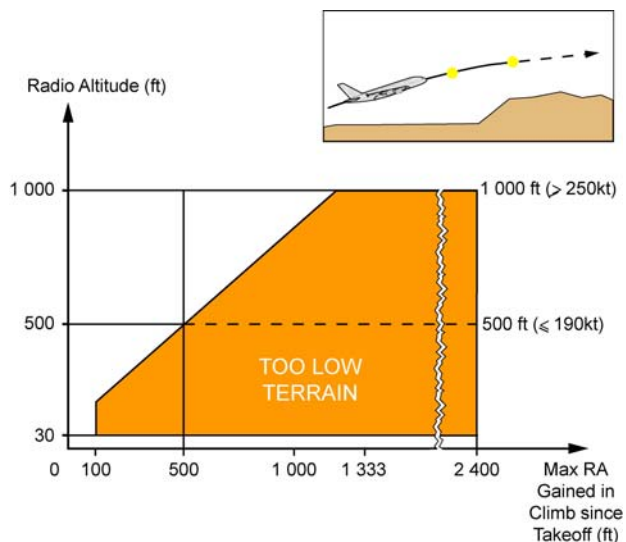
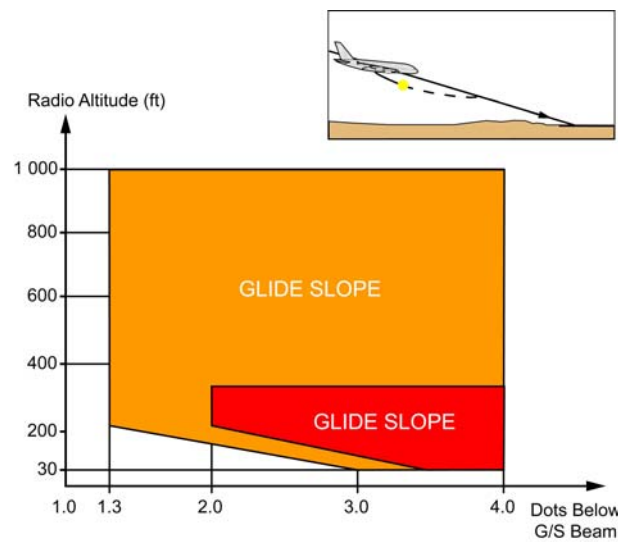
Gear up and flaps not in landing configuration

**Mode 4B – Unsafe Terrain Clearance**

Gear down and flaps not in landing configuration

**Mode 4C – Unsafe Terrain Clearance (EGPWS only)**

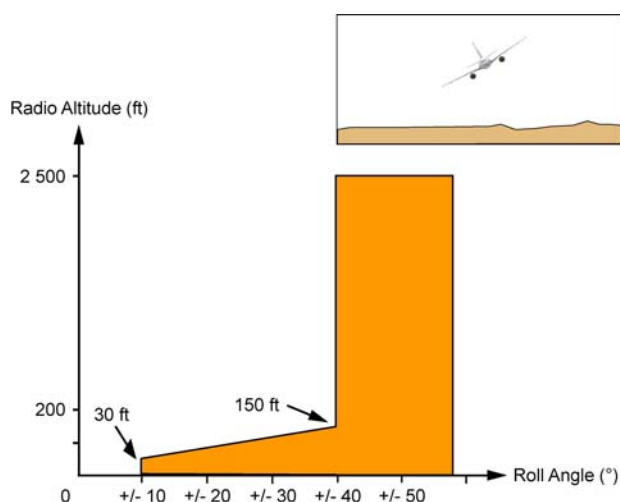
Gear up or flaps not in landing configuration

**Mode 5 – Excessive Glide Slope Deviation****A318: TAWS with Steep Approach**

At the time of writing the brochure, only A318 aircraft is certified for steep approaches. To avoid nuisance alerts during steep approaches, the TAWS Mode 1 envelope is slightly modified.

Note: T2CAS Mode 2 is inhibited to avoid inadvertent alerts during approaches. When there is a lateral position error, T2CAS reactivates Mode 2. For the same purposes, EGPWS applies an envelope modulation (refer to 4.1.2.1.1 – EGPWS Envelope Modulation).

4.1.2.1. 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%.

4.1.2.1.1. 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 crosschecks the FMS position with nav aids 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 4.1.4.1 – EGPWS Geometric Altitude) to reduce the caution and warning envelopes during the approach on specific areas.

4.1.3. PREDICTIVE TAWS FUNCTIONS

EGPWS or T2CAS only (not GPWS) includes predictive TAWS functions (also known as the enhanced functions for EGPWS). EGPWS and T2CAS 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.

4.1.3.1. ENHANCED GPWS FUNCTIONS

4.1.3.1.1. EGPWS Terrain Awareness and Display (TAD)

The TAD function analyses the terrain in caution and warning envelopes (see Figure 4-3) 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.
- **A width** that starts at $\frac{1}{4}$ 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 4-4.

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 **EGPWS** provides two different modes of terrain display on ND:

- **Standard mode:** the terrain is displayed according to the vertical displacement between the terrain elevation and the current aircraft altitude (left

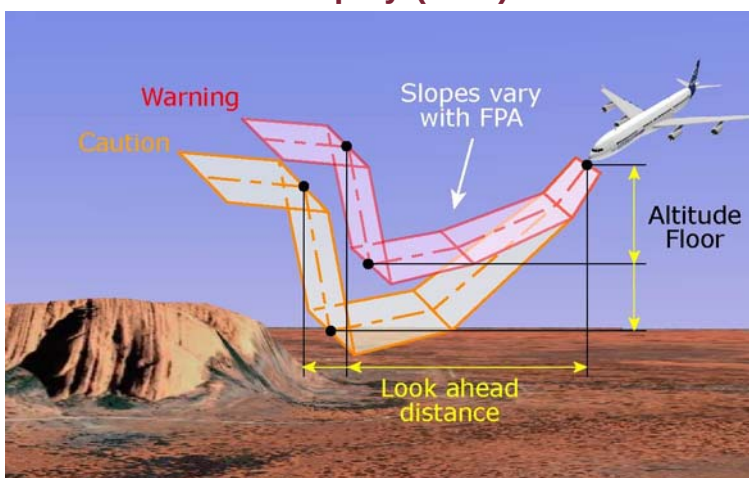


Figure 4-3: EGPWS terrain caution and warning envelopes

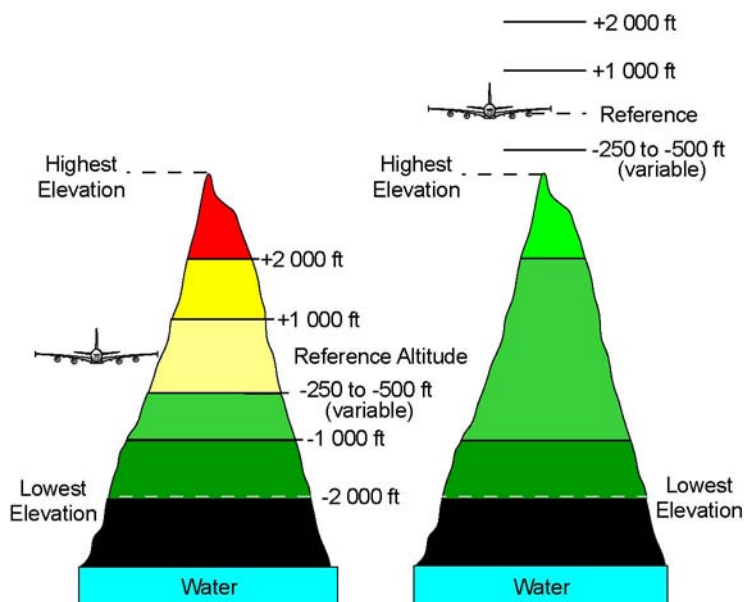


Figure 4-4: EGPWS color coding with peaks option

side of Figure 4-4). If the aircraft is more than 2 000 ft above the terrain, there is no terrain information displayed.

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- **Peaks mode** (refer to 4.1.5.4 – EGPWS: 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 4-4). 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.

Tips: EGPWS Peaks mode and RNP AR

The EGPWS Peaks mode has been identified as mandatory during the RNP AR certification process. For the time being, only the EGPWS Peaks mode feature is eligible for RNP AR operations.

The future T3CAS will encompass an equivalent feature called Eleview (see 4.1.3.3 – EGPWS/T2CAS Comparison).

4.1.3.1.2. EGPWS 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 triggers aural and visual alerts.

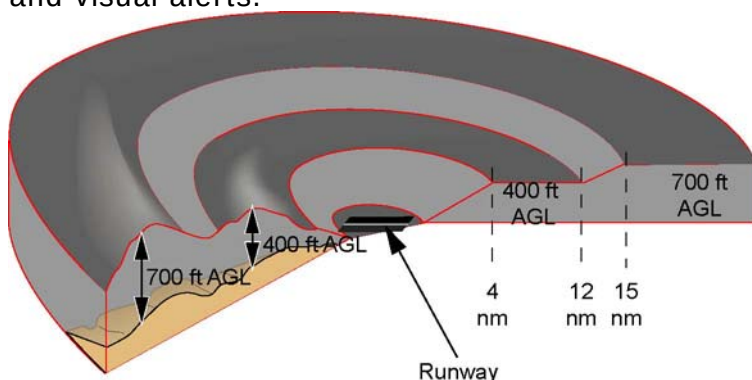


Figure 4-5: TCF envelope

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 4-5.

4.1.3.1.3. EGPWS 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.

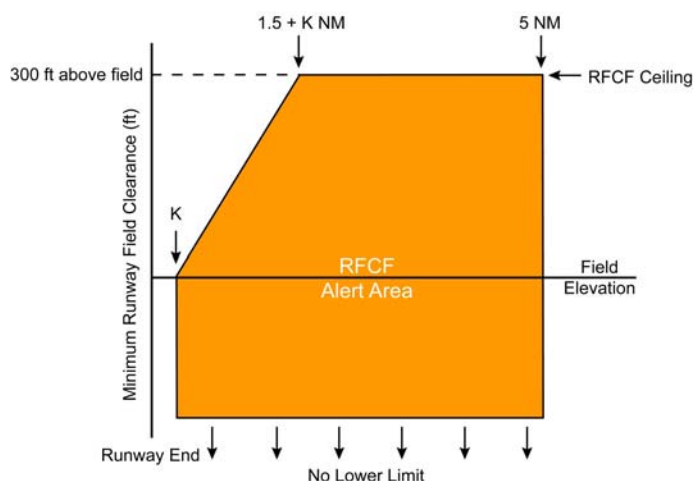


Figure 4-6: RFCF envelope

4.1.3.2. PREDICTIVE T2CAS FUNCTIONS

4.1.3.2.1. T2CAS 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 T2CAS 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 4-8.

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.

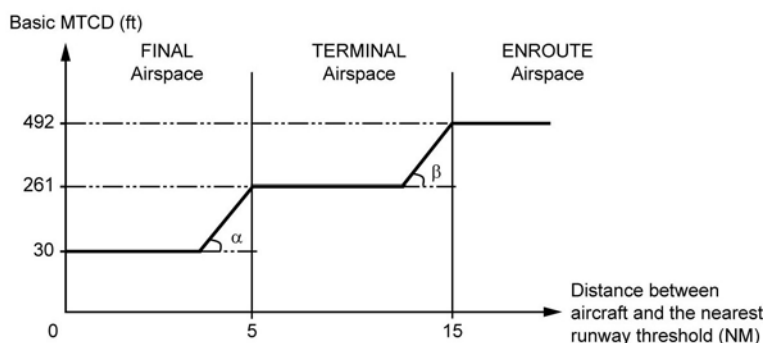


Figure 4-7: Variation of the basic MTCD

The variation of the **basic MTCD** is given in Figure 4-7. 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.

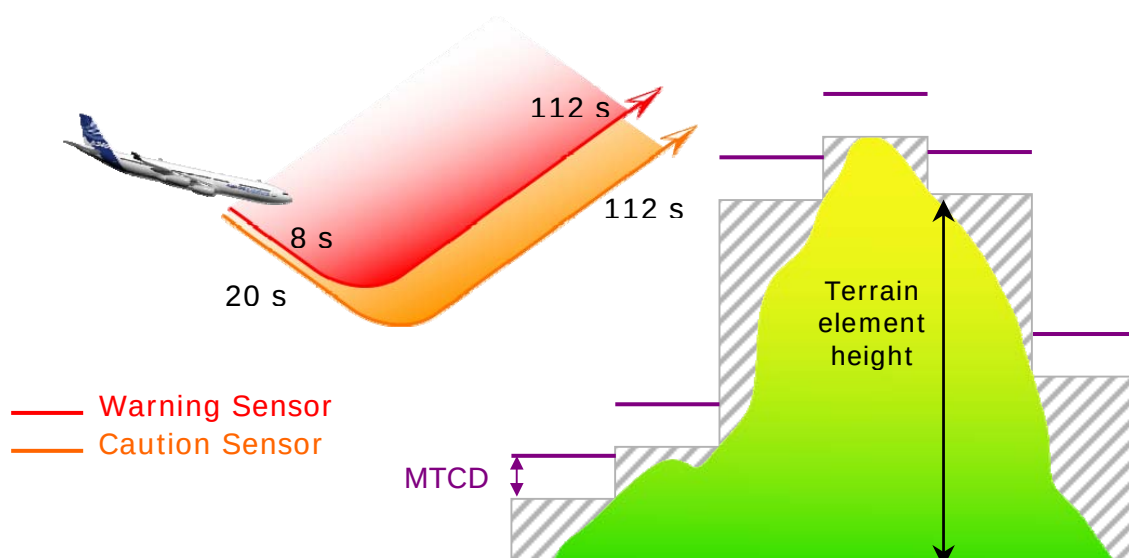


Figure 4-8: T2CAS terrain caution and warning envelopes

Three segments compose the clearance sensors (see Figure 4-8):

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 T2CAS 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 T2CAS orders a lateral maneuver (AVOID TERRAIN warning).

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 T2CAS only. When T2CAS triggers the AVOID TERRAIN warning, the flight crew should consider a lateral avoidance (turn). Refer to your FCOM for the applicable procedure.

On the horizontal plane (see Figure 4-9), 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).

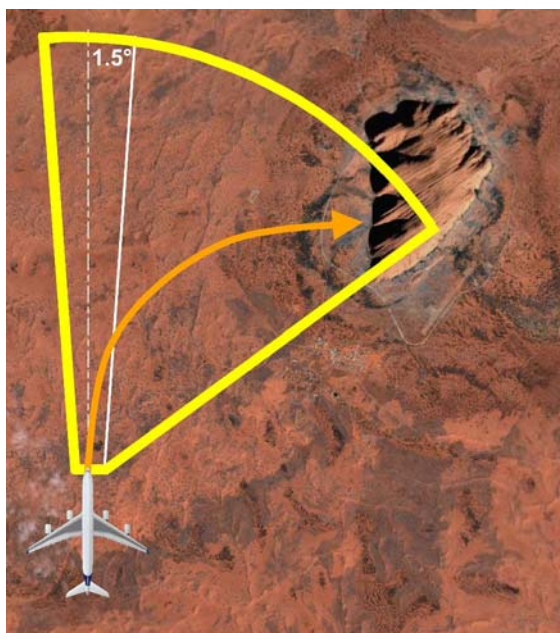


Figure 4-9: T2CAS horizontal sensor coverage

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.

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 T2CAS 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.

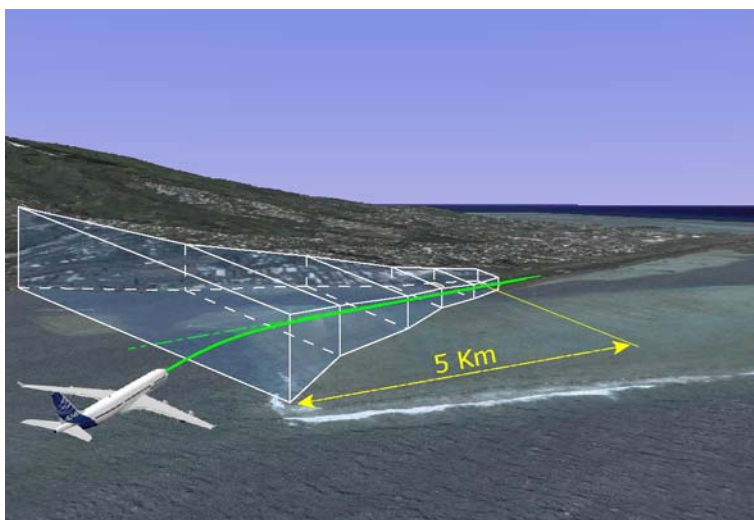


Figure 4-10: Runway convergence envelope

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.

4.1.3.2.2. T2CAS Terrain Hazard Display (THD)

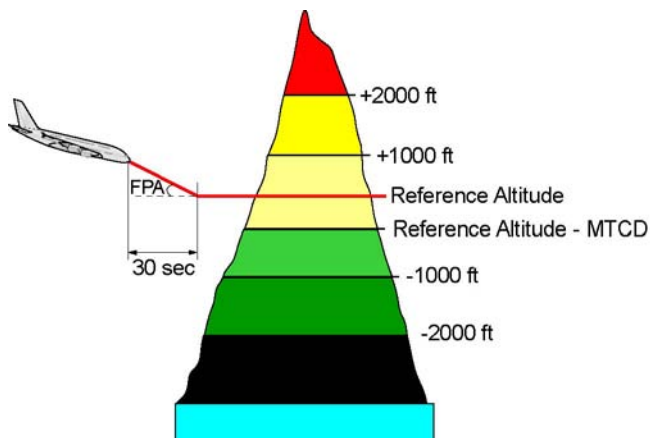


Figure 4-11: T2CAS color coding

The **T2CAS** provides only the **Standard mode** display (compared to EGPWS, see Figure 4-4). In descent, the T2CAS provides an anticipated terrain situational awareness. The **Reference Altitude** is defined as the aircraft altitude projected 30 seconds along FPA (refer to Figure 4-11).

4.1.3.2.3. T2CAS 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.

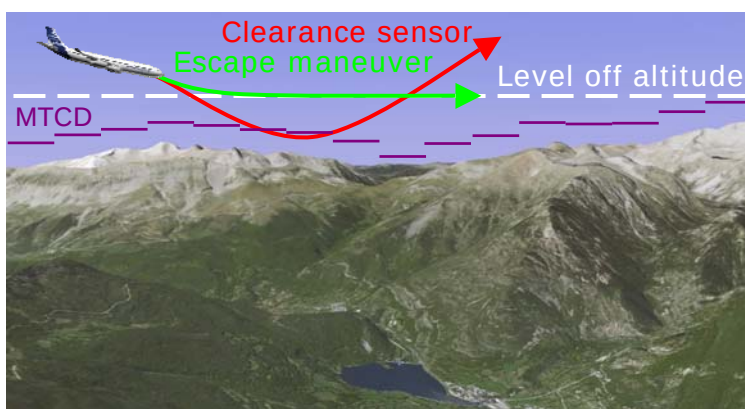


Figure 4-12: Level off with Premature Descent Alert

The T2CAS 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).

4.1.3.3. EGPWS/T2CAS COMPARISON

		EGPWS	T2CAS
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 »	
		Premature Descent Alerting « Too Low Terrain »	
		Terrain Display Terrain Alerting and Display (TAD) based on Terrain database	
Other functions		Terrain Hazard Display (THD) based on Terrain database	
		Voice call outs Managed by FWS (500ft or 400ft call out)	
		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 (Hybrid or Autonomous GPS Architecture)	Radio Altitude Blending + GPS altitude activation (Hybrid or Autonomous GPS Architecture)
		GPS Lateral Position (Hybrid or Autonomous GPS Architecture)	
		Obstacle database	
		Peaks mode	
		Compatible with Honeywell Autotilt weather radar	Not compatible with Honeywell Autotilt weather radar
		FLS support (mode 5)	
		Runway Awareness and Advisory System (RAAS)	

Note: Functions shaded in yellow are basically activated in forwardfit.

4.1.4. INTRODUCTION OF GPS POSITION INTO TAWS ARCHITECTURE

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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:

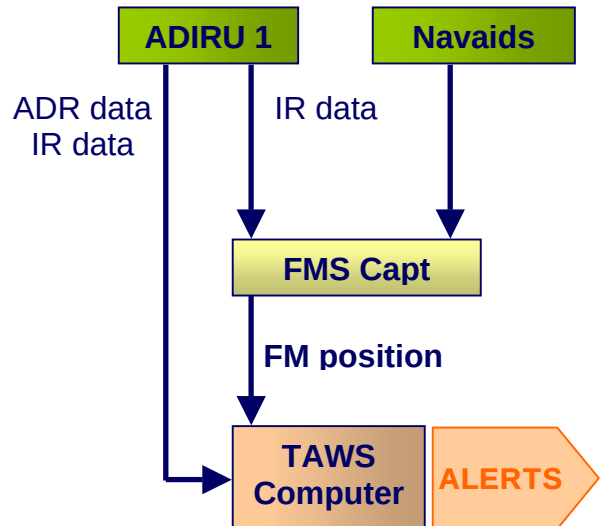


Figure 4-13: Former TAWS architecture

- **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).

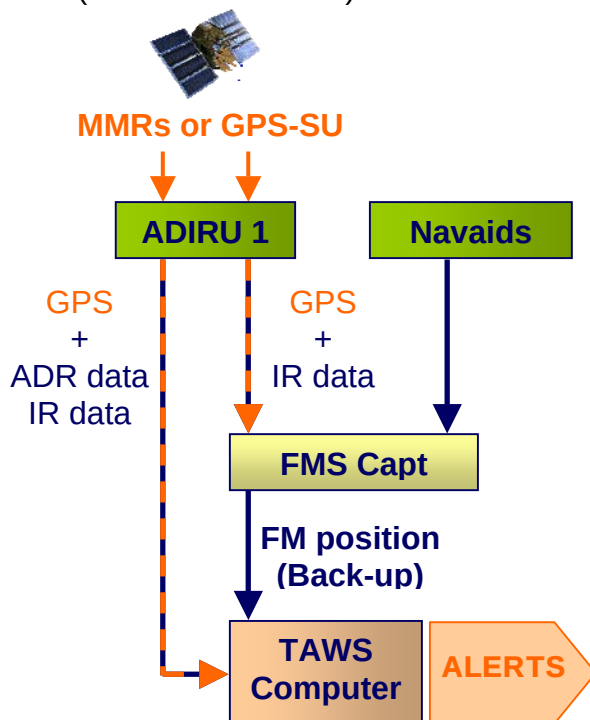


Figure 4-14: Hybrid architecture

- **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).

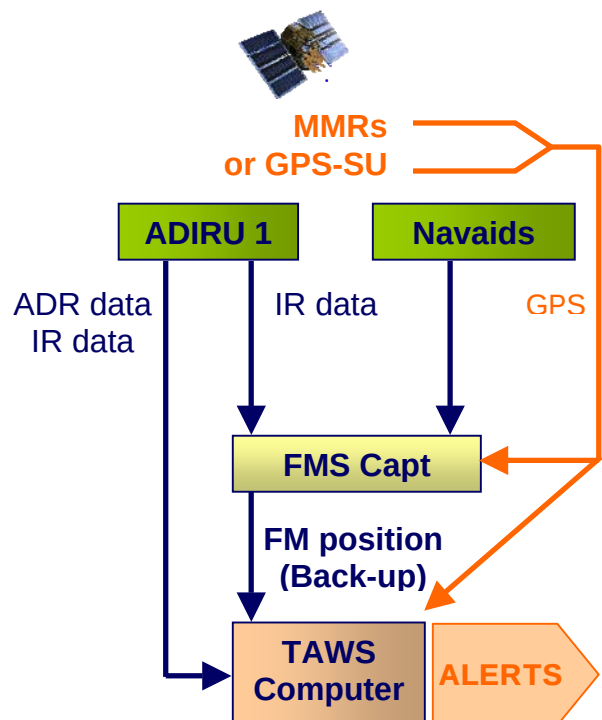


Figure 4-15: Autonomous architecture

Both new EGPWS (P/N 965-1676-002 and subsequent) and T2CAS (Standards 1 & 2) 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 new EGPWS and T2CAS. Besides, the installation of new EGPWS or T2CAS 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. Refer to [AIRBUS References](#) for OITs on this topic.

4.1.4.1. EGPWS GEOMETRIC ALTITUDE – T2CAS 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 T2CAS). 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**.

4.1.4.2. USE OF GPS FOR LATERAL POSITIONING

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**.

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

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 4-16 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 T2CAS) 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 4-13), 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 4-14) **or autonomous architecture** (refer to Figure 4-15), 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)

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 4.1.6 – TAWS Controls).

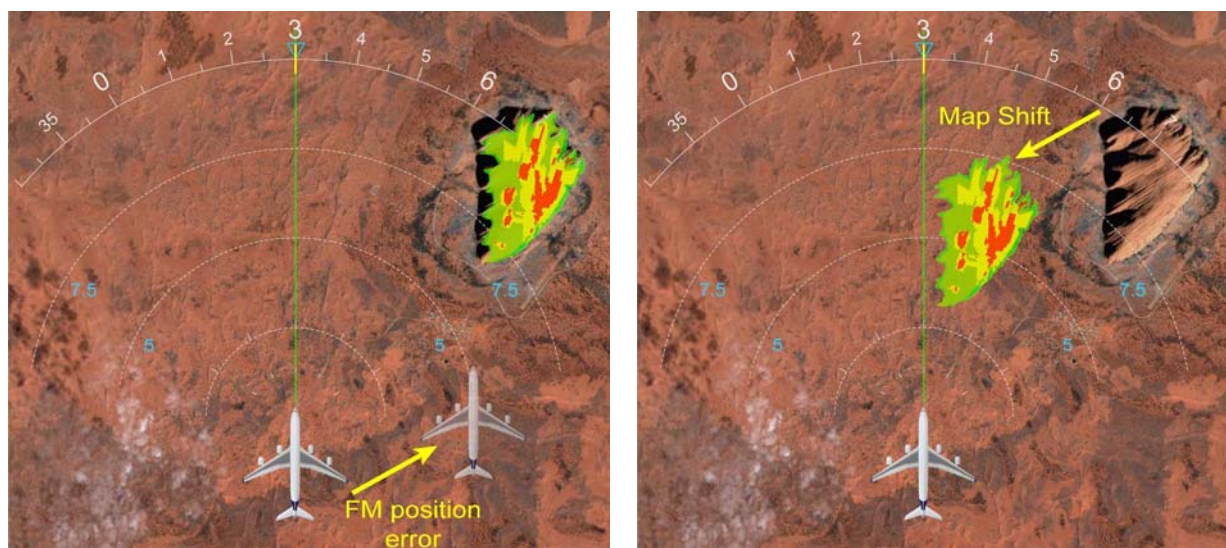


Figure 4-16: Map Shift due to an FM position error

4.1.5. TAWS INDICATIONS

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

4.1.5.1. TAWS BASIC MODE INDICATIONS

Please refer to 4.1.2 for the aural alerts provided in TAWS basic modes.

For EGPWS or T2CAS:

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



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



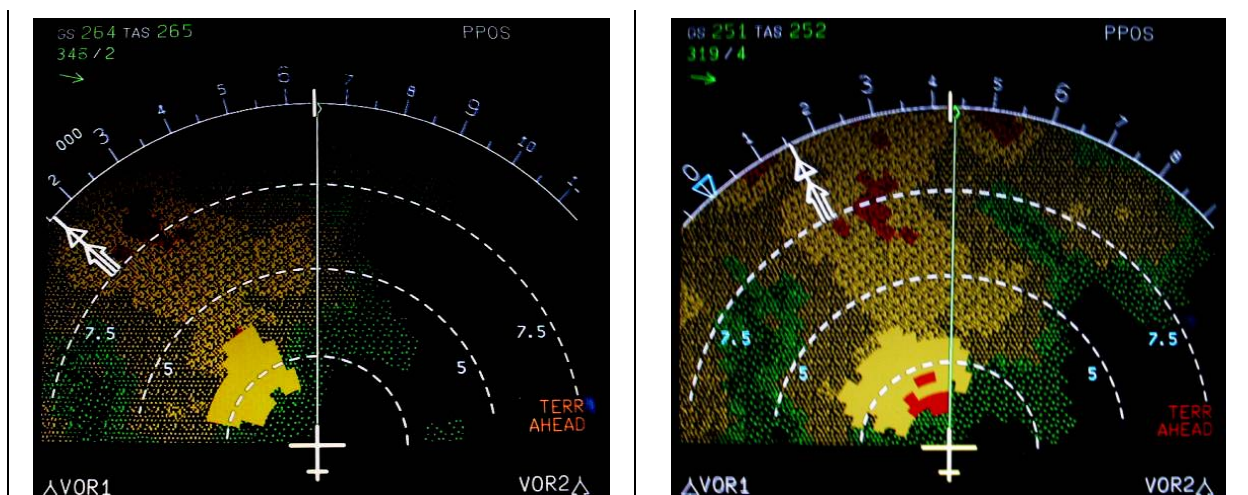
4.1.5.2. TAWS PREDICTIVE FUNCTIONS

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

TERRAIN AHEAD Caution	TERRAIN AHEAD Warning
 TERRAIN AHEAD¹ <ul style="list-style-type: none">- EGPWS: Every 7 seconds until conditions disappear.- T2CAS: When the caution sensor penetrates the MTCD for at least 2 seconds. Every 5 seconds until conditions disappear. 	 TERRAIN AHEAD – PULL UP² <ul style="list-style-type: none">- EGPWS: Repeated until condition disappears.- T2CAS: When the warning sensor penetrates the MTCD for at least 2 seconds. Repeated until conditions disappear. 

¹ The European EASA regulations require the wording TERRAIN AHEAD. The FAA regulations require CAUTION TERRAIN.

² The European EASA regulations require the wording TERRAIN AHEAD – PULL UP. The FAA regulations require TERRAIN TERRAIN – PULL UP.



TOO LOW TERRAIN

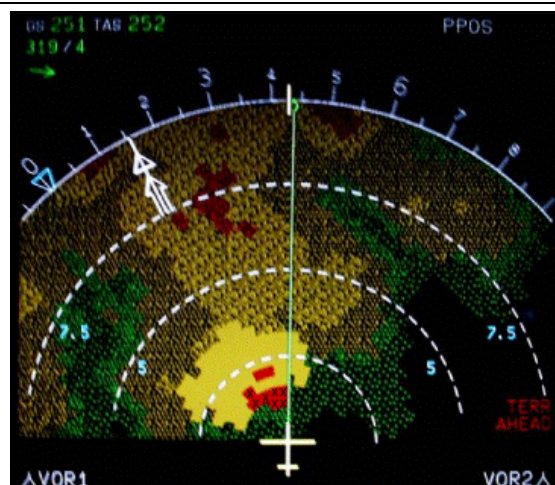
- **EGPWS TCF:** When the aircraft penetrates the TCF envelope and each time the AGL altitude deteriorates by 20%.
- **T2CAS PDA:** Refer to 4.1.3.2.3 – T2CAS Premature Descent Alert (PDA) for triggering conditions.



AVOID TERRAIN Warning



AVOID TERRAIN³ - T2CAS only - 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.

³ The TERRAIN AHEAD – PULL UP warning (or the equivalent FAA warning) always precedes the AVOID TERRAIN warning.

4.1.5.3. EGPWS: OBSTACLE

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

OBSTACLE AHEAD Caution	OBSTACLE AHEAD Warning
 <p>OBSTACLE AHEAD⁴ every 7 seconds until conditions disappear.</p> 	 <p>OBSTACLE AHEAD – PULL UP⁵ repeated until condition disappears.</p> 
<p>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 4.1.5.2 – TAWS Predictive Functions.</p>	

4.1.5.4. EGPWS: PEAKS MODE

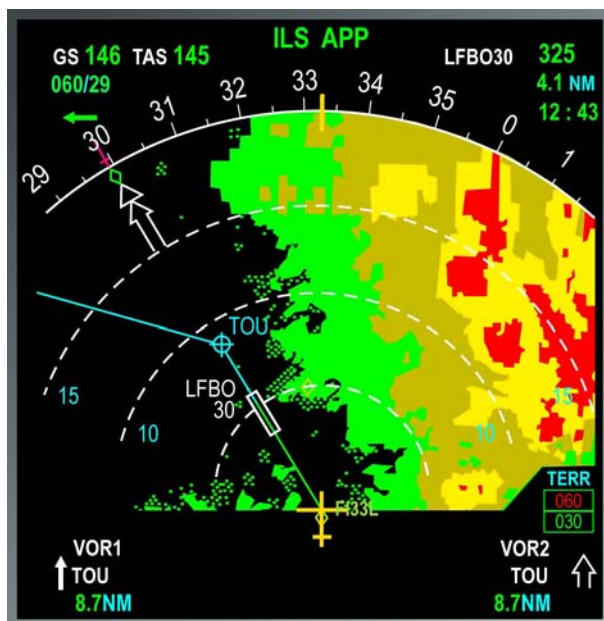
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Figure 4-17: EGPWS Peaks mode

The Peaks mode display is optional. It improves the terrain awareness of the flight crew by displaying the terrain data further than 2 000 ft below the aircraft. Refer to Figure 4-4.

The highest and the lowest terrain altitudes are displayed in the ND bottom right corner. The lowest terrain altitude is available on EIS2 only. Refer to Figure 4-17.

⁴ The European EASA regulations require the wording OBSTACLE AHEAD. The FAA regulations require CAUTION OBSTACLE.

⁵ The European EASA regulations require the wording OBSTACLE AHEAD – PULL UP. The FAA regulations require OBSTACLE OBSTACLE – PULL UP.

4.1.5.5. TERRAIN DISPLAY IN POLAR AREAS

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 7-10). Only **EGPWS** is affected.

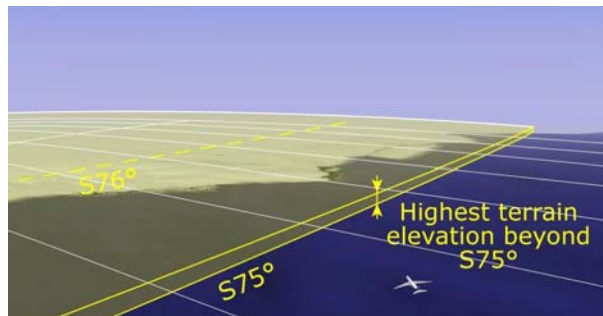


Figure 4-18: Unique terrain elevation beyond N75° or S75°

The **T2CAS** 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 4-18.

In other words, the T2CAS considers this region as a cylindrical mountain. The height of this cylindrical mountain is equal to the highest elevation in this region.

Figure 4-19 provides the areas contained in the N75° and S75° circles.

Refer to 7.1.3.3 – Terrain Display in Polar Areas for more details.

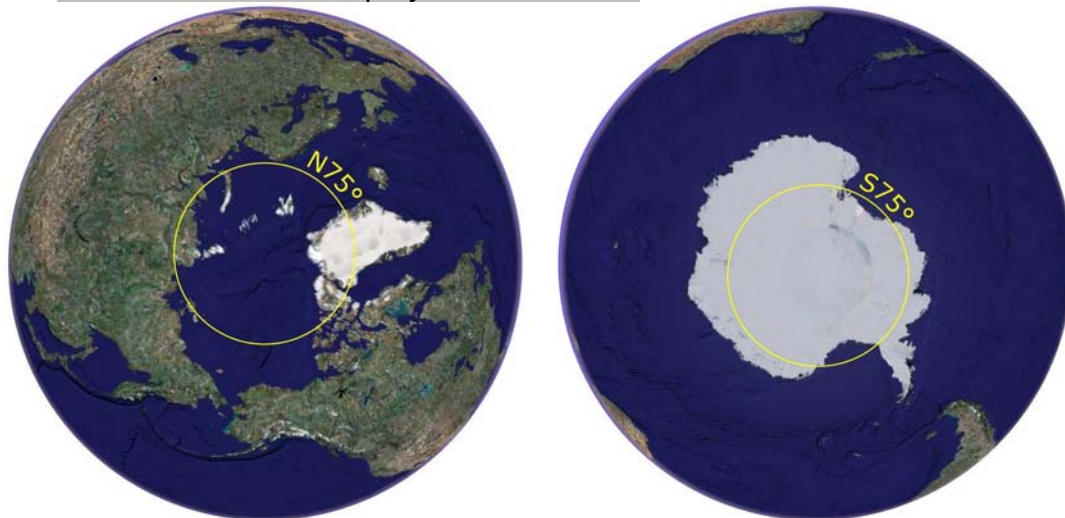


Figure 4-19: Areas beyond N75° and S75°

4.1.6. TAWS CONTROLS

4.1.6.1. A300/A310 CONTROLS



Figure 4-20: GPWS landing SLATS/FLAPS switch

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.



Figure 4-21: Control panel on Captain side

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 T2CAS).

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.



Figure 4-22: TERR ON ND pushbutton

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

4.1.6.2. A320/A330/A340 CONTROLS



Figure 4-23: A320 overhead panel



Figure 4-24: A330 / A340 overhead panel

TERR: Inhibition of predictive functions (TAD/TCF for EGPWS or CPA/THD for T2CAS).

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).

Tips: 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 4-16) may occur and false alerts may be triggered.



Figure 4-25: 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.

4.2. 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.

4.2.1. 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:** <http://www.honeywell.com/sites/aero/Egpws-Home.htm>.
 - **T2CAS:** <http://www.acsscusterservices.com/CustomerServices/>.

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.**

- 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.

- **AIRBUS strongly recommends the implementation of the GPS position into the TAWS architecture.** 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).
- **Take cognizance of the Flight Safety Foundation (FSF) Approach-and-Landing Accident Reduction (ALAR) tool kit** (available at <http://www.flightsafety.org/ecommerce/>) and spread out its contents inside the company as necessary.

4.2.2. FOR THE FLIGHT CREW

- **Stick to the procedures.** Refer to your FCOM for the appropriate procedures. Refer to FOBN “Operating Environment – Enhancing Terrain Awareness” (See AIRBUS References) for a comprehensive set of recommendations.
- **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). Refer to FOBN “Supplementary Techniques – Use of Radio Altimeter” (See AIRBUS References).
- **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). Refer to FOBN “Human Performance – Effective Pilot/Controller Communications” (See AIRBUS References).

4.3. 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 EU OPS 1.665:

- TAWS with a predictive terrain hazard warning function is mandatory.

As per FAA FAR 121.354:

- TAWS is mandatory for aircraft manufactured after 29 MAR 2002.
- TAWS is mandatory since 29 MAR 2005 for aircraft manufactured on or before 29 MAR 2002.

4.4. MANUFACTURERS FOR TAWS

To fulfill the Terrain Awareness function, AIRBUS proposes the following two systems: the Honeywell EGPWS and the ACSS T2CAS, available at the time of writing the brochure.

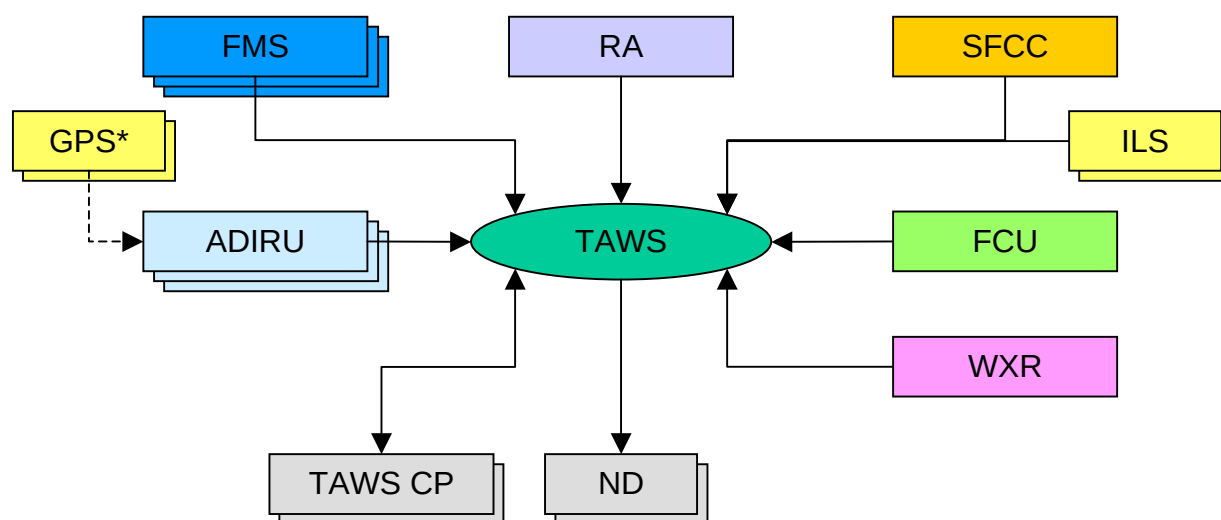


Figure 4-26: TAWS architecture

Figure 4-26 provides a simplified view of the TAWS architecture.

* Refer to 4.1.4 – Introduction of GPS Position into TAWS Architecture for details.

4.4.1. HONEYWELL EGPWS

The Honeywell GPWS was the first system to be certified on AIRBUS aircraft in early 1990s. The Honeywell EGPWS was the first system capable of predictive functions to be certified on AIRBUS aircraft in late 1990s on A300/A310/A320/A330/A340 aircraft.

More information is available at <http://www.honeywell.com/sites/aero/Egpws-Home.htm>.

4.4.2. ACSS T2CAS

The ACSS T2CAS includes a TAWS module capable of predictive functions. It was certified in 2004 on AIRBUS aircraft.

As the name indicates, the T2CAS encompasses two functions (traffic awareness and terrain awareness) into the same Line Replaceable Unit (LRU). In terms of

architecture, the T2CAS LRU is inserted into the ACAS LRU (e.g. TCAS 2000) and EGPWS wirings are directly connected to the T2CAS (refer to Figure 4-28).

The advantages of T2CAS are less weight, simplified maintenance, less wiring, less sparing.

More information is available at <http://www.acssonboard.com/products/t2cas/>.

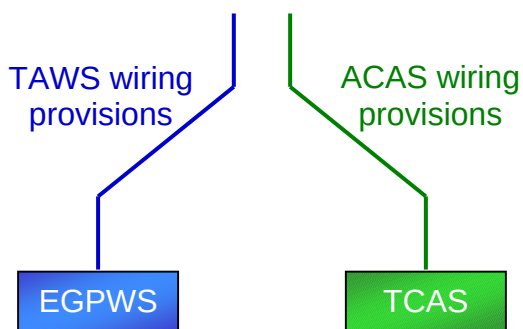


Figure 4-27: Standard architecture

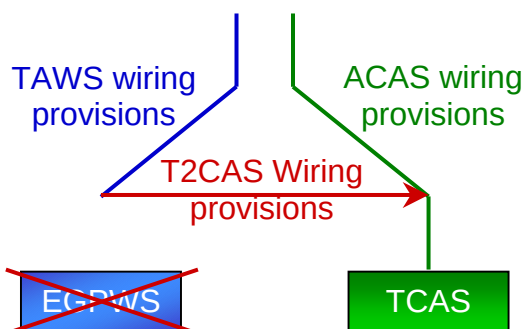


Figure 4-28: T2CAS architecture

4.4.3. TAWS MODULE OF ACSS T3CAS

The ACSS T3CAS is a further step of integration including:

- A Mode S transponder capable of ADS-B OUT as per DO-260A Change 2
- A TCAS compliant with TCAS II Change 7.1
- An enhanced TAWS module derived from T2CAS TAWS module.

The advantages of this integration are the same as for T2CAS, a step further: reduced weight, volume, wiring, and power consumption.

The TAWS module of T3CAS is developed from the TAWS module of T2CAS. It will also include additional features such as:

- The Eleview (equivalent to the EGPWS Peaks mode) that enables RNP AR operations
- The obstacle database.

The certification of the T3CAS is expected by end 2009. More information is available at <http://www.acssonboard.com/media/brochures/T3CAS.pdf>.

4.5. FUTURE SYSTEMS

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, and Runway Field Clearance Floor (RFCF).
- **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 Elevew and an obstacle database.

Refer to **4.1.3.3 – EGPWS/T2CAS Comparison** to compare both 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.

Refer to **4.2 – Operational Recommendations for TAWS.**

Regulations

The carriage of TAWS is mandatory as per ICAO Annex 6 – Operation of Aircraft – Part I.

Future systems

At the time of writing the brochure, no new TAWS computer is expected on a short term.



5. RUNWAY SURVEILLANCE

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The unfortunately famous 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 such as EMMA2 (European airport Movement and Management by A-SMGCS), which encompasses new technologies (ATC clearances through CPDLC, on-board traffic awareness thanks to ADS-B).

Today, two systems are available on AIRBUS aircraft. These two systems are quite different as they are based on different principles.:

- The **On-board Airport Navigation System (OANS)** is a new system that provides visual indications: the aircraft position on an interactive airport moving map. Therefore, OANS provides the flight crew with a precise aircraft position on an airport surface. OANS is developed by Thales and is integrated in the A380 cockpit. In future standards, OANS will take benefit of emerging technologies (e.g. ground ATC data link clearances, positions of surrounding aircraft thanks to ADS-B).
- The **Runway Awareness and Advisory System (RAAS)** is an add-on module of the EGPWS by Honeywell. It provides aural indications (call-outs) based on GPS position when operating in the vicinity of a runway (airborne or on ground). RAAS was certified on A320 and A330/A340 family aircraft in 2007. and on A300/A310 family aircraft in 2008.

The runway excursion is another risk during runway operations (e.g. Toronto, Canada, 2005). To that end, AIRBUS proposes a Runway end Overrun Warning (ROW) and a Runway end Overrun Protection (ROP). ROW and ROP provide aural and visual indications when a risk of runway end overrun is detected during the landing phase.

In combination with ROW and ROP, AIRBUS also proposes the Brake-To-Vacate (BTV) function. BTV aims at optimizing the brake utilization and the passenger comfort when the flight crew selects a runway exit. Some ROW/ROP and BTV visual indications are provided on the OANS display.

On-board Airport Navigation System – OANS

5.1. DESCRIPTION OF OANS

OANS is a new system introduced by the A380. 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 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.

5.1.1. OANS TERMINOLOGY

5.1.1.1. 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).

5.1.1.2. AIRPORT DATA BASE (ADB)

The Airport Data Base (ADB) contains a set of AMDBs and customization settings (i.e. AMI files). ADB is updated on a 28-day cycle.

Note: OANS does not provide information about temporary airport taxi restrictions. In addition, OANS may not display recent changes (new buildings or construction areas). Refer to NOTAM.

5.1.1.3. AIRPORT MAP

OANS displays on ND a background picture called the Airport Map. OANS constructs the Airport Map with AMDBs.

5.1.1.4. 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.

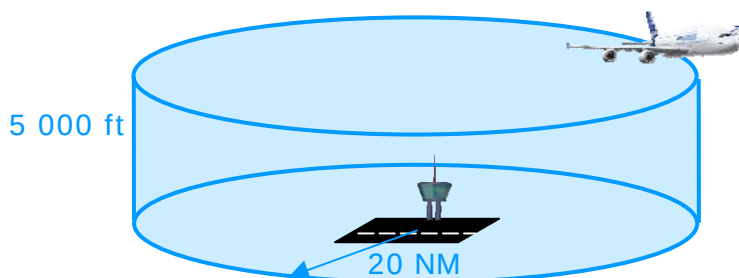


Figure 5-1: Coverage volume

5.1.1.5. 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.

5.1.1.6. 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 ft or 2 min after lift off), particularly for proximate airports (less than 300 NM).

5.1.1.7. 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.

5.1.2. OANS PRINCIPLES

5.1.2.1. 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:

- 10 m (33 ft) for the position
- 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 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:**
 - 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 **5.1.4 – OANS Controls** for details.

5.1.2.2. 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 **5.1.3.5 – Approaching Runway Indication**).

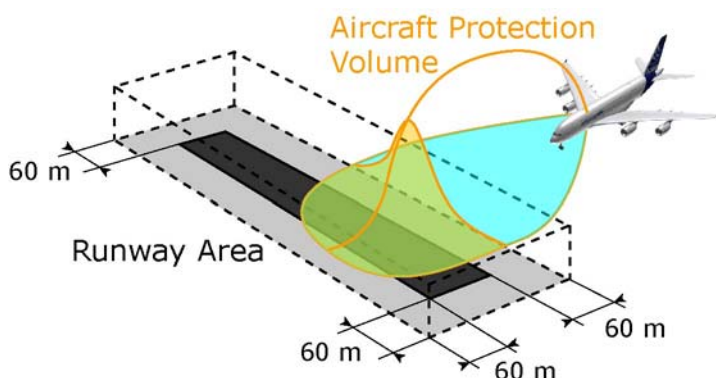


Figure 5-2: Detection of runway proximity

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.

5.1.3. OANS INDICATIONS

The OANS indications are displayed on ND and are split into three parts.



Figure 5-3: 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 5.1.4.5 – Interactive Control Menu).

The **Soft Control Panel** provides several controls (e.g. airport selection, activation of new ADB, addition of crosses and flags, etc). Refer to 5.1.4.6 – Soft Control Panel.

5.1.3.1. 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.

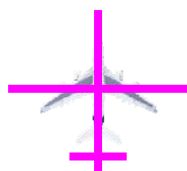


Figure 5-4

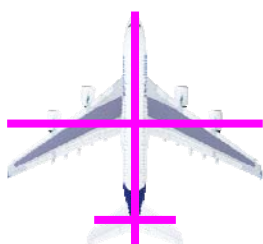


Figure 5-5

For display ranges from 0.5 to 5 NM, the aircraft symbol is displayed with the same size (Figure 5-4).

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 5-5).

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.

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.

5.1.3.2. 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.

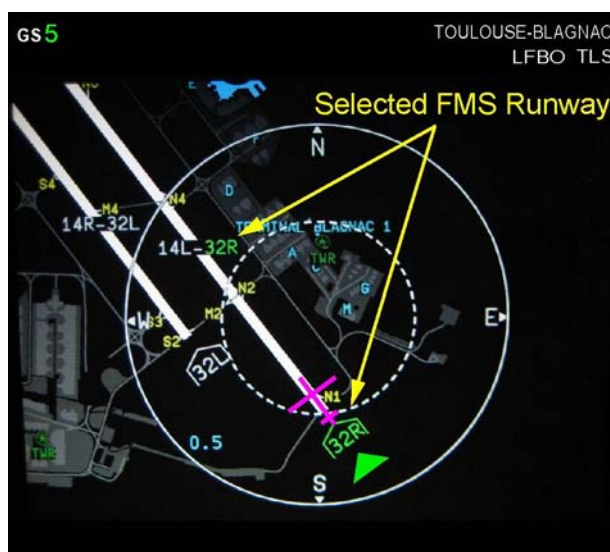


Figure 5-6: FMS active runway

5.1.3.3. 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.

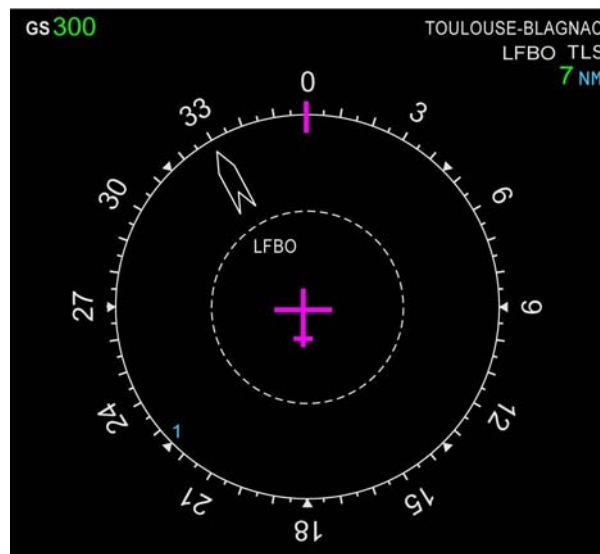


Figure 5-7: Destination arrow

Note: 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.

5.1.3.4. AIRPORT MAP

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.

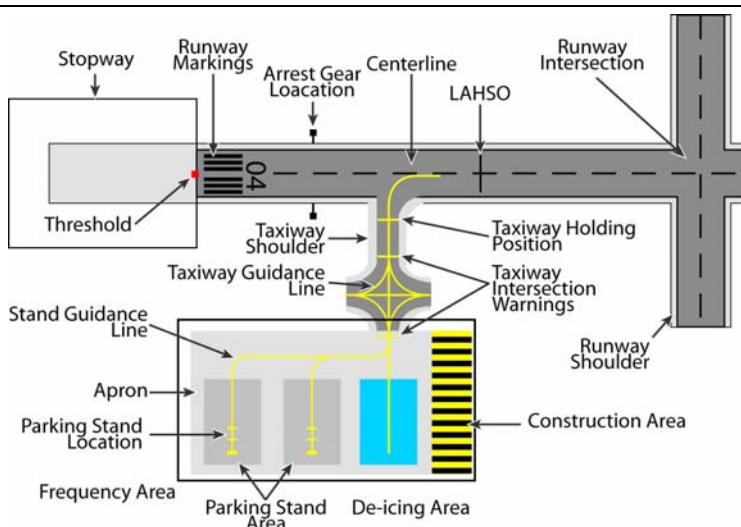
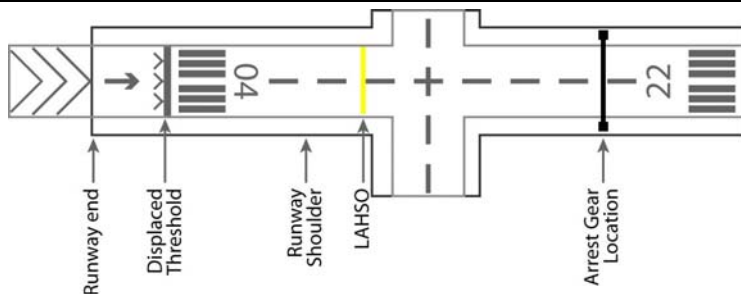
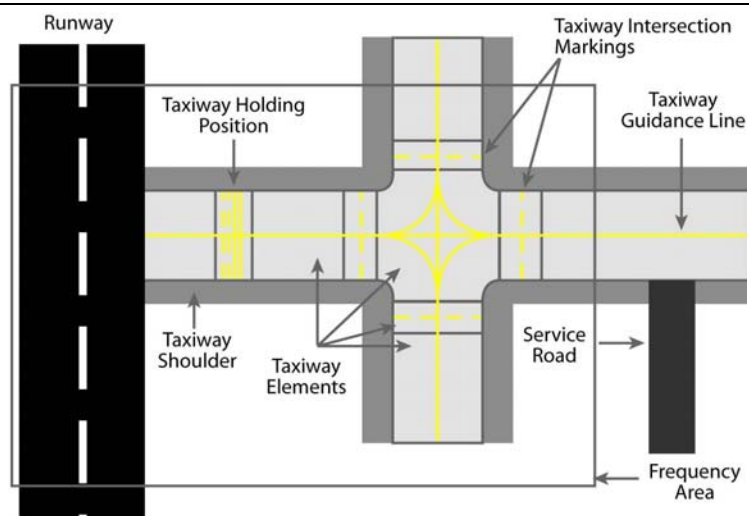


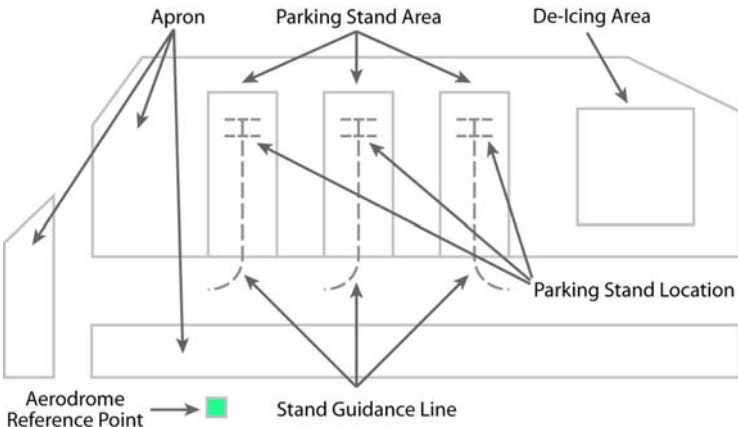
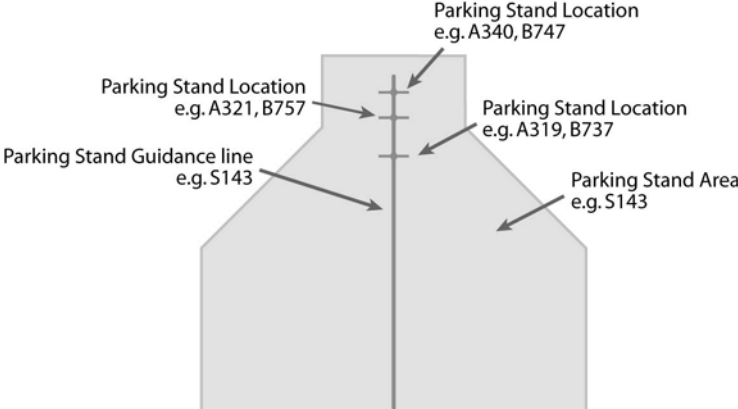
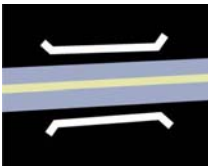
Cross

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.



The flight crew can use flags as checkpoints to draw the taxiing path and crosses to identify forbidden taxiways.

AMDB elements**Runway elements****Taxiway elements**

Apron elements	
Parking stand elements	
Labels OANS identifies the following elements with a label: <ul style="list-style-type: none"> - Runways, - Taxiways, - Parking stands, - Stand lines, - Vertical structures, - Control towers. 	<div style="background-color: black; color: yellow; text-align: center; padding: 2px;">P20</div> Taxiway example
Bridge symbol The OANS depicts a bridge as follows.	

5.1.3.5. APPROACHING RUNWAY INDICATION

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.



Figure 5-8: APPROACHING RUNWAY advisory in ARC mode

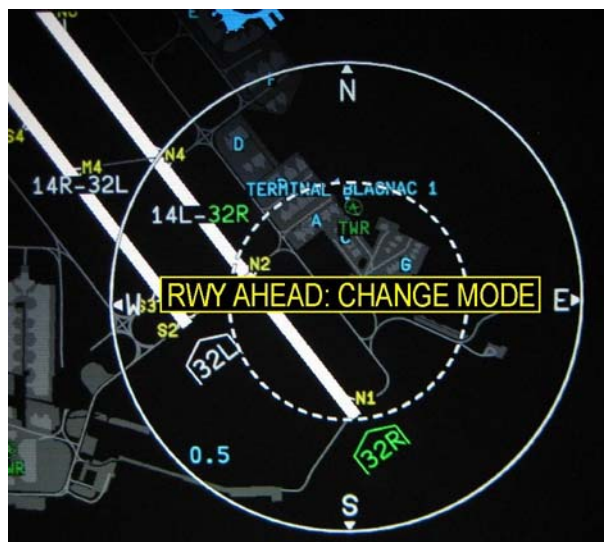


Figure 5-9: APPROACHING RUNWAY advisory in PLAN mode

5.1.3.6. OANS MESSAGES

Airport Map

Message	Color	Triggering condition
PLEASE WAIT	White	When the OANS processing time (e.g. map loading) exceeds 1 second.
ARPT NOT IN ACTIVE F-PLN	White	In PLAN mode, when: <ul style="list-style-type: none"> - 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.

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	White	In the AIRPORT SELECTION Page, when the OANS does not find an airport in the airports list. [filter] refers to ICAO, IATA or CITY NAME.
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).

5.1.4. OANS CONTROLS

5.1.4.1. 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.

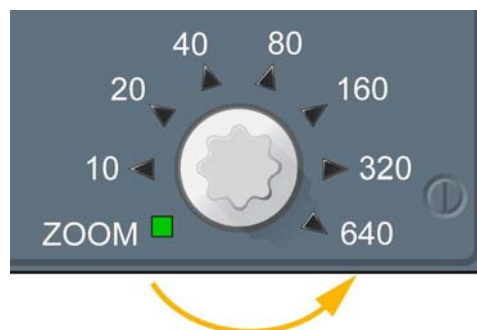


Figure 5-10: A380 EFIS CP range selector

5.1.4.2. EFIS CP ND DISPLAY MODE



Figure 5-11: A380 EFIS CP mode selector

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.

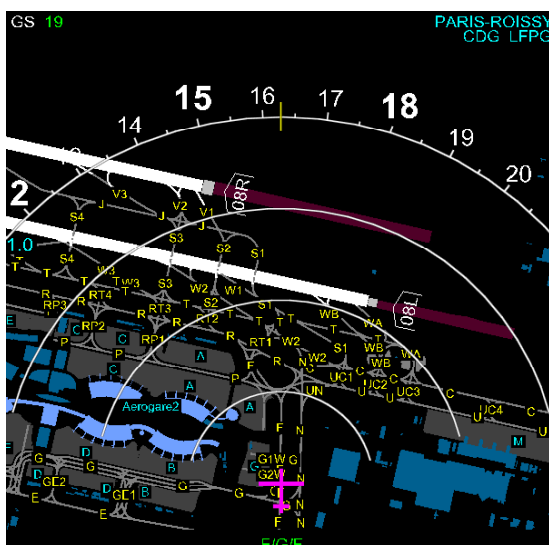


Figure 5-12: ND ARC mode

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.

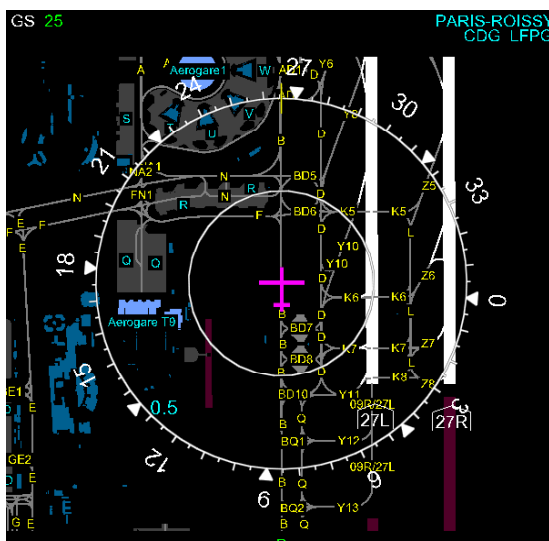


Figure 5-13: ND ROSE NAV mode

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.

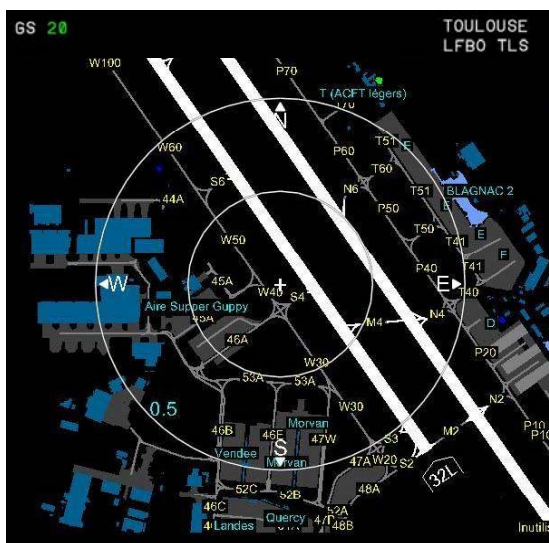


Figure 5-14: ND PLAN mode

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.

5.1.4.3. KCCU

The flight crew uses the 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.

5.1.4.4. 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.



Figure 5-15: KCCU

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.

5.1.4.5. INTERACTIVE CONTROL MENU

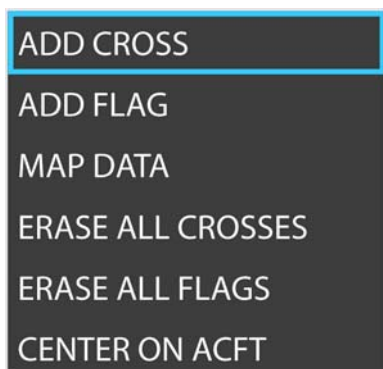


Figure 5-16: Interactive Control Menu

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.

5.1.4.6. 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 (refer to 5.6.5.1 – Runway Shift).

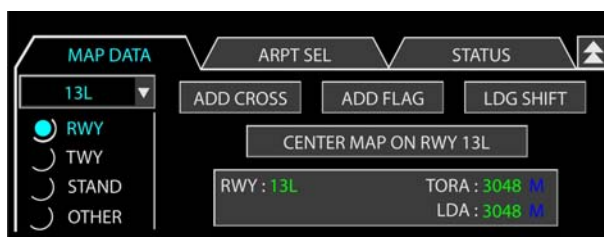


Figure 5-17: MAP DATA page

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.

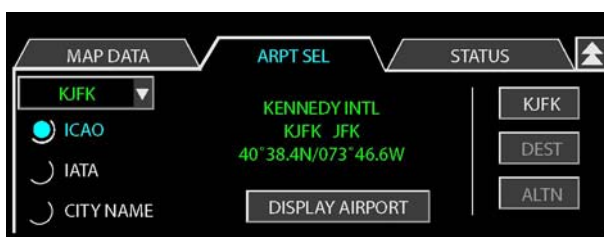


Figure 5-18: ARPT SEL page

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 activation¹ when the ADB is outdated, missing or incorrectly loaded.

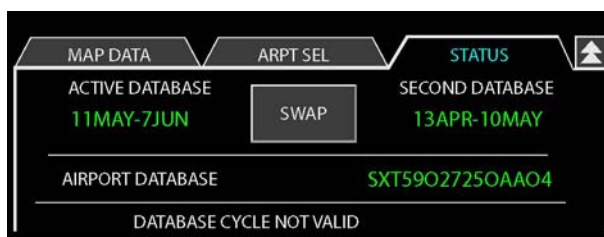


Figure 5-19: STATUS page

5.2. OPERATIONAL RECOMMENDATIONS FOR OANS

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.

5.2.1. FOR THE AIRLINE

- **Do not use OANS as a guidance tool.** OANS is designed to improve the situational awareness.
- **Keep the OANS databases up to date.** ADB is updated every 28 days. Please refer directly to your chart provider.

¹ First OANS activation when the aircraft is at the gate.

5.2.2. FOR THE FLIGHT CREW

- **Do not use OANS as a guidance tool.** OANS is designed to improve the situational awareness.
- **Always correlate the OANS aircraft position with outside visual references.**
- **Outside visual references supersede OANS 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). Refer to FOBN “Human Performance – Effective Pilot/Controller Communications” (See [AIRBUS References](#)).
- Refer to FOBN “Runway and Surface Operations – Preventing Runway Incursions” (See [AIRBUS References](#)).
- **PF: Refer to outside visual references. PNF: Assist PF with OANS indications as necessary.**
- **PNF: In reduced visibility conditions, announce when approaching active runways.**
- **Before takeoff, when OANS is no longer used, set the minimum ND range to display the first waypoint after departure, or as required for weather purposes.**

5.3. REGULATIONS FOR OANS

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.

5.4. MANUFACTURER FOR OANS

Thalès and AIRBUS jointly developed OANS. At the time of writing the present brochure, OANS is available on A380 aircraft (basic configuration).

[Figure 5-20](#) provides a simplified view of the OANS architecture.

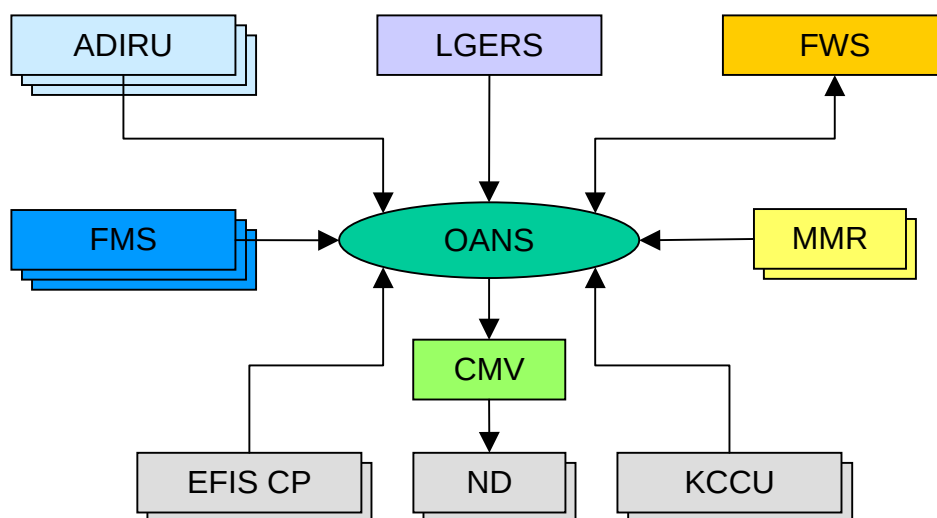


Figure 5-20: OANS architecture

5.4.1. UPDATE OF OANS DATABASES

The OANS 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.

5.5. FUTURE SYSTEMS

OANS will take benefits of emerging technologies. The new functions under studies are the integrations of:

-
- ADS-B IN data to detect aircraft conflicting with own aircraft path.
- The ATSA-SURF application to display surrounding aircraft on the airport map,
- Data link applications to display NOTAM and ATC ground clearances (e.g. taxi path on airport map).

Please bear in mind...**Description**

The **On-board Airport Navigation System (OANS)** is a new system introduced by the A380. It improves the flight crew situational awareness during taxi by locating the aircraft on an airport map.

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.

Operational recommendations

The main recommendations (but non exhaustive) are:

- **OANS is not a guidance tool**
- A regular update of OANS Airport Data Base (ADB)
- **The check of NOTAM before taxiing**
- **The correlation of OANS indications with outside visual references.**

Refer to 5.2 – Operational Recommendations for OANS.

Regulations

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

Future systems

The future evolutions of OANS are expected for the integration of:

- The ADS-B data for Traffic Surveillance
- Data link applications to display NOTAM and ATC ground clearances.

Runway end Overrun Warning and Protection (ROW / ROP)

5.6. DESCRIPTION OF ROW/ROP

The goal of ROW/ROP is to help the flight crew anticipating an overrun of the runway end during the landing phase. ROW/ROP computes braking distances and compares them to the Landing Distance Available (LDA) in real time:

- **When the aircraft is on final approach: ROW** provides aural and visual indications if the aircraft braking performances are not sufficient to stop on the runway. The flight crew should perform a go-around.
- **When the aircraft is on the runway: ROP** provides aural and visual indications if the current aircraft braking performances are not sufficient to stop on the runway. ROP applies the maximum braking and the flight crew shall apply or maintain MAX REVERSE.

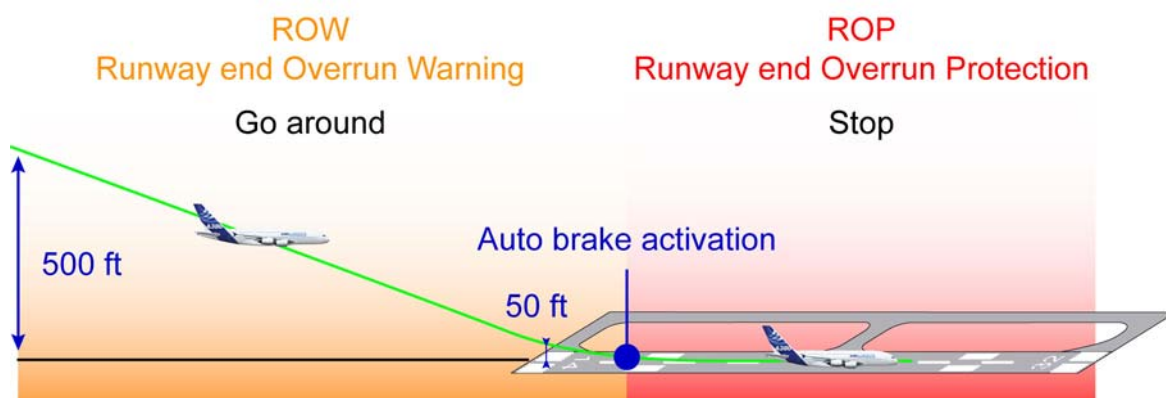


Figure 5-21: ROW and ROP concept

The ROW/ROP function is available:

- In all auto brake modes (including Brake To Vacate – BTV, see note below)
- On all runway conditions (dry, wet and contaminated)
- For all aircraft landing configuration (weight, CG, slats/flaps configuration, etc)
- For any wind and visibility conditions within the aircraft envelope
- With or without autopilot.

At present, ROW and ROP are designed for a utilization with an automatic braking only. Refer to **5.10 – Future systems**.

Note: 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:
 - Brake temperature (reduction of hydraulic fluid temperature, reduction of carbon brake oxidation)
 - Risk of tire deflation
 - Tire wear
 - Turn around 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.

5.6.1. ROW/ROP PRINCIPLES

The ROW/ROP function:

- Computes the landing distances considering the auto brake is set to HI in:
 - **Dry conditions:** Dry runway with the use of reversers
 - **Wet conditions:** The greatest landing distance between:
 - Wet runway without the use of reversers
 - Water contaminated runway with the use of reversers.
- Compares these landing distances to the Landing Distance Available (LDA – including potential runway shifts) taking into account parameters like:
 - Aircraft weight
 - Ground speed
 - Wind
 - Vertical profile (glide slope, 50 ft RA, flare)
 - Landing configuration.
- Triggers an alert when one of the landing distances is greater than LDA.

Definitions of runway states as per EU-OPS1

Contaminated runway: A runway is considered to be contaminated when more than 25 % of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:

- i. Surface water more than 3 mm (0.125 in) deep, or by slush, or loose snow, equivalent to more than 3 mm (0.125 in) of water, or
- ii. Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow), or
- iii. Ice, including wet ice.

Dry runway: A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain “effectively dry” braking action even when moisture is present.

Wet runway: A runway is considered wet when the runway surface is covered with water, or equivalent, less than specified in [contaminated runway] or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

5.6.1.1. AUTOMATIC DETECTION OF THE RUNWAY FOR LANDING

When the destination airport is known (i.e. in the FMS flight plan), the runway for landing is automatically detected. The auto-detection of the landing runway aims at coping with mistakes or omissions of the flight crew, or late runway changes.

When the flight crew selects:

- An auto brake mode (except BTV), the automatic detection of the landing runway is active between 500 ft and 300 ft.
- BTV, the automatic detection of the landing runway is active at 300 ft.

If the automatic detection of the landing runway fails (i.e. no detected runway), the ROW/ROP function is lost. Besides, if the ROW/ROP function is lost, the BTV function is lost.

5.6.1.2. ROW ARMED

ROW arms when the landing runway is automatically detected (refer to 5.6.1.1 – Automatic Detection of the Runway for Landing). Therefore:

- OANS highlights QFU of the automatically detected runway.
- ROW computes, in real time, the minimal braking distances in dry and wet conditions.
- If the flight crew selects BTV, OANS displays the braking distances computed in dry and wet conditions (**DRY and WET lines** – refer to 5.6.3.1 – ROW Indications When Armed) over the landing runway. As ROW computes the minimal braking distances in real time, OANS adjusts the DRY and WET lines on the landing runway.

5.6.1.3. ROW ENGAGED

ROW engages when the minimal braking distance computed in dry or wet conditions exceeds LDA. It means that ROW engages when the DRY or WET line (in BTV mode only) exceeds the runway end on OANS display.

When ROW engages, it triggers an alert with visual and/or² aural indications:

- When the braking performances computed in **wet** conditions are not sufficient **and** the runway is currently **wet**, the flight crew should perform a go-around.
- When the braking performances computed in **wet** conditions are not sufficient **and** the runway is currently **dry**, the flight crew should disregard the alert.
- When the braking performances computed in **dry** conditions are not sufficient, the flight crew should perform a go-around.

ROW disengages and disarms when the flight crew performs a go-around.

ROW disengages (but remains armed) when updated braking distances in dry and wet conditions do not exceed LDA anymore.

² ROW triggers an aural alert only below 200 ft RA when the braking performances in **dry** conditions are not sufficient.

5.6.1.4. ROP ARMED

ROP arms when the auto brake engages. The auto brake engages in landing mode when:

- The ground spoilers extend and the nose landing gear is on ground, or
- 5 seconds after the ground spoiler extension, whichever occurs first.

When ROP arms:

- ROP computes, in real time, a braking distance to reach a target speed that equals to:
 - 0 kt if the flight crew selected an auto brake mode (except BTV), or
 - 10 kt if the flight crew selected BTV.
- OANS displays this computed braking distance over the landing runway (**STOP bar** – refer to 5.6.3.3 - ROP Indications When Armed).

ROP remains armed until the flight crew disconnects the auto brake.

5.6.1.5. ROP ENGAGED

ROP engages:

- When the STOP bar exceeds the runway end, or
- As soon as the auto brake engages if ROW had previously engaged between the deployment of ground spoilers and the activation of auto brake.

Therefore, ROP:

- Controls the maximum braking performance³ (same as in RTO mode).
- Triggers aural and visual indications to apply or maintain MAX REVERSE.

ROP disengages (but remains armed) when the STOP bar does not exceed the runway end anymore. Therefore, the auto brake reverts to the mode selected by the flight crew.

5.6.2. AUTO BRAKE DISCONNECTION

The flight crew disconnects the auto brake by:

- Pressing the brake pedals, or
- Pressing the A/THR instinctive disconnect pushbutton on the thrust levers, or
- Switching the auto brake mode selector to DISARM.

Pressing the A/THR instinctive disconnect pushbutton on the thrust levers is a new method to disconnect the auto brake introduced by ROW/ROP/BTV.

The auto brake automatically disconnects when the aircraft reaches:

- 0 kt if the flight crew selected an auto brake mode (except BTV), or
- 10 kts if the flight crew selected BTV.

³ If the ROW/ROP function is lost during the period when ROP is engaged, the auto brake maintains the maximum braking performance.

5.6.3. ROW/ROP INDICATIONS

5.6.3.1. ROW INDICATIONS WHEN ARMED

If the flight crew selected an auto brake mode (except BTV), ROW highlights the runway QFU.

If the flight crew selected BTV, ROW displays the DRY and WET lines in magenta.

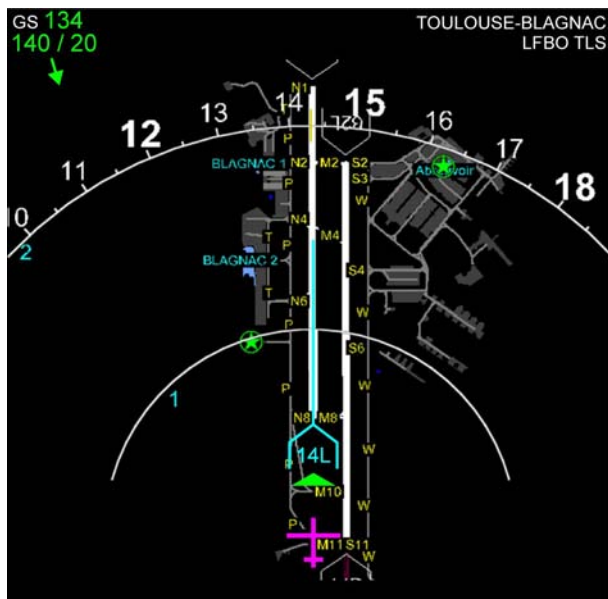


Figure 5-22: ROW armed with auto brake (except BTV) selected

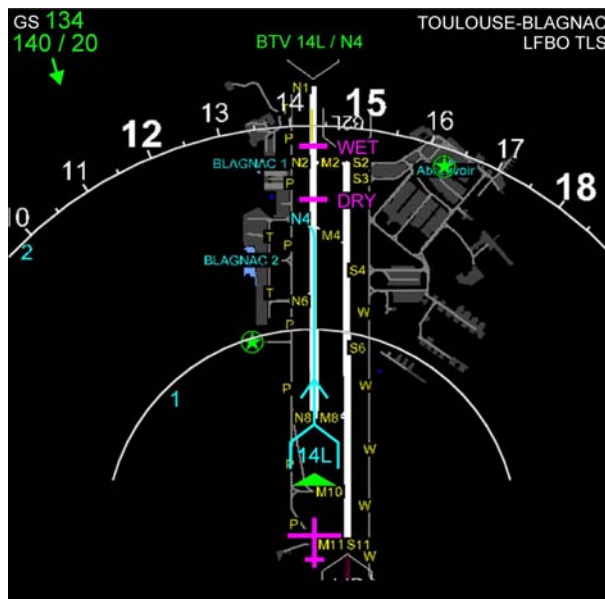


Figure 5-23: ROW armed with BTV selected

Note 1: ROW computes the braking distances in real time. Therefore, the DRY and WET lines move along the runway according to the current flight conditions (Vapp, landing configuration, aircraft position, ground speed, wind, aircraft weight).

Note2: The green triangle refers to the runway selected in the FMS.

5.6.3.2. ROW INDICATIONS WHEN ENGAGED

- **Computed braking performances not sufficient in wet conditions**

On ND

If the flight crew selected an auto brake mode (except BTV), there is no additional ROW indication on ND when ROW engages. Refer to [Figure 5-22](#).

If the flight crew selected BTV, when ROW engages, it displays:

- The WET bar in amber
- The path between the runway end and the WET bar in amber.



Figure 5-24: ND – ROW engaged with BTV selected (wet conditions)

On PFD

ROW displays an amber message IF WET: RWY TOO SHORT on PFD, regardless of the selected auto brake mode.



Figure 5-25: PFD – ROW engaged

- **Computed braking performances not sufficient in dry conditions**

On ND

If the flight crew selected an auto brake mode (except BTV), there is no additional ROW indication on ND when ROW engages. Refer to Figure 5-22.

If the flight crew selected BTV, when ROW engages, it displays:

- The WET and DRY lines in red
- The path between the runway end and the WET and DRY lines in red.



Figure 5-26: ND – ROW engaged with BTV selected (dry conditions)

On PFD

ROW displays a red message RWY TOO SHORT on PFD, regardless of the selected auto brake mode. In case of wind shear, the red message WINDSHEAR has priority.

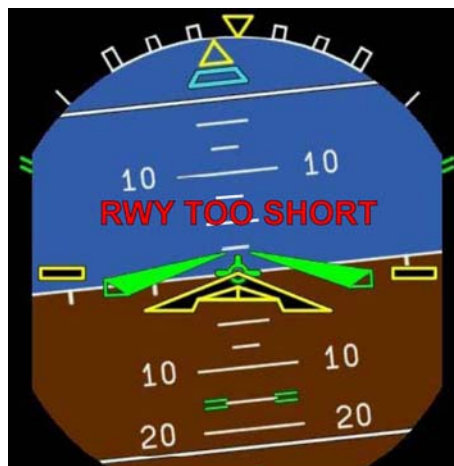


Figure 5-27: PFD – ROW engaged



RUNWAY TOO SHORT

ROW triggers the aural alert RUNWAY TOO SHORT below 200 ft RA.

5.6.3.3. ROP INDICATIONS WHEN ARMED

If the flight crew selected an auto brake mode (including BTV), ROP displays the STOP bar.

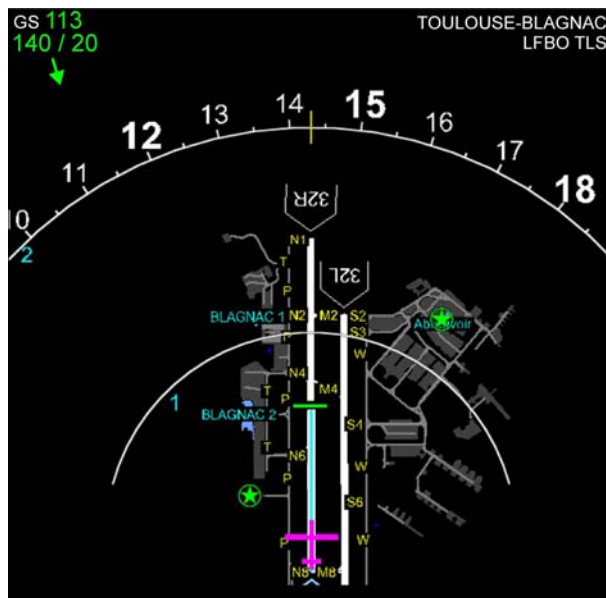


Figure 5-28: ROP armed with auto brake (except BTV) selected

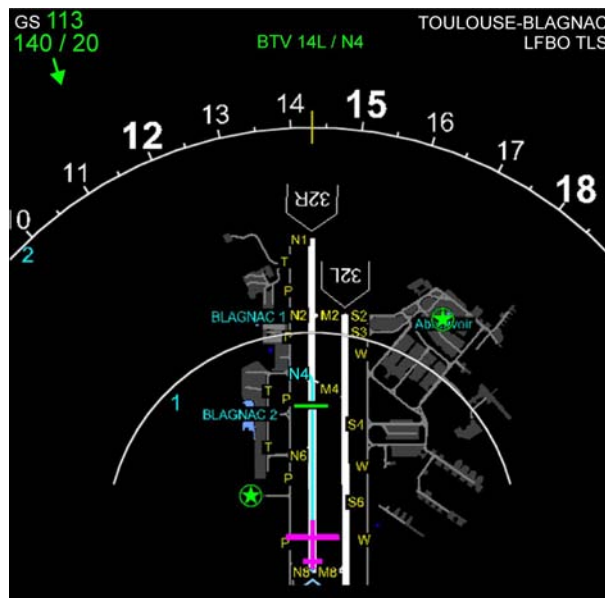


Figure 5-29: ROP armed with BTV selected

Note: The STOP bar moves along the runway as the braking distance is computed in real time according to the current flight parameters.

5.6.3.4. ROP INDICATIONS WHEN ENGAGED

When ROP detects a runway end overrun, it:

- Displays the computed braking distance in red on ND
- Displays the red message MAX REVERSE on PFD.

Refer to [Figure 5-30](#) and [Figure 5-31](#).



MAX REVERSE or KEEP MAX REVERSE

ROP triggers the aural alert:

- MAX REVERSE continuously until the complete deployment of reversers, or
- KEEP MAX REVERSE one time:
 - At 80 kt if the flight crew fully deployed the reversers and ROP still detects a runway end overrun, or
 - Below 80 kt if the flight crew fully deploys the reversers below 80 kt and ROP still detects a runway end overrun.

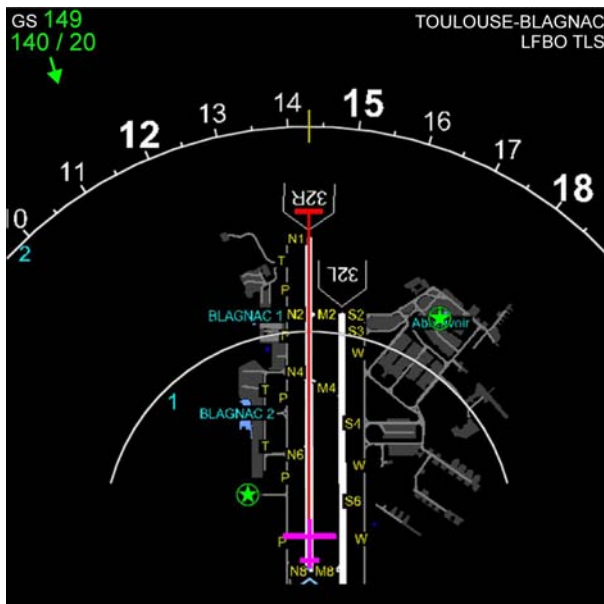


Figure 5-30: ND – ROP engaged

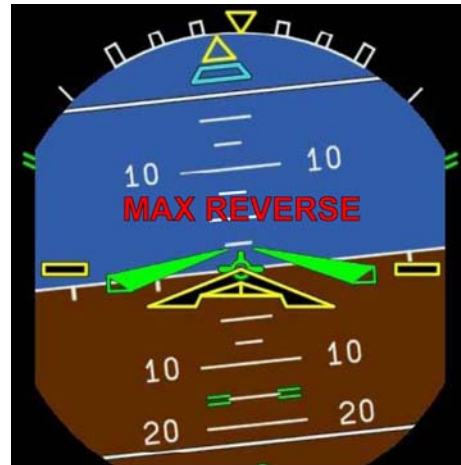


Figure 5-31: PFD – ROP engaged

5.6.4. INDICATIONS FOR AUTO BRAKE DISCONNECTION

When the flight crew deliberately disconnects the auto brake (i.e. press two times on the A/THR instinctive disconnect pushbutton), there is no indication in the cockpit.

When the auto brake is inadvertently or automatically disconnected, aural and visual indications are provided.



Figure 5-32: Indications for inadvertent or automatic auto brake disconnection

In addition, all ROW, ROP and BTV indications are removed from display.

5.6.5. ROW/ROP CONTROLS

5.6.5.1. RUNWAY SHIFT

The flight crew inserts runway shifts via the OANS MAP DATA page (Figure 5-33 to Figure 5-35). The flight crew can insert runway shifts for one runway only at a time.

Used unit (m or ft) is defined by pin-programming.

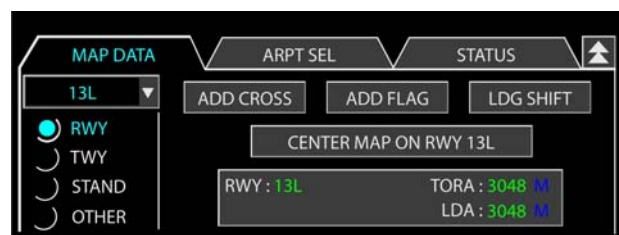


Figure 5-33: Select LDG SHIFT



Figure 5-34: Enter runway shifts

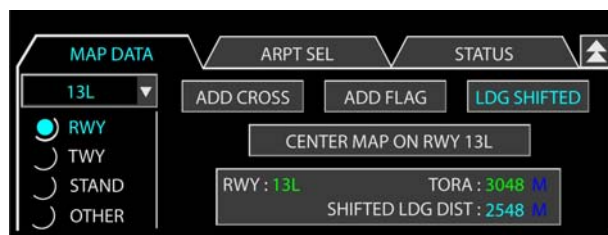


Figure 5-35: Runway shifts entered

Note: Runway shifts are not erased at the end of the flight. They remain active for the next flight unless the next flight crew deletes them.

5.7. OPERATIONAL RECOMMENDATIONS FOR ROW/ROP

5.7.1. FOR THE AIRLINE

- **Train your flight crews** to properly operate ROW and ROP. Particular attention should be paid to task sharing, monitoring of ROW/ROP indications during approach.

5.7.2. FOR THE FLIGHT CREW

- **Be sure to understand ROW and ROP indications.** The DRY and WET lines and the STOP bar move along the runway according to the current flight conditions. Overrun situations can be anticipated thanks to these indications.
- Monitoring of the DRY and WET lines under 500 ft is at PNF's discretion. PNF should concentrate on basic flying parameters.
- Use the A/THR instinctive disconnect pushbutton on the thrust levers to disconnect the auto brake.

5.8. REGULATIONS FOR ROW/ROP

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 ROW/ROP function.

5.9. MANUFACTURERS FOR ROW/ROP/BTV

AIRBUS developed ROW and ROP that are distributed among several systems. They are optional functions and are simultaneously activated via pin-programming.

Figure 5-36 provides a simplified view of the ROW/ROP architecture.

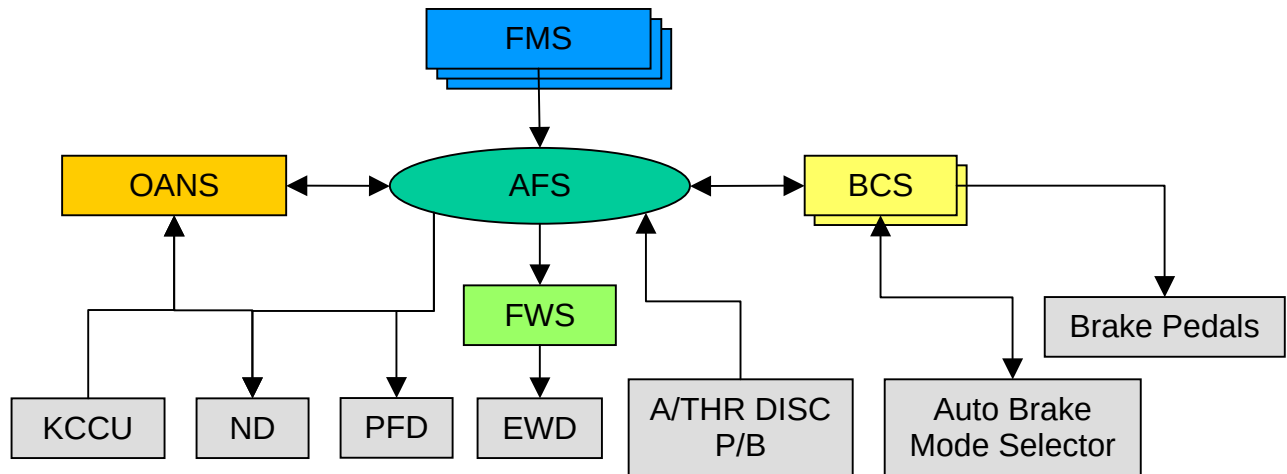


Figure 5-36: ROW /ROP /BTV architecture

5.10. FUTURE SYSTEMS

AIRBUS studies the extension of ROW/ROP to the manual braking mode.

Please bear in mind...**Description**

The ROW and ROP functions help the flight crew anticipating an overrun of the runway end at landing. During the final approach, ROW provides aural and visual indications that invite the flight crew to consider a go around. On the runway, ROP provides aural and visual indications for the settings of thrust reversers. ROW/ROP improves the flight crew awareness regarding risks of runway end overrun.

ROW and ROP are optional functions and used in conjunction with OANS.

Operational recommendations

The main recommendations (but non exhaustive) are:

- The correct understanding of ROW and ROP indications
- The proper disconnection of the auto brake.

Regulations

At the time of writing the present brochure, no country has required the carriage of the ROW/ROP function.

Future systems

AIRBUS studies the extension of ROW/ROP to the manual braking mode.

Runway Awareness and Advisory System – RAAS

5.11. 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.

5.11.1. APPROACHING RUNWAY – ON GROUND ADVISORY – ROUTINE

5.11.1.1. 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 5-37).



Figure 5-37: RAAS Approaching Runway advisory

5.11.1.2. 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.

5.11.2. ON RUNWAY ADVISORY – ROUTINE

5.11.2.1. PURPOSE

The On Runway advisory informs the flight crew on which runway the aircraft is lined-up.

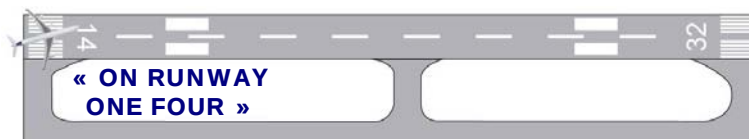


Figure 5-38: RAAS On Runway advisory

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.

5.11.2.2. 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.

5.11.3. TAKEOFF ON TAXIWAY ADVISORY – NON-ROUTINE

5.11.3.1. PURPOSE

The Takeoff On Taxiway advisory informs the flight crew of excessive taxi speed or inadvertent takeoff on taxiway.



Figure 5-39: RAAS Take-Off On Taxiway advisory

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.

5.11.3.2. 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.

5.12. 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).

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.

5.13. 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.

5.14. MANUFACTURER FOR RAAS

The RAAS is part of the Honeywell EGPWS. Additional information is available at http://www.honeywell.com/sites/aero/Egpws-Home3_CB54AACBB-D557-208D-8CE0-EC44CECAAB3B_HD821C499-7201-CF0B-5533-6EFD92534345.htm.

The RAAS requires recent EGPWS software version and terrain database. Refer to the Honeywell RAAS Product Description available at the link mentioned above.

5.15. FUTURE SYSTEMS

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.

Future systems

At the time of writing the present brochure, no evolutions are expected, from an AIRBUS perspective, for RAAS in terms on new functions.



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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 thanks to the weather radar.

At the time of writing the brochure, three types of weather radar are available on Airbus aircraft:

- **Conventional weather radar:** The weather display is synchronized with the movement of the radar antenna.
- **Weather radar with an automatic tilt¹:** It is a radar capable to compute automatically a tilt angle.
- **Weather radar using a buffer:** The weather information from the radar antenna is stored in a buffer. Weather information only applicable for display is extracted from this buffer. Weather radars that use a buffer are Rockwell Collins Multiscan and the AESS weather radar from Honeywell.

The present chapter describes weather radars available on A300/A310/A320/A330/A340 aircraft. For the Honeywell weather radar of AESS available on A380 aircraft, refer to [7 – Aircraft environment Surveillance](#).

6.1. DESCRIPTION OF WEATHER RADAR

Thanks to the characteristics of weather radar pulses, the weather radar detects precipitations, wind shears, turbulence and prominent terrains. 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.

Note: for A380 aircraft, please refer to [7.1.4 – Weather Radar Function](#). However, the weather radar basic principles on-board the A380 remain identical to the ones described in this chapter.

6.1.1. RADAR THEORY

6.1.1.1. 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

¹ Autotilt is a registered trademark of Honeywell.

time, the radar pulse is not able to penetrate wet hail. The weather behind wet hail is often hidden.

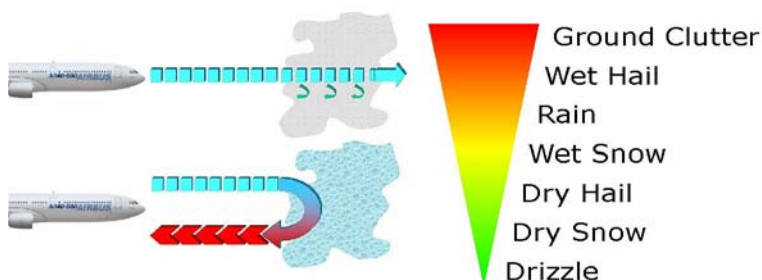


Figure 6-1: Reflectivity of precipitations

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. Indeed, in this area, ice crystals start to melt and are covered of water.

6.1.1.2. REFLECTIVITY OF THUNDERSTORMS

Based on the principle described above, weather radars are optimized to detect rains. Consequently, thunderstorms may be divided into four layers according to the reflectivity of each layer.

- **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.

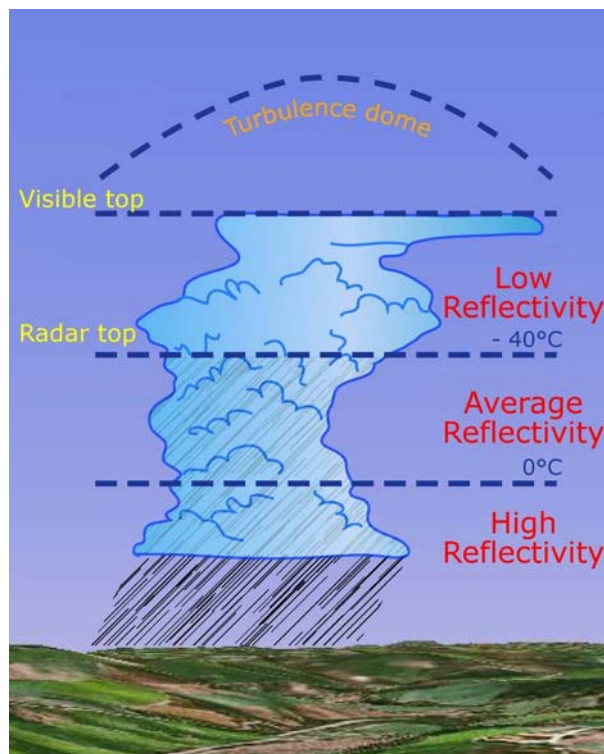


Figure 6-2: Thunderstorm

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.

6.1.1.3. FREQUENCY BAND

As a general physics rule, the propagation of a wave is closely linked to its length or frequency.

As a reminder: $\text{wavelength} = \frac{\text{wave celerity}}{\text{wave frequency}}$

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 6-3 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.**

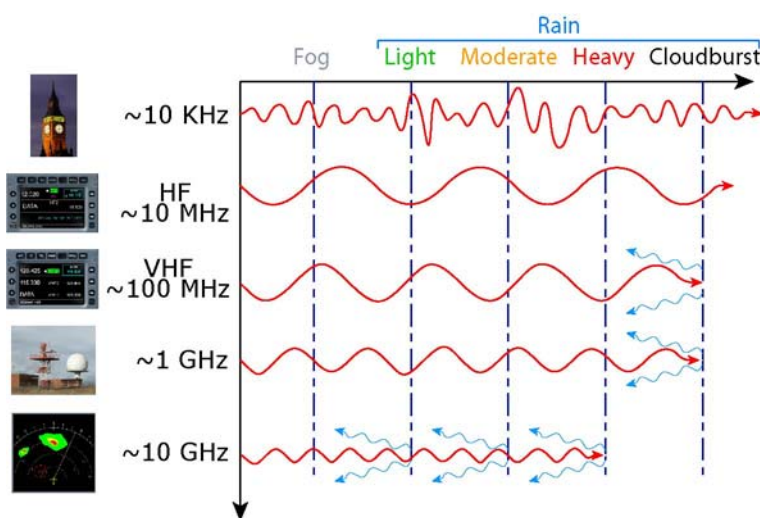


Figure 6-3: Reflectivity per frequency band

6.1.1.4. 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 ² (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

² 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).

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 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).

Note: Turbulence remains magenta regardless of the gain setting.

6.1.1.5. ANTENNA

6.1.1.5.1. Parabolic and Flat Antennas

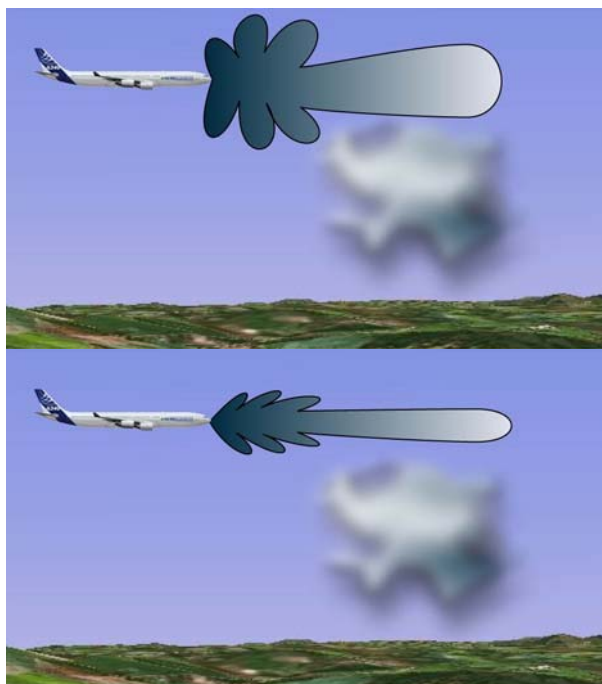
There are two types of weather radar antenna: **parabolic** for the first generation of weather radar (on A300/A310 and former A320 aircraft) and **flat** for the recent generation (on A320/A330/A340 aircraft).

- **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.



6.1.1.5.2. 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 $\pm 45^\circ$ 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.

Tips: 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.



- **False Wind Shear Alerts**

The weather radar may wrongly interpret strong returns due to large side lobes as wind shears. This explains why the first generation of weather radars is not able to detect wind shears.

6.1.1.5.3. 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).

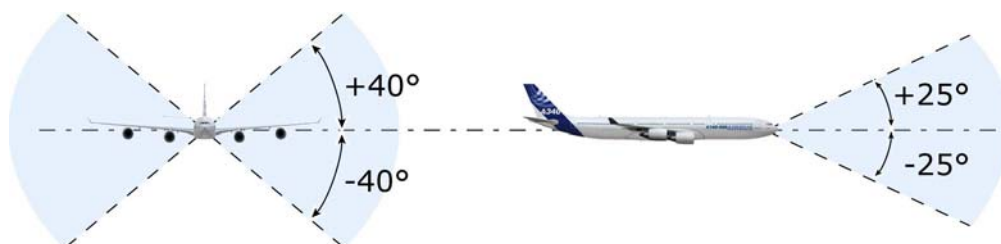


Figure 6-4: Antenna stabilization limits

6.1.1.6. RADAR BEAM

6.1.1.6.1. 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:

$$\text{Beam diameter [ft]} = 3.5 \times (\text{Distance [NM]} + "00")$$

Example:

Distance = 50 NM

Distance + "00" = 5 000

Beam diameter = 17 500 ft

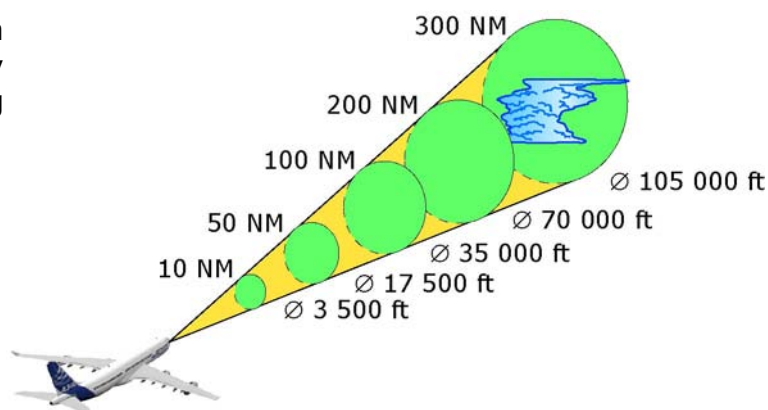


Figure 6-5: Beam diameters

• 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), higher 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), higher the *azimuth* resolution.

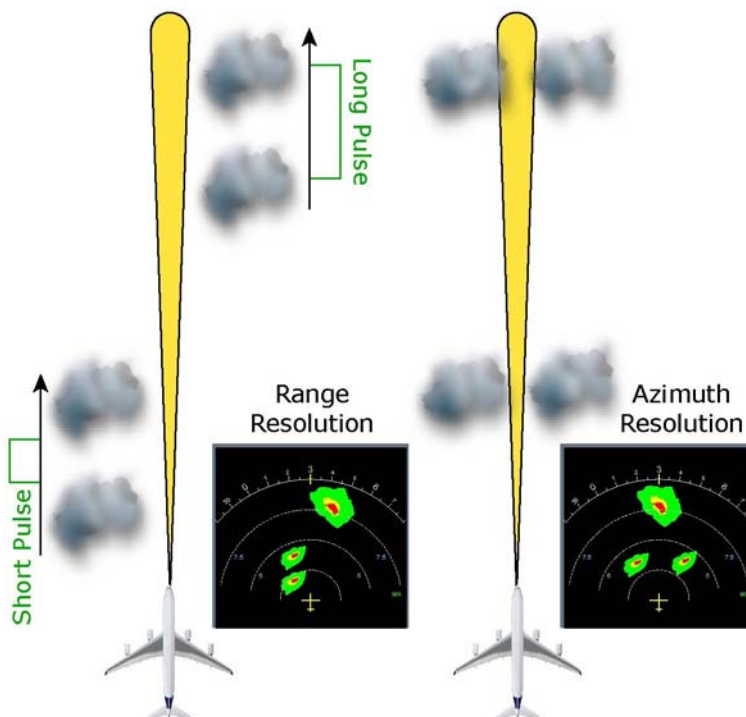


Figure 6-6: Range and Azimuth resolutions

6.1.1.6.2. 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**.

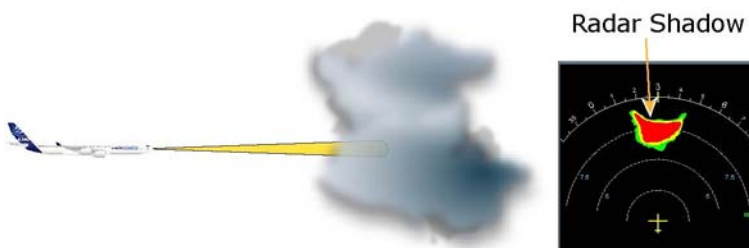


Figure 6-7: Path attenuation or Radar shadow

6.1.1.6.3. 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.

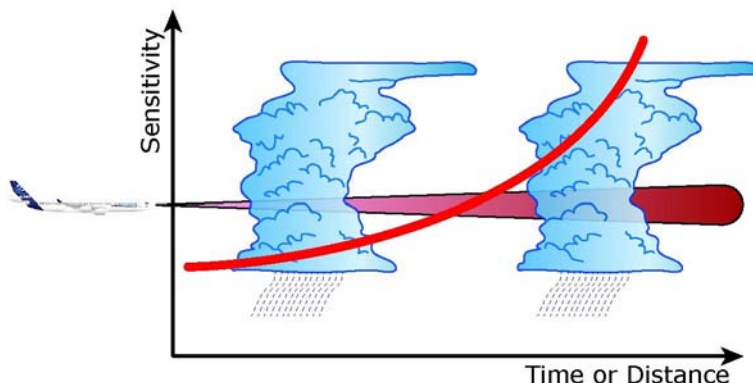


Figure 6-8: Sensitivity Time Control

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.

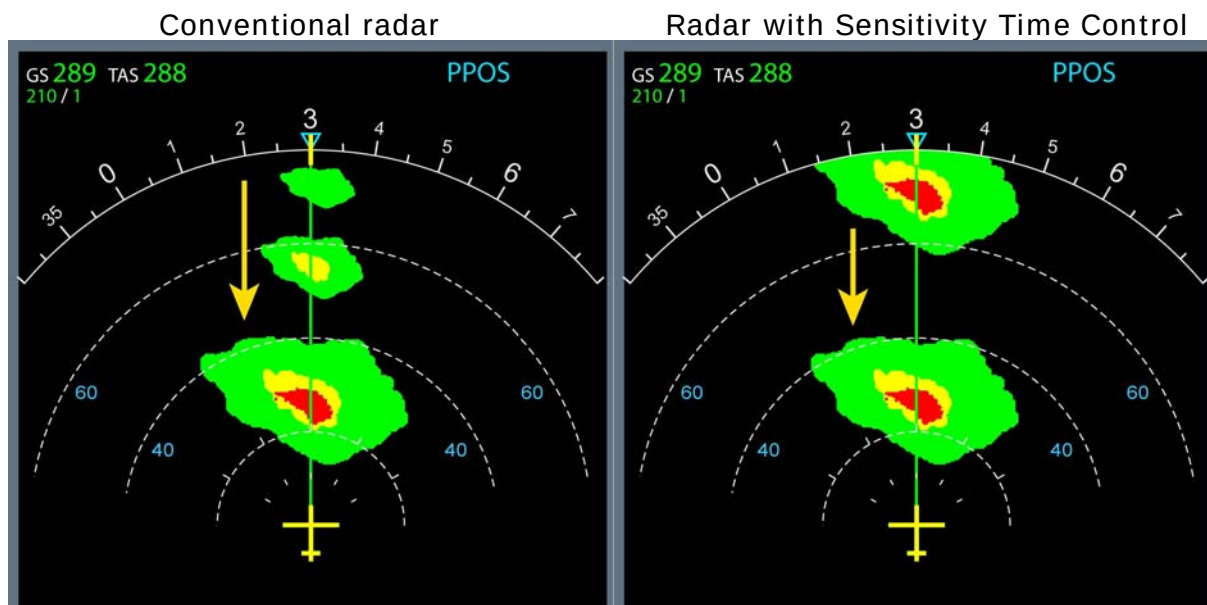


Figure 6-9: Weather displays with and without STC

6.1.1.6.4. 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.

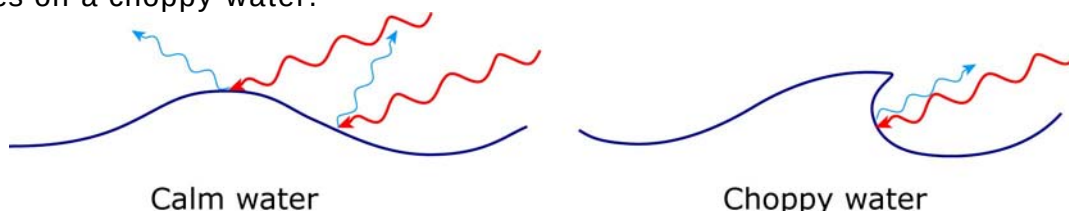


Figure 6-10: Radar returns on calm and choppy waters

6.1.1.7. 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 Rockwell Collins WXR 2100 weather radar includes a filter that partly attenuates these interferences.

Figure 6-11 shows a display when the radar does not filter the interferences from radio transmitters.

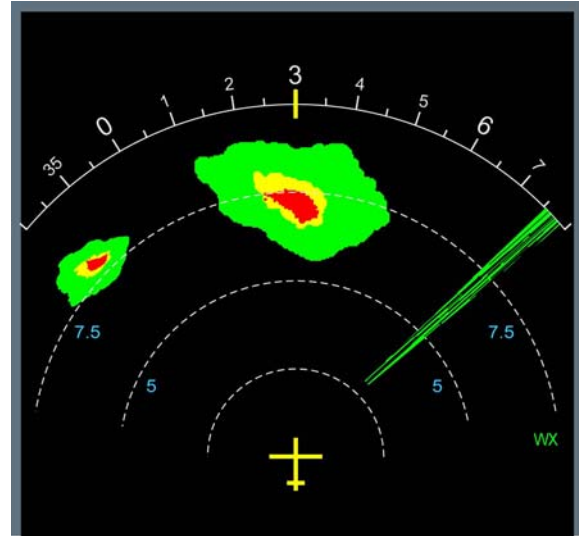


Figure 6-11: Interfering radio transmitters

6.1.1.8. RADIATION HAZARDS

Before activating the weather radar, make sure that:

- **No one is within a sector defined by a radius of 5 m and $\pm 135^\circ$ from the aircraft centerline,**
- **No large metallic obstacle is within a sector defined by a radius of 5 m and $\pm 90^\circ$ from the aircraft centerline.**

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

* for A380 aircraft, it is the fuselage width.

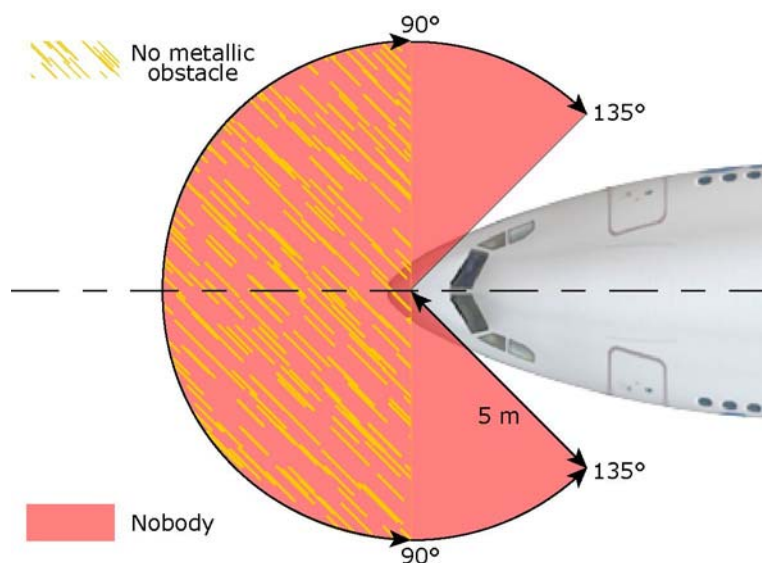


Figure 6-12: Radiation hazard boundary

6.1.2. WEATHER, TURBULENCE AND WIND SHEAR DETECTION

6.1.2.1. COVERAGE

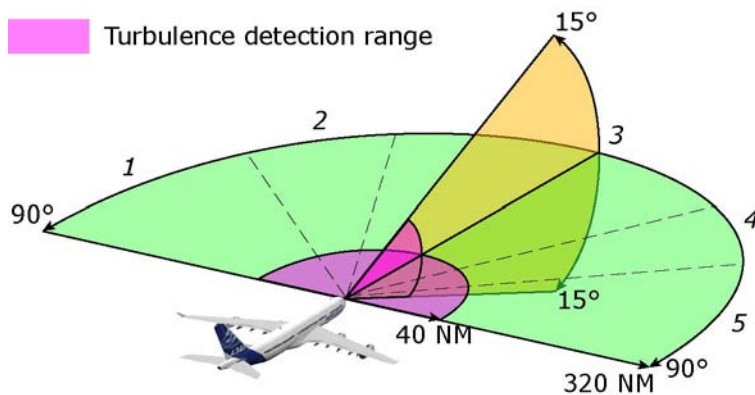


Figure 6-13: Radar coverage

The weather and turbulence detections (Honeywell and Rockwell Collins weather radars) cover an area as defined in Figure 6-13.

For Honeywell radar only, the horizontal plane is divided into five sectors (dashed on Figure 6-13) for **Autotilt** purposes. Refer to 6.1.5.1 – Autotilt (Honeywell).

Note: For any radars, the tilt angle refers to the horizon and not to the longitudinal centerline.

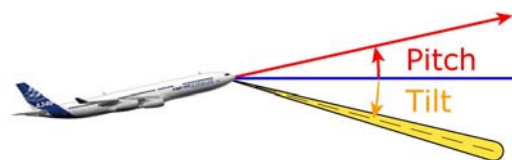


Figure 6-14: Pitch and Tilt

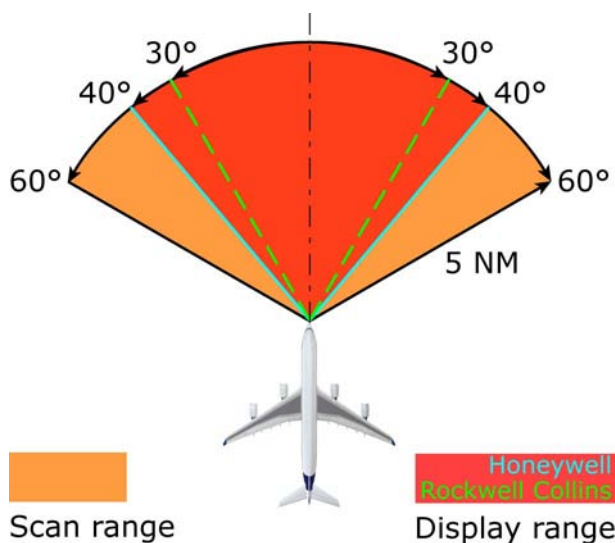


Figure 6-15: Wind shear detection range

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.

6.1.2.2. WIND SHEAR DETECTION

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 6-16: Predictive and Reactive Wind Shear

Appendix H – Low level Wind shear effects on aircraft performances summarizes the effects of wind shears on aircraft performances.

6.1.3. 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)
- Wind shears
- The ground.

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).

6.1.3.1. 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 6.1.1.4 – Gain for the color code.

6.1.3.2. 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**.

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.

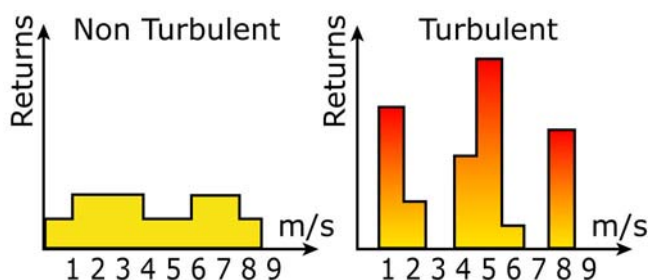


Figure 6-17: Non turbulent and turbulent spectra

The left part of **Figure 6-17** 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 6-17** 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.

6.1.3.3. 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.

6.1.3.4. 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.

6.1.3.4.1. 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. $-\frac{V}{A_s}$ 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. $W_h = 0$), a downdraft of 18.2 kt would be required to trigger the wind shear alerts, with an airspeed of 140 kt.

6.1.3.4.2. PWS Automatic Activation

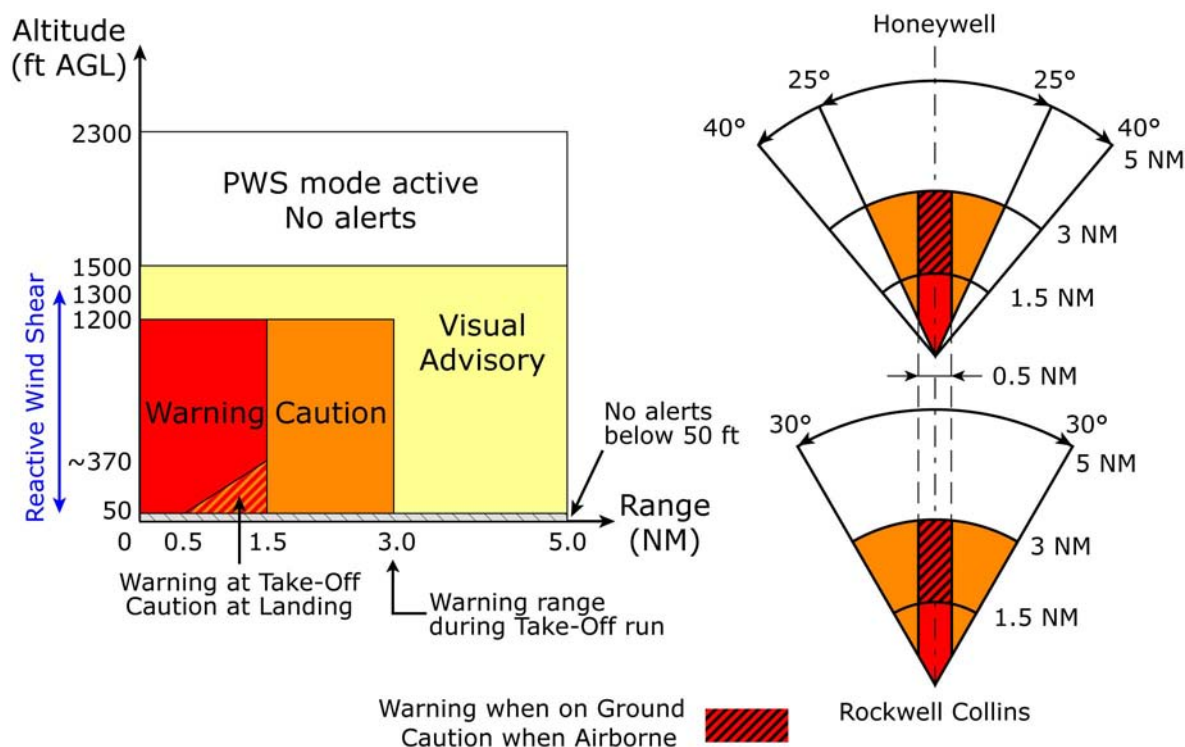


Figure 6-18: Envelopes of Wind Shear alerts

The PWS mode automatically activates when the aircraft is below 2 300 ft RA at take-off or landing, **even if the weather radar is OFF** (provided that the PWS switch is on AUTO). 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 WXR 2100 – Multiscan:**
 - o One of the engines 1 or 2 is running
 - o One of the following conditions is met:
 - The ground speed is above 30 kt, or
 - The longitudinal acceleration is above 0.07 g.

For both weather radar models, the controls of TILT and GAIN are automatic in PWS mode.

For both 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).

6.1.4. REACTIVE WIND SHEAR

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.

The Severity Factor (SF) determines the severity of a wind shear.

SF = SF_{Longitudinal} + SF_{Vertical} With $\begin{matrix} \text{SF}_{\text{Longitudinal}} & \text{for longitudinal tail wind gradient} \\ \text{SF}_{\text{Vertical}} & \text{for downward wind.} \end{matrix}$

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.

6.1.5. WEATHER RADAR FUNCTIONS PER MANUFACTURER

The main manufacturers for weather radar on A320/A330/A340 aircraft are Honeywell and Rockwell Collins. They use two different philosophies for the weather detection: the **Autotilt for Honeywell** and the **Multiscan for Rockwell Collins**. The Autotilt and the Multiscan 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.

6.1.5.1. AUTOTILT (HONEYWELL)

6.1.5.1.1. Principle

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 EGPWS³ for the tilt angle adjustment.**

For Autotilt purposes, the radar scan is divided into five sectors (refer to Figure 6-13). For each sector, the Autotilt function adjusts the tilt angle (beam 2 in Figure 6-19) 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.

Practically, the Autotilt function prevents errors encountered when the flight crew manually set the tilt angle. Refer to Figure 6-19.

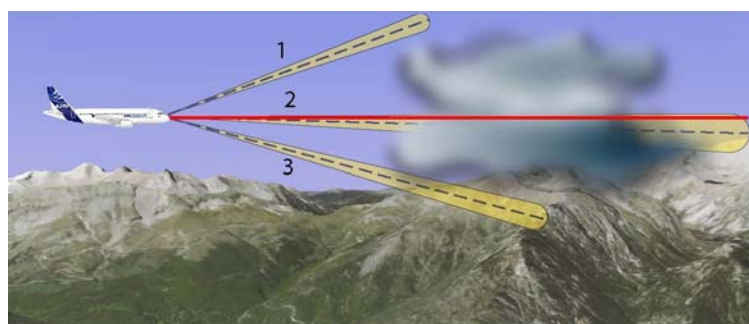


Figure 6-19: Optimization of tilt setting

- 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.

6.1.5.1.2. Autotilt Scan Pattern

- 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.

³ Only Honeywell EGPWS is able to provide the terrain altitude to Honeywell Autotilt function. The Autotilt function is not compatible with ACSS T2CAS.

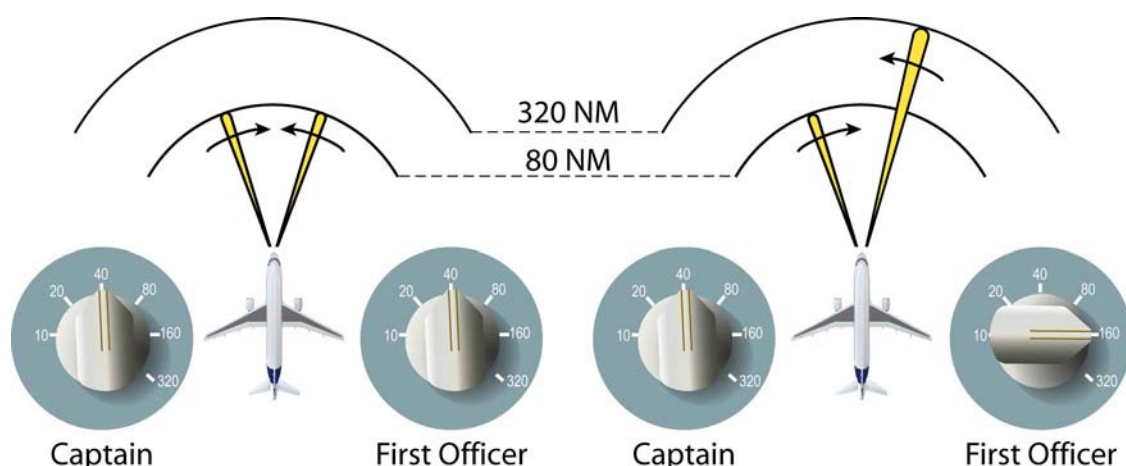


Figure 6-20: Autotilt scans according to range selections

- **In PWS Mode**

The Autotilt function does not modify the PWS mode. **Below 2 300 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.

6.1.5.2. MULTISCAN (ROCKWELL COLLINS)

6.1.5.2.1. Principle

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.**

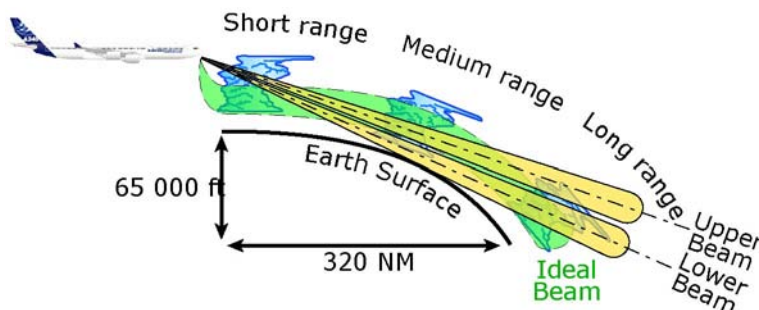


Figure 6-21: Ideal beam and Multiscan

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 6.1.5.3 – Ground Clutter Suppression – GCS (Rockwell Collins)). According to the range selected on ND, the relevant information is extracted from the database for display.

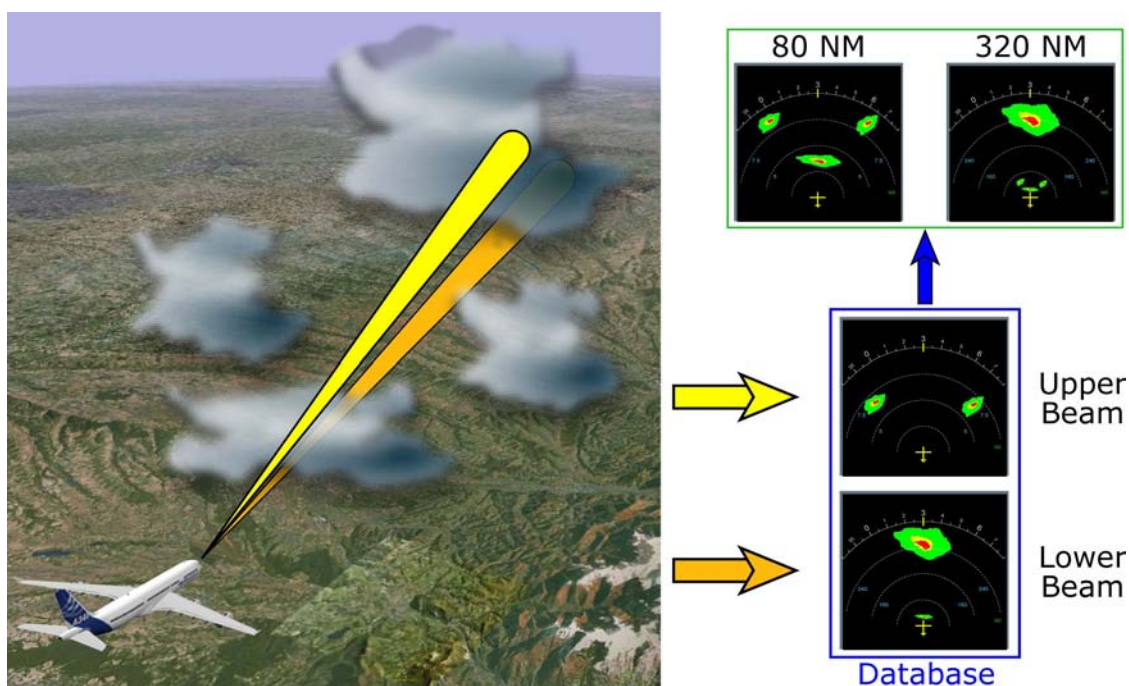


Figure 6-22: Multiscan processing

6.1.5.2.2. Multiscan Scan Pattern

- **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.

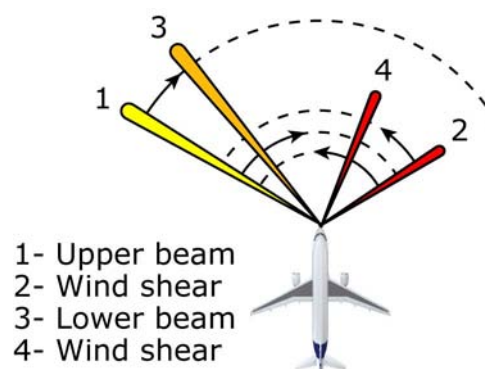


Figure 6-23: Multiscan scans in PWS mode

6.1.5.3. GROUND CLUTTER SUPPRESSION – GCS (ROCKWELL COLLINS)

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.

6.1.5.4. LONG RANGE COLOR ENHANCEMENT (ROCKWELL COLLINS)

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.

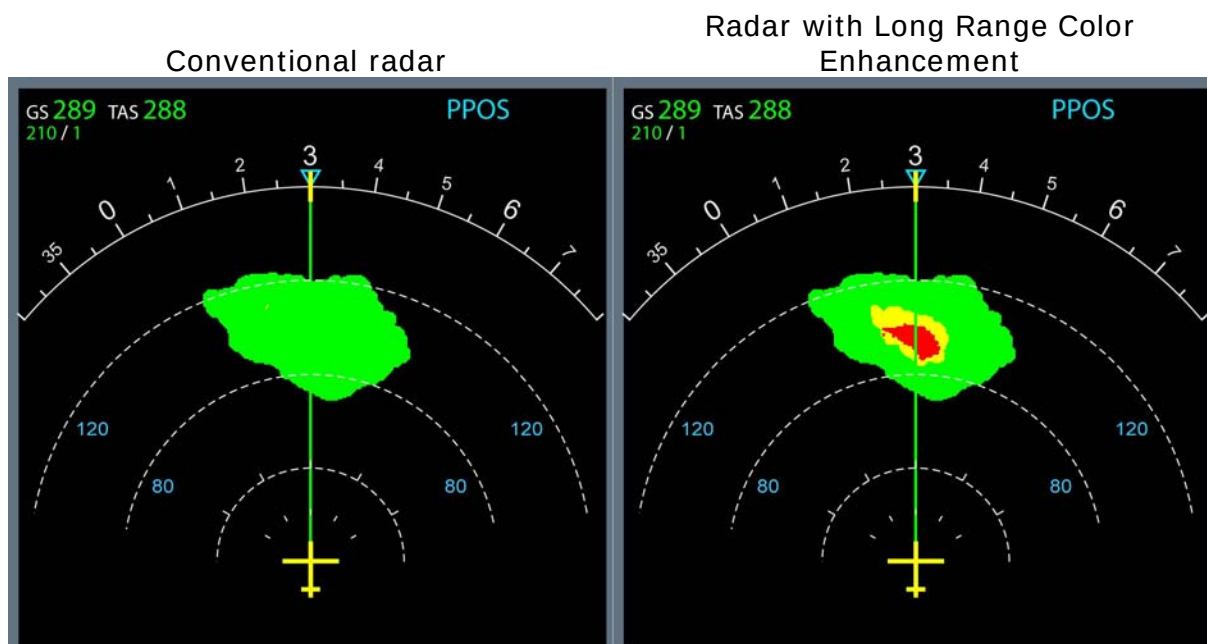


Figure 6-24: Weather displays with and without Long Range Color Enhancement

6.1.5.5. GAIN PLUS (ROCKWELL COLLINS)

The GAIN PLUS includes a set of functions available in the automatic Multiscan mode:

- Conventional increase and decrease of receiver sensitivity,
- Variable temperature based gain,
- Path Attenuation Compensation (PAC) alert,
- Over-flight protection,
- Oceanic weather reflectivity compensation.

6.1.5.5.1. Conventional Increase and Decrease of Receiver Sensitivity

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 6.1.1.4 – Gain.

6.1.5.5.2. Variable Temperature Based Gain

The reflectivity of water changes according to its state (i.e. liquid or ice). Refer to 6.1.1.1 – Reflectivity of Water Molecules. 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.

6.1.5.5.3. Path Attenuation Compensation (PAC) alert

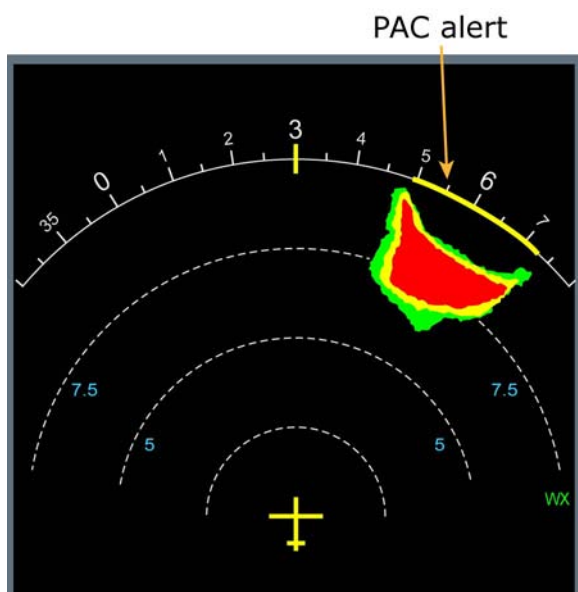
OPS+


Figure 6-25: PAC alert

When the radar beam is attenuated (radar shadow, refer to 6.1.1.6.2 – Attenuation), 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.

6.1.5.5.4. Over-Flight Protection

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 6-26).

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.

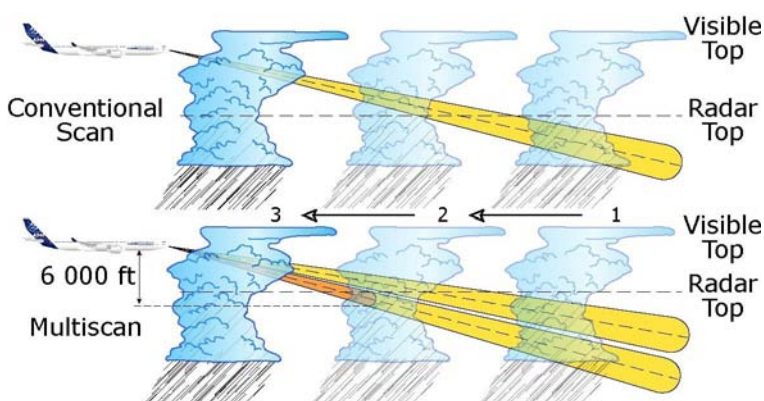


Figure 6-26: Over-Flight Protection with Multiscan

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.

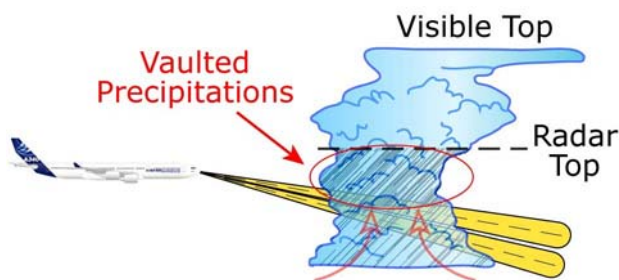


Figure 6-27: Thunderstorm vault

Therefore, as the upper beam scans the intermediate part, the flight crew is able to correctly evaluate the thunderstorm threat.

6.1.5.5.5. Regional Weather Reflectivity Compensation

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.

6.1.6. REACTIVE WIND SHEAR INDICATIONS



**WIND SHEAR, WIND SHEAR,
WIND SHEAR**

The red WIND SHEAR indication on PFD flashes.

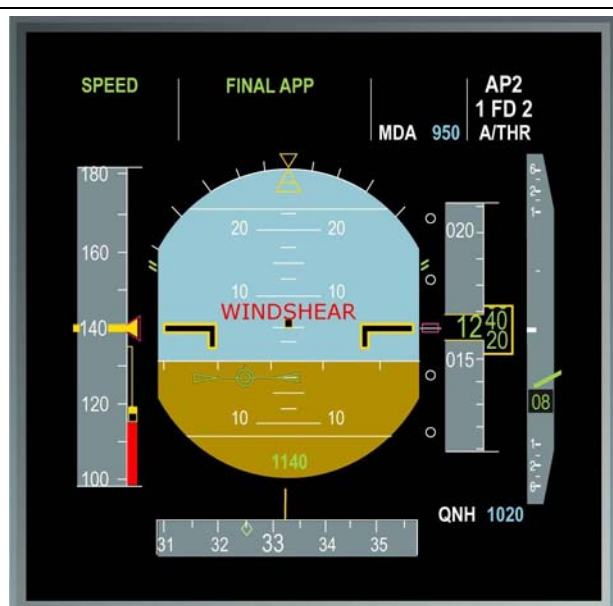


Figure 6-28: Reactive Wind Shear warning on PFD

6.1.7. WEATHER RADAR INDICATIONS

The weather radar display on ND is **available in ROSE and ARC modes**.



Figure 6-29: Weather display

The weather radar displays weather information on ND according to the reflectivity of targets (i.e. green, yellow or red, refer to 6.1.1.4 – Gain).

Instead of *WXR MSG* (rounded in dash red on Figure 6-29), indications from the weather radar about the operating modes or failures are displayed. 6.1.7.1 – Weather Radar Messages provides the list of these indications.

Tips: 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 6-30).
- A steep reflectivity gradient (variation of colors on a short distance) indicates strong convective movements and severe turbulence (Figure 6-31).
- U-shape cells, hooks, fingers, scalloped-edge cell indicate strong wind shears and turbulence (Figure 6-32 to Figure 6-35).

Shapes that change rapidly also indicate strong activity and turbulence. Intense and frequent lightning is also a good sign for severe turbulence.

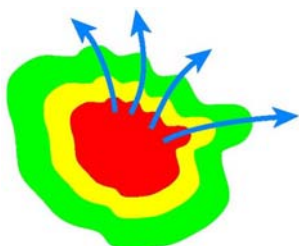


Figure 6-30: Cell distortion

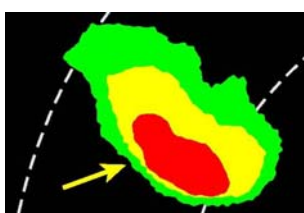


Figure 6-31: Steep reflectivity gradient

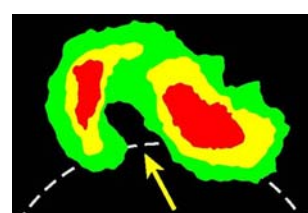


Figure 6-32: U-shape cell

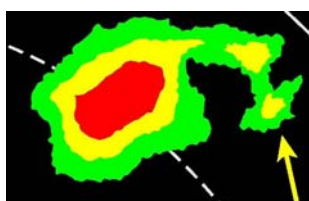


Figure 6-33: Hook

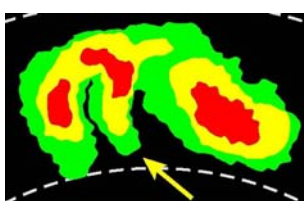


Figure 6-34: Finger

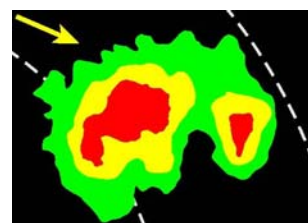


Figure 6-35: Scalloped edge

Tips: 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.

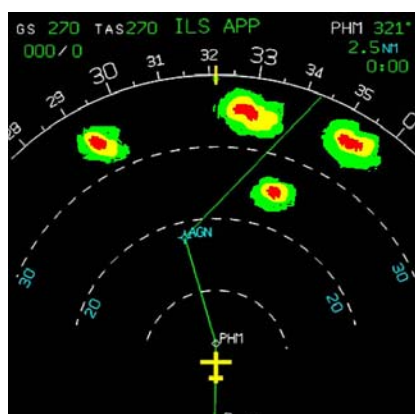
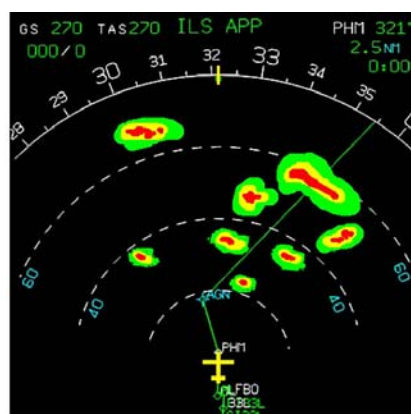


Figure 6-36: Blind Alley effect – Right ND range = 40 NM, Left ND range = 80 NM

6.1.7.1. WEATHER RADAR MESSAGES

Message	Cause	Effect	Message	Cause	Effect
WXR DU ⁴	DU overheating	Image lost	MAN XX.X	Manual tilt	Manual mode
WXR R/T	WXR transceiver failure		PRED W/S	W/S failure	Image not lost
WXR ANT	WXR antenna failure		WXR ATT	Attitude stabilization failure	
WXR CTL	WXR control unit failure		NO AUTOTILT ⁵	Autotilt failure	
WXR RNG	Discrepancy between EFIS CP range selection and DMC range		WXR STAB	Loss of antenna stabilization	Test image
			WXT TEST	Test mode	
MAN GAIN	Manual gain	Manual mode	PWS SCAN ⁶	Weather radar OFF	PWS mode

Note: Shaded cells above apply to Honeywell radar only.

6.1.7.2. 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
<p>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 6-37 and Figure 6-38). 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 6-18), only the ND indication is provided (no indication on PFD).</p>	

⁴ This message indicates an overheating of the display unit. It is not a weather radar message.

⁵ With EIS1 display units, the message (Honeywell radar only) is displayed in the middle of ND.

⁶ This message is available with EIS 2 display units only.

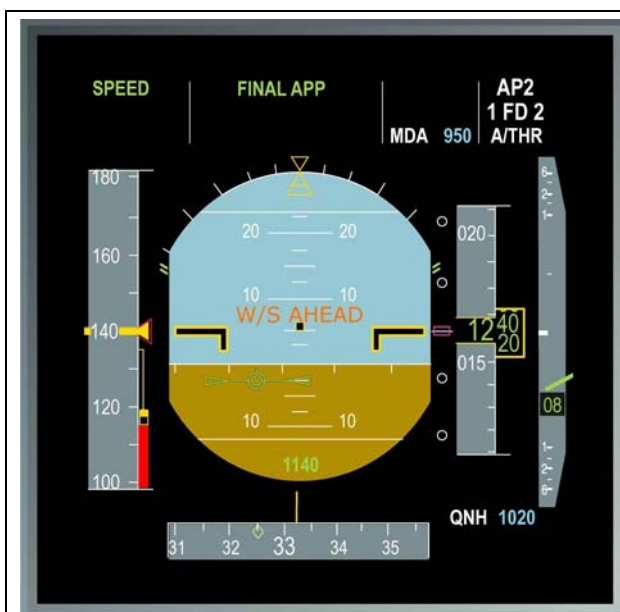


Figure 6-37: Wind shear alert on PFD



Figure 6-38: Wind shear alert on ND

6.1.8. WEATHER RADAR CONTROLS

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).



Figure 6-39: Honeywell control panel with Autotilt function



Figure 6-40: Rockwell Collins control panel with Multiscan function

Note: 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.

Tips: 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:

$$\text{Height [feet]} = \text{Tilt (degrees)} \times (\text{Distance [NM]} + \text{"00"})$$

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.

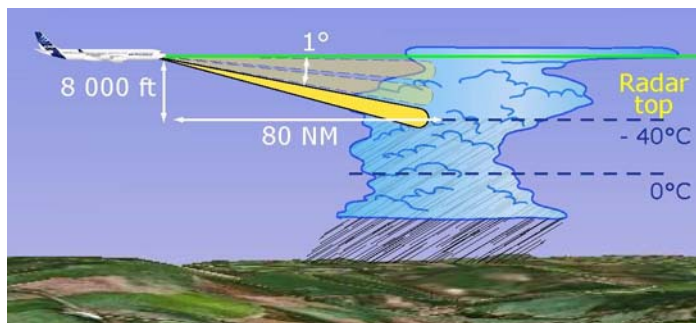


Figure 6-41: Vertical extension measurement with tilt

6.2. 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](#).

6.2.1. WEATHER RADAR OPERATIONS

6.2.1.1. 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.

6.2.1.2. 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 6-31 to Figure 6-35). 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.
- **PNE: Monitor long-range weather (above 80 NM) for long-term avoidance strategy. PE: Monitor short-range weather (below 80 NM) for tactical weather avoidance.** Refer to Figure 6-36.
- Refer to **FOBN “Adverse Weather Operations – Optimum Use of the Weather Radar”** (See AIRBUS References) for more recommendations.

6.2.2. WIND SHEAR

- Refer to **FOBN “Adverse Weather Operations – Wind Shear Awareness”** (See AIRBUS References).

6.2.2.1. 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.

6.2.2.2. 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 **FOBN “ Take-off and Departure Operations – Revisiting the STOP OR GO Decision”** (See **AIRBUS References**).

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.

6.3. 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 EU OPS 1.670:** The weather radar is required for pressurized aircraft operated at night or when IMC apply in areas where potentially

hazardous weather conditions, detectable by weather radar, may exist along the route.

- **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 EU OPS 1,** 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.

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.”

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.

6.4. 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 Rockwell Collins WXR 701X
- The Rockwell Collins WXR 2100 capable of predictive wind shear and Multiscan.

Figure 6-42 provides a simplified view of the weather radar architecture.

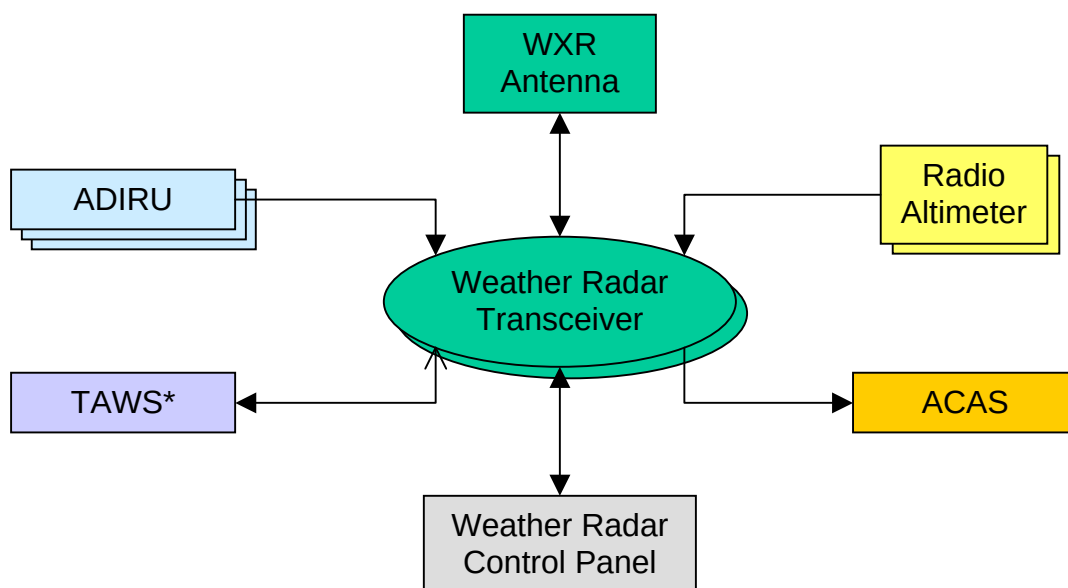


Figure 6-42: Weather Radar architecture

* Link TAWS to WXR only applicable between Honeywell EGPWS to Honeywell weather radar capable of Autotilt.

6.4.1. HONEYWELL RDR-4B

From Honeywell, the RDR-4B capable of PWS and Autotilt is available on AIRBUS aircraft. The Autotilt function is optional.

More information is available at

http://www.honeywell.com/sites/aero/Radar3_C867EC130-221E-7DEE-00E1-9B9088CBF060_H5CBA7513-E2B2-3320-D5A0-AF32226E4F40.htm

6.4.2. ROCKWELL COLLINS WXR 701X AND WXR 2100

From Rockwell Collins, the WXR 701X capable of PWS and the WXR 2100 capable of PWS and Multiscan are available on AIRBUS aircraft.

More information is available at

<http://www.rockwellcollins.com/products/cs/at/avionics-systems/weather-hazard/index.html>

6.5. FUTURE SYSTEMS

6.5.1. HONEYWELL RDR 4000

The Honeywell RDR 4000 uses the buffering of weather data in a 3D data base thanks to a multiple scanning. The RDR 4000 supports the weather radar function in the A380 AESS (refer to 7.1.4 – Weather Radar Function). Honeywell and AIRBUS are studying the opportunity to install the RDR 4000 on A320 family aircraft for early 2010 and on A330/A340 aircraft for end 2010. The RDR 4000 builds the weather display based on the 3D data base. This method improves the weather awareness and the workload of the flight crew. The RDR 4000 on A320/A330/A340 aircraft will propose new features (refer to 7.1.4 – Weather Radar Function for details):

- The automatic correction of the Earth curvature,
- Automatic modes to display on-path and off-path weather,
- The elevation mode: extraction of weather information via a horizontal cut across the 3D buffer.

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 (RDR-4B)** and **Rockwell Collins (WXR701X/2100)**. The automatic function (Autotilt for RDR-4B or Multiscan for WXR 2100) is optional.

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.

Refer to **6.2 – 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.

Future systems

The Honeywell RDR 4000, already available on A380 aircraft, will introduce the benefits of the 3D weather scanning on A320/A330/A340 aircraft in 2010 such as:

- The automatic correction of the Earth curvature
- Automatic modes to display on-path and off-path weather
- The elevation mode.



7. AIRCRAFT ENVIRONMENT SURVEILLANCE

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7.1. DESCRIPTION OF AESS

7.1.1. INTEGRATION OF SURVEILLANCE FUNCTIONS

The **Aircraft Environment Surveillance System (AESS)** is an integrated system that ensures the surveillance function on-board the A380 aircraft. AESS includes:

- The Aircraft Identification and Position Reporting function: Transponder
- The Traffic Surveillance function: TCAS II
- The Terrain Surveillance function: TAWS
- The Weather Surveillance function: Weather radar with PWS capability.

The Runway Surveillance function is outside the AESS scope and is supported by the OANS (refer to [5.1 – Description of OANS](#)).

The integration of these functions removes some drawbacks brought by individual surveillance systems. Indeed, the well-known surveillance systems had been defined to cope with one single issue and had appeared all along the aviation history: the weather radar in 1970's, the GPWS in 1974, the TCAS in 1990's and the PWS in 1994.

The drawbacks of a cumulative architecture, resulting from the history of surveillance functions, are:

- Limited management of alert priority,
- Poor interactivity between functions,
- Multiplication of control panels,
- Heterogeneous alerts from various manufacturers,
- Complex management of spares of different systems from various manufacturers,
- Complex installation (wiring, antennas),
- Weight, size, consumption, and maintenance tasks multiplied by the number of systems,
- High global cost.

From an operational perspective, AESS optimizes the layout of controls and displays in the cockpit:

- EFIS CP: Controls of display
- ND: Display of surveillance information
- PFD: Display of alerts
- ECAM: Display of failures or memo
- SURV panel on pedestal: Quick access to controls of main surveillance functions
- MFD SURV page: Access to all surveillance functions (settings, status, and reconfiguration).

7.1.2. AESS ARCHITECTURE

The AESS includes:

- **Two Aircraft Environment Surveillance Units (AESU),**
- **Two Radar Transceiver Units (RTU)** that makes the interface between AESU and the weather radar antenna,
- **One Weather Antenna Drive Unit (WADU)** that ensures the scanning movement of the weather radar antenna and its stabilization,
- **One weather radar flat antenna,**
- **One SURV panel,**
- **Four identical TCAS/Mode S antennas.**

Each AESU includes three modules:

- **TCAS/XPDR module:** A single module contains the TCAS and XPDR functions to take benefits from a higher integration: smaller size, lower consumption, simpler design, shared TCAS/XPDR antennas,
- **TAWS module** is roughly equivalent to EGPWS,
- **WXR/PWS module** ensures the basic functions (detection of weather, wind shears, turbulence, ground mapping) and introduces a new feature (3D buffer).

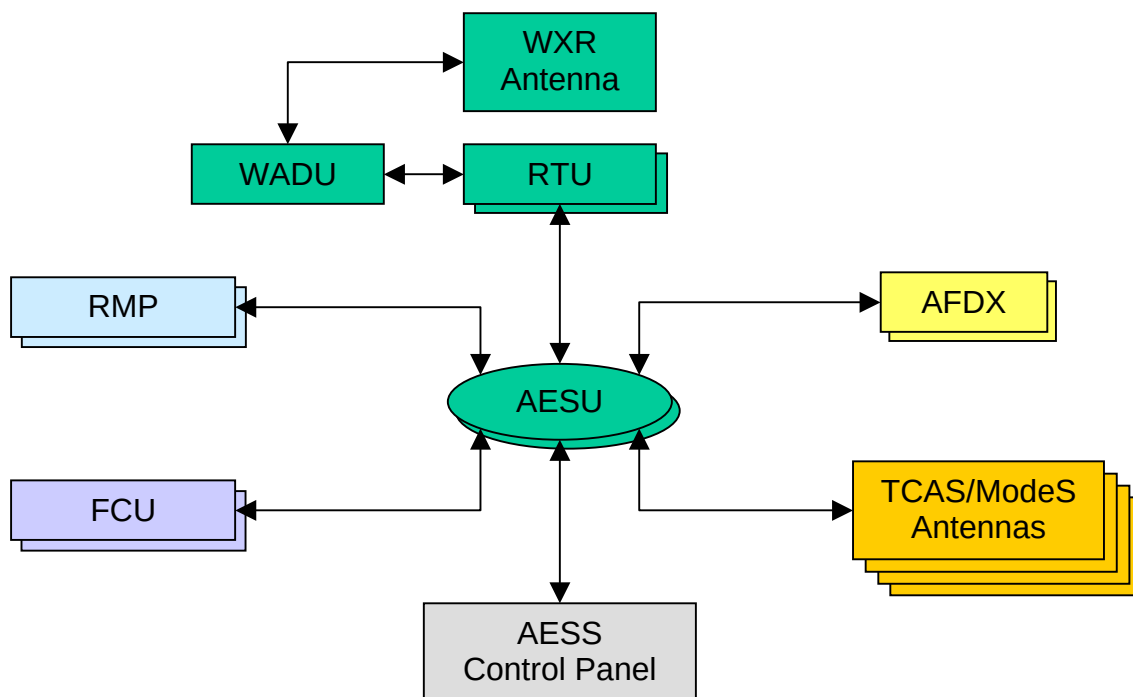
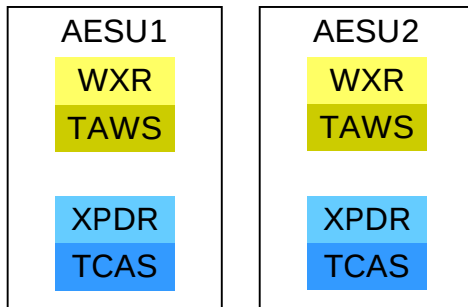


Figure 7-1: Simplified AESS architecture

For any module, each AESU records various parameters for any events that occur during the flight (e.g. TCAS parameters relative to an RA).

7.1.2.1. GROUPS OF FUNCTIONS

The integration highly simplifies the architecture. However, it introduces some new rules in terms of operations. The architecture with two AESUs duplicates each surveillance function.



Each AESU groups the functions as follows:

- WXR/TAWS,
- TCAS/XPDR.

Figure 7-2: AESU groups of functions

7.1.2.2. AESS OPERATING MODES

AESS presents three different operating modes:

1. **Normal mode:** one AESU performs all functions. It is the Master AESU. **The Master AESU is the AESU with the active WXR/TAWS group,**
2. **Mixed mode:** one AESU performs the functions of one group, and the other AESU performs the functions of the other group, with or without failure (e.g. WXR/TAWS on AESU1 and TCAS/XPDR on AESU2),
3. **Downgraded mode:** a failure prevents the performance of all functions despite the redundancy of functions. Refer to examples below.

In the examples below, **active functions are framed in green** and **failed functions are shaded in amber**.

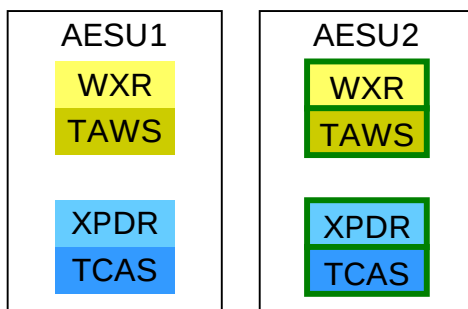


Figure 7-3: Normal mode

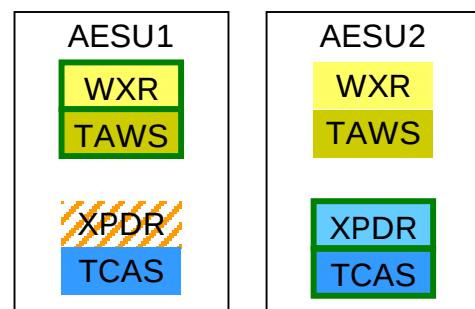


Figure 7-4: Mixed mode

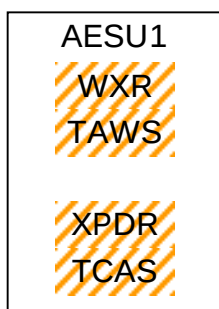


Figure 7-5: Downgraded mode – Loss of WXR

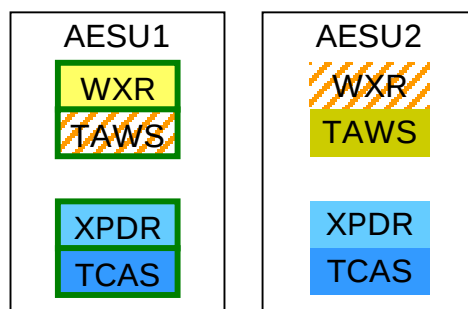


Figure 7-6: Downgraded mode – TAWS alerts remain available via an interconnection with TAWS 2

Note: In normal mode, when the aircraft is on ground, the master AESU is:

- When an **odd** flight number is entered (e.g. AIB123), AESU**1**.
- When an **even** flight number is entered (e.g. AIB234), AESU**2**.

7.1.2.3. AESS RECONFIGURATION PRINCIPLES

Two successive faults lead the AESS to operate in degraded mode. A fault is a loss of a function (e.g. WXR1) or a loss of a group of functions (e.g. WXR/TAWS of AESU2).

Note 1: The TCAS automatically switches to STBY when the XPDR is in STBY or when the ALT RPTG is OFF. Indeed, the TCAS is not able to determine the vertical separation with the intruder. Therefore, the TCAS is not able to evaluate the threat. Refer to [3.1.4 – Collision Threat Evaluation](#).

Note 2: The TAWS function of one AESU is able to feed the other AESU for TAWS alert generation, when the TAWS function of the other AESU is faulty. Refer to [Figure 7-9](#).

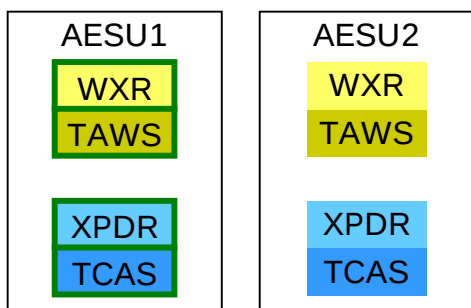


Figure 7-7: AESS in normal mode

Figure 7-7 to Figure 7-9 illustrate a sequence of events that leads to reconfiguration in degraded mode.

Figure 7-7: The AESS operates normally.

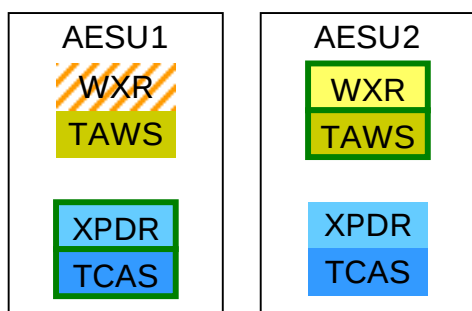
**Figure 7-8: AESS in mixed mode**

Figure 7-8: The first failure is the loss of WXR function of AESU1. Per procedure, the WXR/TAWS function is switched to AESU2.

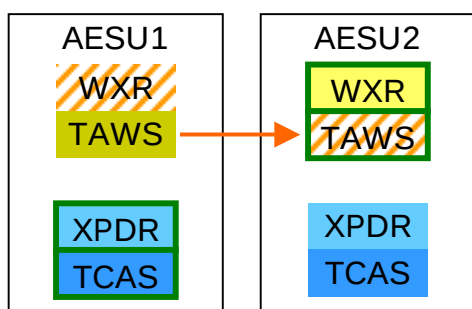
**Figure 7-9: AESS in downgraded mode**

Figure 7-9: The second failure is the loss of TAWS function of AESU2. As the TAWS function of AESU1 is still available, TAWS alerts remain available thanks to an interconnection between TAWS functions of AESU1 and 2.

Refer to your FCOM for more reconfiguration scenarios.

7.1.3. TAWS FUNCTION

The AESS TAWS function is equivalent to the reactive and predictive functions provided by the EGPWS (refer to **4.1 – Description of TAWS**, see reactive modes, TCF, RFCF, TAD, envelope modulation, obstacle, peaks mode).

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 VD.

7.1.3.1. TAWS RNP

The TAWS RNP is defined according to the flight phase.

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

* According to the runway selected into the FMS.

AESS uses the TAWS RNP to select the position source (GPIRS or FMS), and to define the width of the vertical cuts for vertical terrain view (refer to **7.1.7.1 – Generation of Vertical Terrain View**).

7.1.3.2. SELECTION OF LATERAL POSITION SOURCE

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 (TERR SYS to OFF on MFD SURV page, refer to 7.1.9.4.1 – CONTROLS Page).

7.1.3.3. TERRAIN DISPLAY IN POLAR AREAS

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.

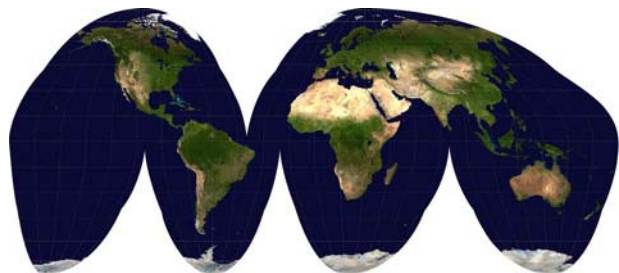


Figure 7-10: World map with interrupted Goode's projection

Figure 7-10 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.

- **Magenta Areas: Unavailable Terrain Information**

The latitude range is -90° to $+90^{\circ}$. 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).

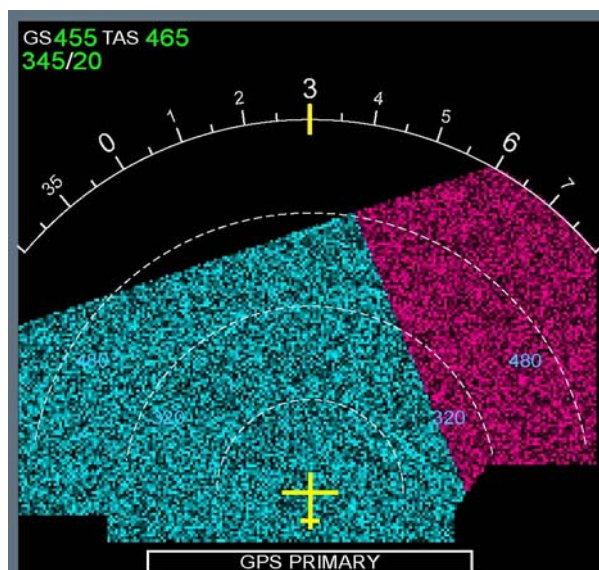


Figure 7-11: Terrain display in polar areas

Note: EGPWS is also affected by these limitations. Refer to **4.1.5.5 – Terrain Display in Polar Areas**.

7.1.4. WEATHER RADAR FUNCTION

The AESS Weather Radar function provides the same functions as conventional weather radars: **weather detection with PWS and turbulence detection**. The range goes up to 320 NM. The antenna scans an envelope of $\pm 80^{\circ}$ in azimuth and $\pm 15^{\circ}$ in tilt. Refer to **Figure 7-24**.

The AESS Weather Radar function introduces a new concept: **the weather radar does not directly display the weather information to the flight crew, but stores it in a 3D buffer**. The 3D buffer significantly improves the weather analysis (i.e. on/off path weather, elevation mode, vertical view, Earth curvature correction, automatic ground mapping, weather displayed behind the aircraft) and the weather awareness.

OPS+

Note: The weather radar basic principles remain identical to the ones described in **6 – Weather Surveillance**. Refer to this chapter for a refresher about weather radar physics.

7.1.4.1. WEATHER DETECTION

With weather returns stored in a 3D buffer, the AESS Weather Radar function provides different operating modes (automatic and manual). The following paragraphs describe the 3D buffer principles, and the automatic and manual operating modes.

7.1.4.1.1. 3D Buffer

Conventional radars directly update the weather display according to the radar antenna position. The AESS radar antenna continuously scans the envelope ahead of the aircraft and stores weather returns in a 3D buffer. Then, the AESS uses weather information stored in the 3D buffer for display on ND and VD. 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 SYS 1 to SYS 2), a minimum scanning is required to fill the 3D buffer in. It takes up to 30 seconds to get a full weather picture on VD and ND.

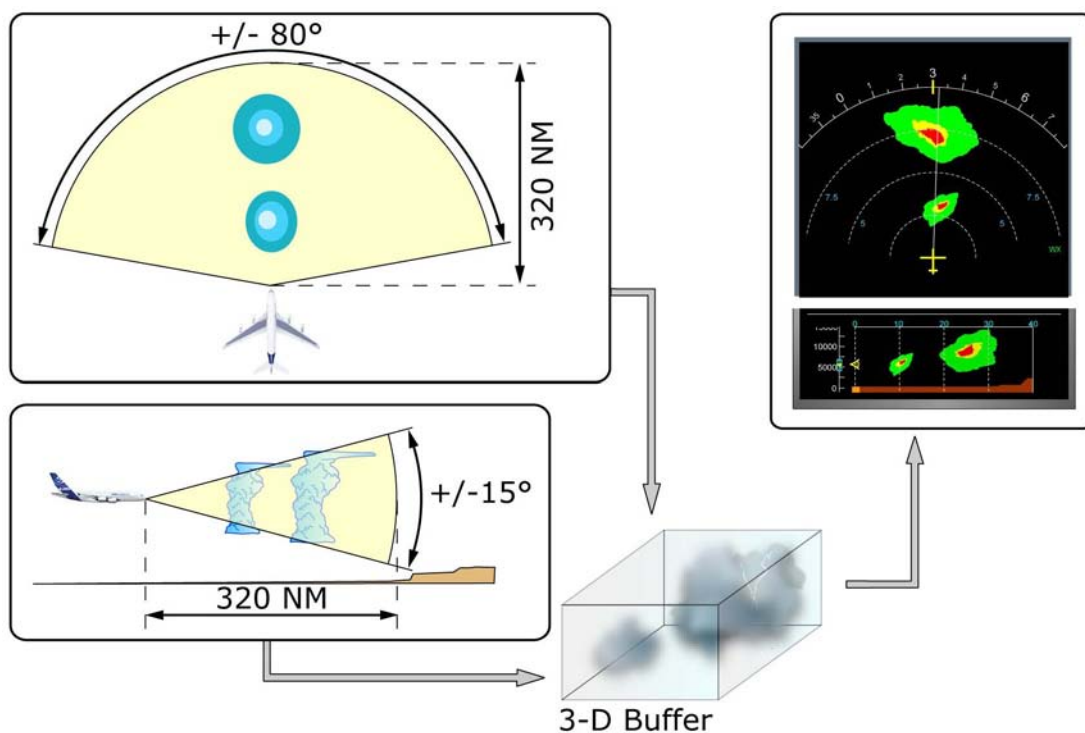


Figure 7-12: AESS 3D buffer

- **Earth Curvature Correction**

AESS 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.

Note: A straight beam over a curved ground surface is equivalent to a curved beam over a plan ground surface. Refer to [Figure 7-13](#).

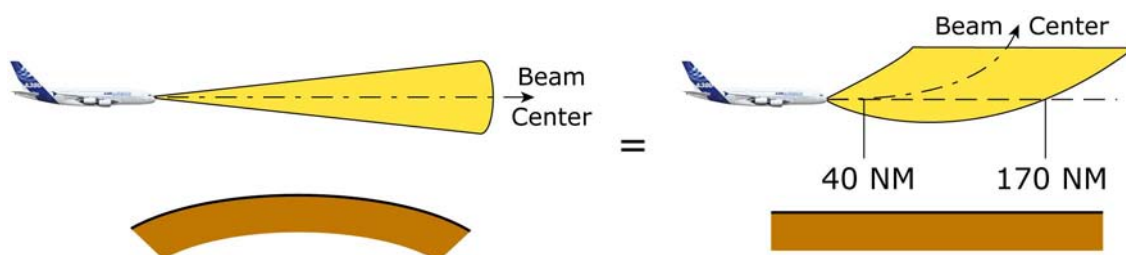


Figure 7-13: Effect of Earth curvature

The following figures illustrate the AESS corrections.

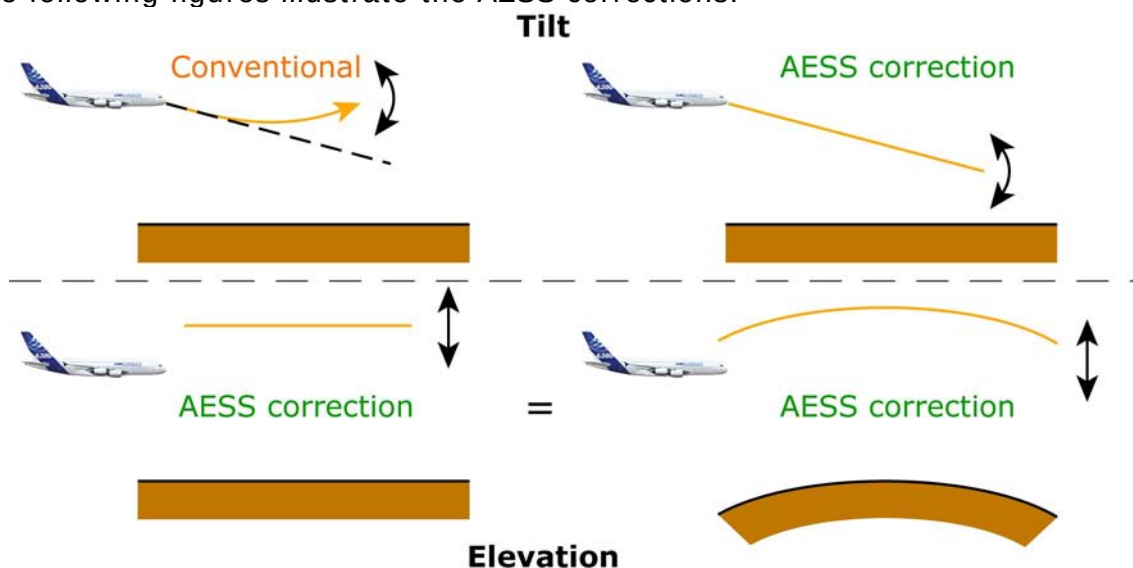


Figure 7-14: AESS correction of Earth curvature for tilt and elevation

7.1.4.1.2. 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 (refer to [Figure 7-15](#)),
- **BASIC WXR AUTO** based on flight path along FPA up to FCU altitude when the navigation mode is selected (refer to [Figure 7-16](#)),
- **DEFAULT WXR AUTO** based on flight path along FPA up to 60 NM when the navigation mode is manual (refer to [Figure 7-17](#)).

• The On-Path and Off-Path Weather Concept

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.



- 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 SURV panel or on the MFD SURV CONTROLS page
- The FMS flight plan is available

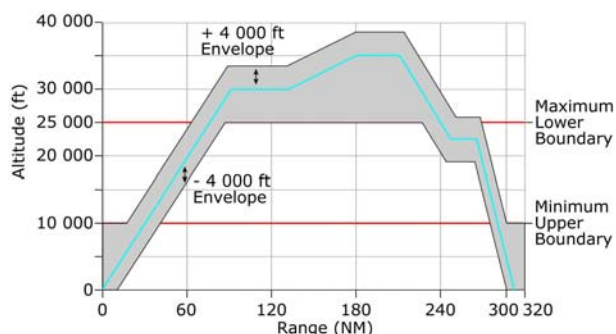


Figure 7-15: STANDARD WXR AUTO envelope

The **BASIC WXR AUTO mode** is active when:

- The flight crew sets WXR AUTO on the SURV panel or on the MFD SURV CONTROLS page
- The navigation mode is selected
- The aircraft is converging to the selected FCU altitude.

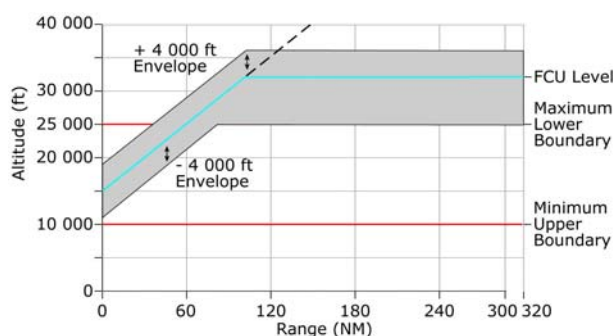


Figure 7-16: BASIC WXR AUTO envelope in climb

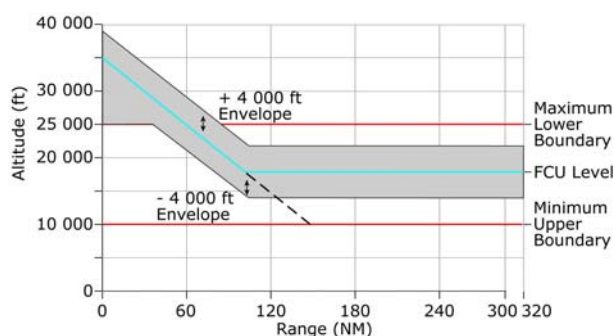


Figure 7-17: BASIC WXR AUTO envelope in descent

The **DEFAULT WXR AUTO mode** is active when:

- The flight crew sets WXR AUTO on the SURV panel or on the MFD SURV CONTROLS page
- The FMS flight plan is not available
- No FCU altitude is selected.

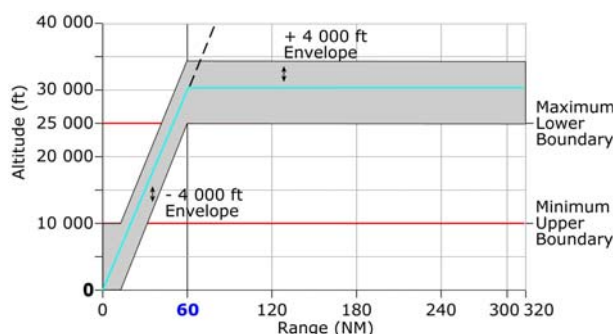


Figure 7-18: DEFAULT WXR AUTO envelope in climb

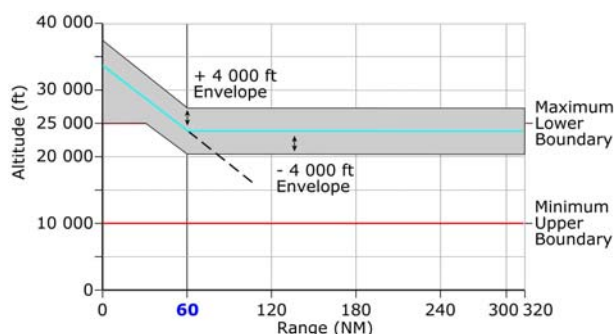
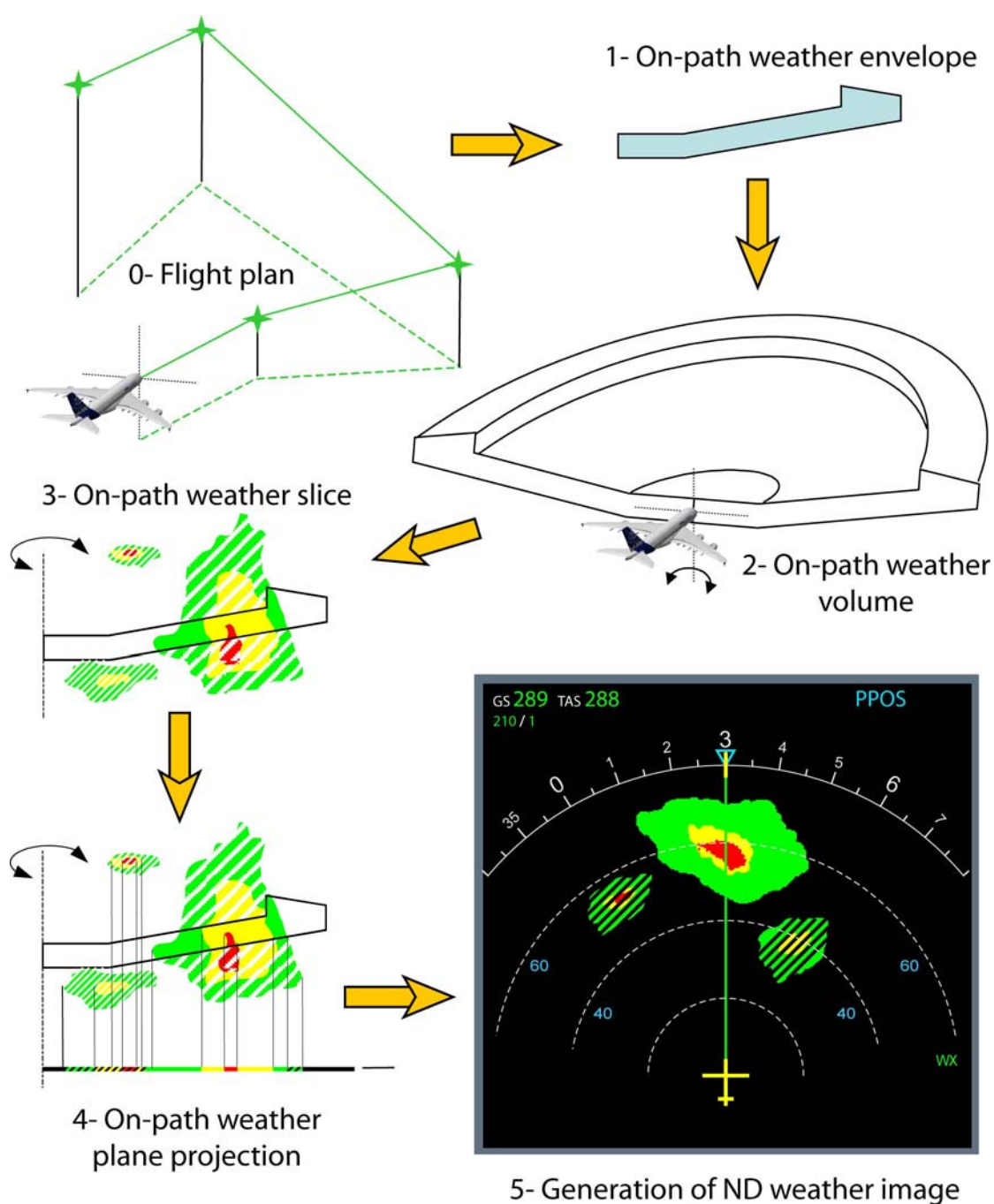


Figure 7-19: DEFAULT WXR AUTO envelope in descent

• Generation of Horizontal Weather View

AESS uses the On-path and Off-path weather concept to generate the horizontal weather view on ND. The AESS displays **On-path weathers with solid colors** and **Off-path weathers with dashed colors**.

**Figure 7-20: Generation of weather view on ND**

Refer to Figure 7-20.

- Step 1:** AECS draws the envelope of the On-path weather on the current aircraft flight path (see above).
- Step 2:** AECS 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 cuts¹ in the 3D buffer.

¹ The thickness of the laser cut is nil. Refer to 7.1.7.2 – Generation of Vertical Weather View.

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.

7.1.4.1.3. Manual Modes

The 3D buffer eases the manual weather analysis with an **enhanced tilt mode**, a **new elevation mode**, and a **new azimuth 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 (refer to 7.1.4.4 – Ground Mapping). In addition, beyond the intersection of the laser cut and the ground, the weather is not displayed. Refer to Figure 7-22.

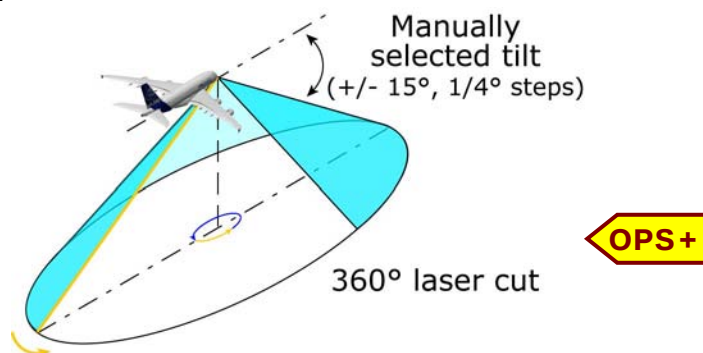


Figure 7-21: Tilt mode

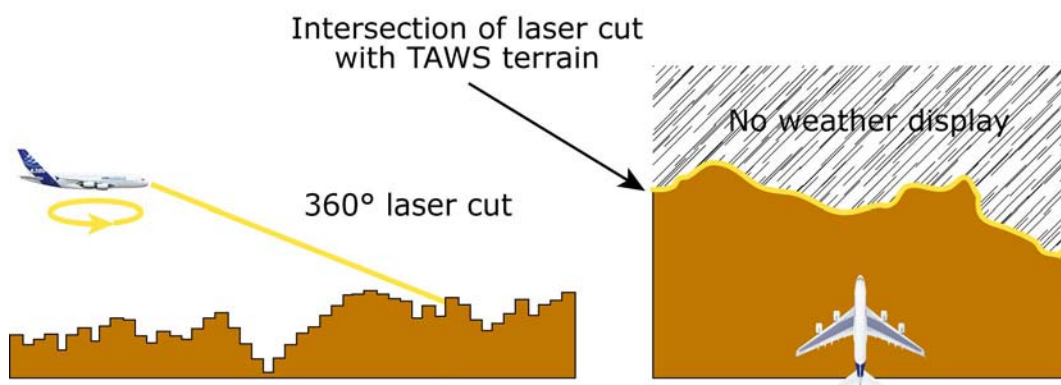


Figure 7-22: Inhibition of weather display beyond the laser cut

• Elevation Mode

In elevation mode, AESS:

- 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 60 000 ft or FL600**.

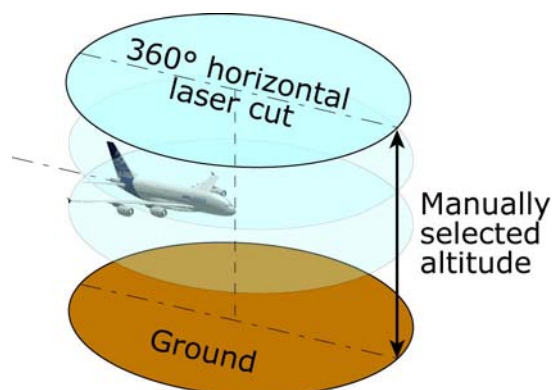


Figure 7-23: Elevation mode

• Azimuth Mode

In azimuth mode, AESS:

- Makes a vertical laser cut at the selected azimuth across the 3D buffer
- Displays the weather contained in the vertical laser cut on VD.

Refer to **7.1.7.2 – Generation of Vertical Weather View** and **Figure 7-33**.

7.1.4.2. ENHANCED TURBULENCE DETECTION

The turbulence detection has been improved thanks to new pulse waveforms and digital signal processing. The detection range is 40 NM from the aircraft and 20 NM laterally on either side from the aircraft centerline.

When the AESS detects turbulence², the AESS displays turbulence on ND in all weather radar operating modes including ground mapping.

The AESS does not display turbulence on the Vertical Display.

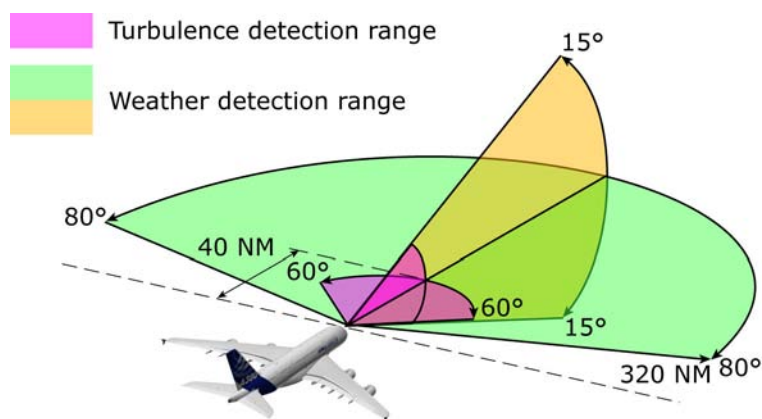


Figure 7-24: AESS radar coverage

7.1.4.3. PREDICTIVE WIND SHEAR (PWS) DETECTION

The AESS automatically activates the PWS detection below 1 500 ft AGL. The detection range goes from 0.5 to 5 NM. When the AESS detects wind shears, the AESS displays wind shears on ND in all weather radar operating modes including ground mapping. **Wind shears are not shown on Vertical Display.**

Refer to **Figure 6-18** for the envelopes of wind shear alerts (Honeywell pattern).

² As a reminder, the weather radar does not detect Clear Air Turbulences (CAT).

7.1.4.4. GROUND MAPPING



The AESS automatically generates the Ground Mapping view without any action from the flight crew (i.e. no tilt and gain settings required). A **Ground Clutter Suppression** continuously runs on data from the weather antenna. To identify ground returns, the Ground Clutter Suppression compares radar returns with the terrain and obstacle databases of the TAWS function. The AESS separates weather and ground returns in the 3D buffer to provide a weather image and a ground image.

Note: if terrain/obstacle elevation from the TAWS database is not valid, the Ground Clutter Suppression does not work properly. The weather image may contain ground returns, and the ground image may contain weather returns.

7.1.5. TCAS FUNCTION

The TCAS function of the AESS is compliant with TCAS II Change 7.0. The collision avoidance principle is not changed. For more details, refer to **3 – Traffic Surveillance**.

7.1.6. TRANSPONDER FUNCTION

The transponder function of the AESS is able to:

- Reply to Mode A and C interrogations,
- Operate in Mode S environments (ELS and EHS),
- Operate with the TCAS function,
- Broadcast ADS-B messages (compliant with DO-260A³).

Refer to **2 – Aircraft identification and position reporting** for more details on transponder principles.

7.1.7. VERTICAL DISPLAY

The Vertical Display (VD) is one of the novelties introduced by the A380 cockpit. It provides the vertical view of:

- | | |
|-------------------------|----------------------------|
| - Safety altitudes, | - Weather information, and |
| - Predicted trajectory, | - Terrain information. |

The description of VD in this paragraph focuses on weather and terrain 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 and terrain 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.

The VD background image runs along the lateral flight path defined by the active navigation mode or a manually selected azimuth.

³ The transponder function of the A380 AESS is compliant with DO-260A including the geographic filtering of Mode A code (refer to **2.2.7 – Geographical Filtering of SQWK Code**).

- **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).

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 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 7-25.

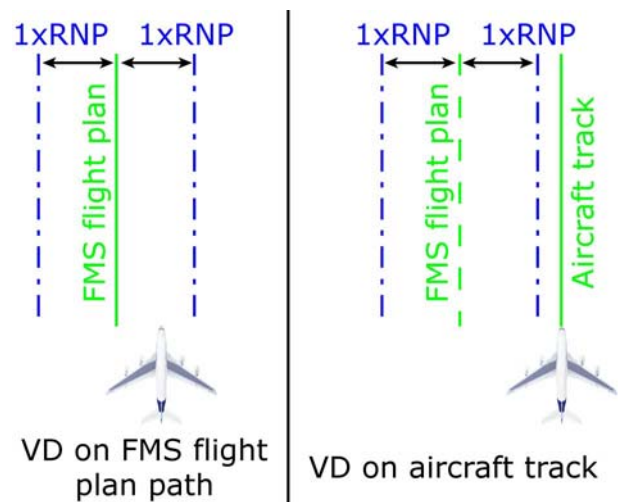


Figure 7-25: VD path reference

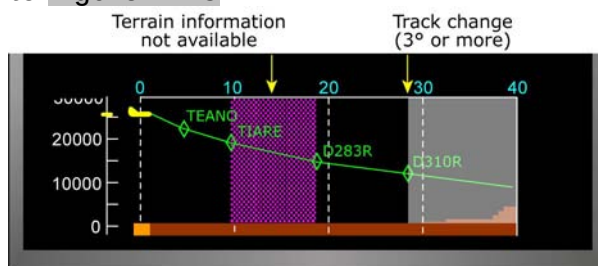


Figure 7-26: Track change and absence of terrain information on VD

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 7-26.

When the terrain information is not available, the corresponding portion of the vertical view is shaded in magenta.

- **VD Background Image on Manually Selected Azimuth**

The VD background image runs along an azimuth selected by a flight crewmember (refer to 7.1.9.3 – SURV Panel). The azimuths selected by the Captain and the First Officer for the VD image are independent. The azimuth range is +/- 60° from the current track with increments of 1°.

7.1.7.1. GENERATION OF VERTICAL TERRAIN VIEW

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.

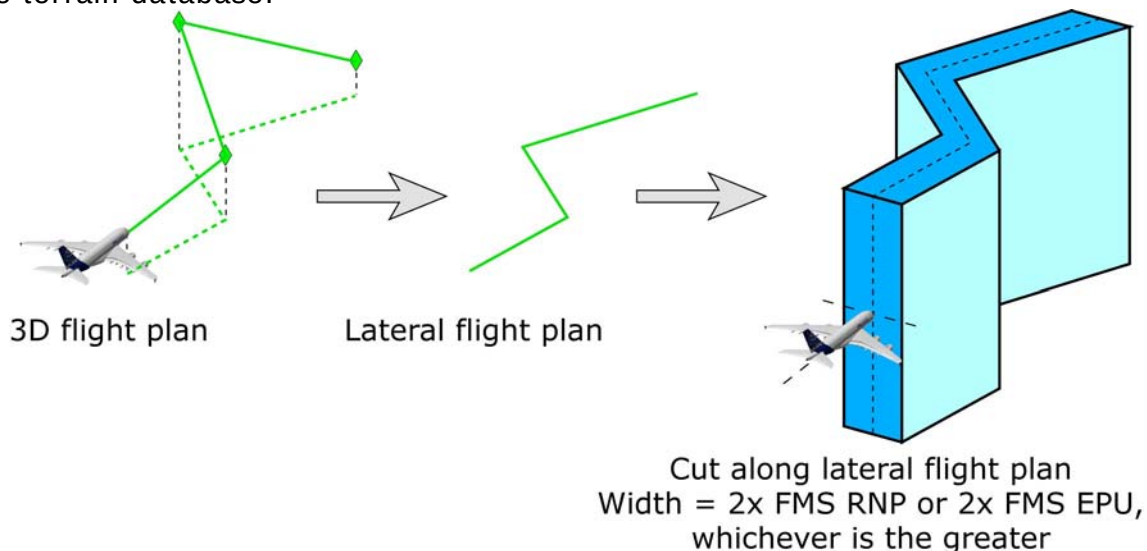


Figure 7-27: Generation of vertical terrain view along FMS flight plan path

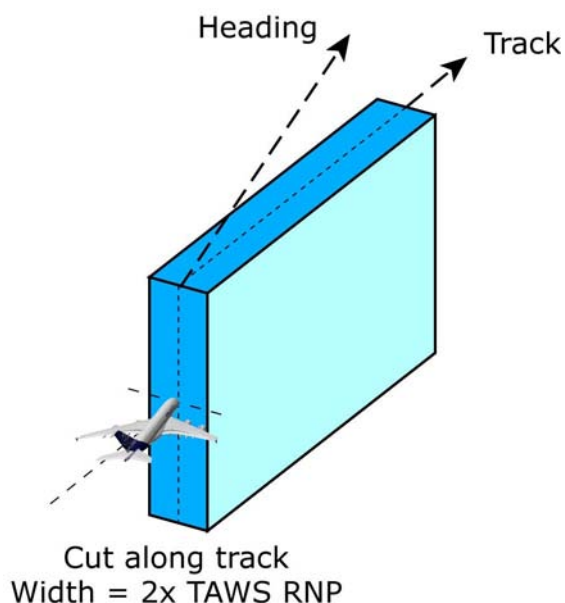


Figure 7-28: Generation of vertical terrain view along track

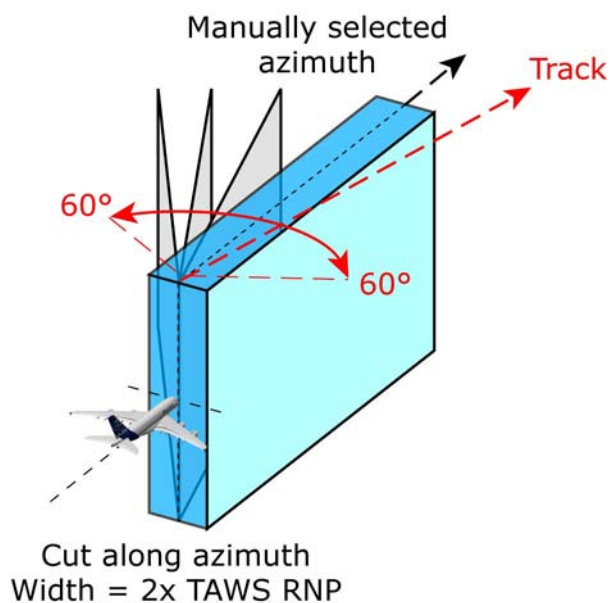


Figure 7-29: Generation of vertical terrain view along azimuth

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 4.1.1.1 – Terrain Database). 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 7-30.

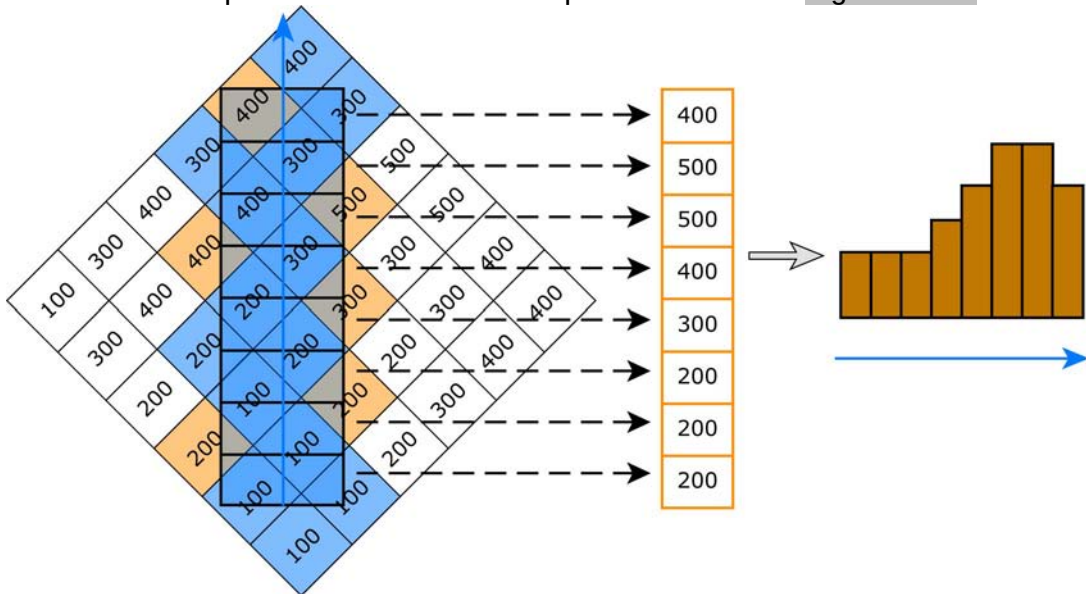


Figure 7-30: Cut through terrain database

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.

7.1.7.2. GENERATION OF VERTICAL WEATHER VIEW

The same principle applies for the generation of vertical weather view. The WXR function makes a vertical cut in the 3D buffer along the VD path reference (aircraft track, FMS flight plan or manual azimuth). However, the vertical cut in the weather radar 3D buffer has no width. It is a “**laser cut**”.

- **Image generation in automatic modes**

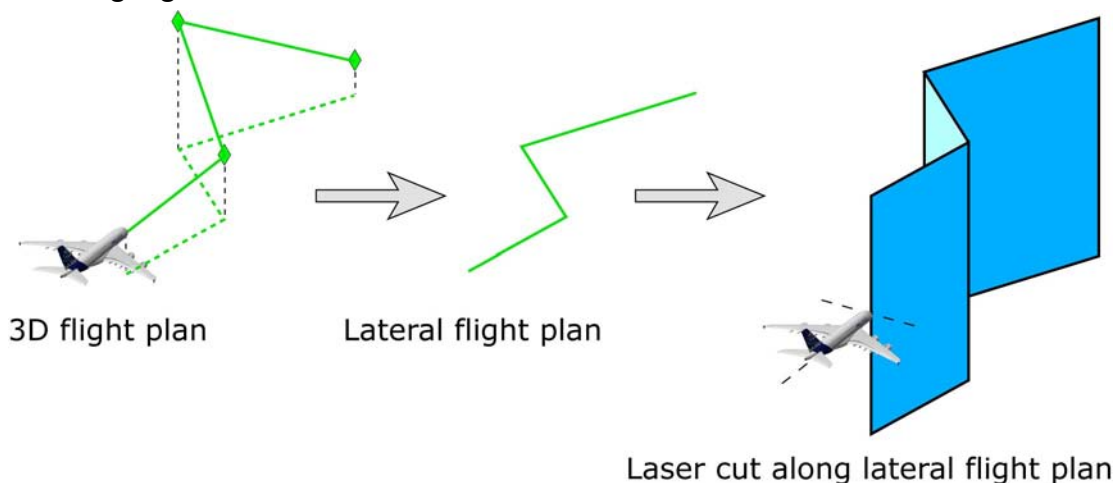
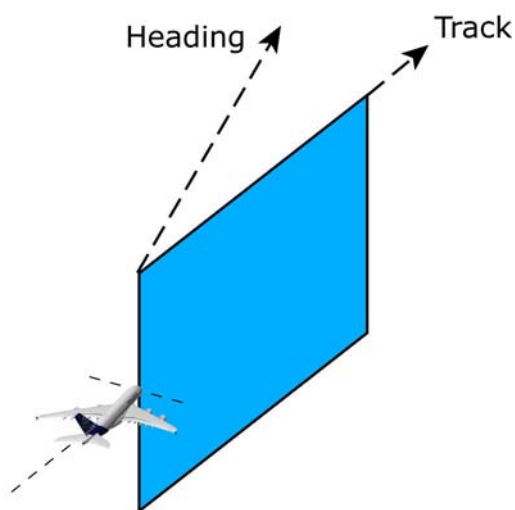
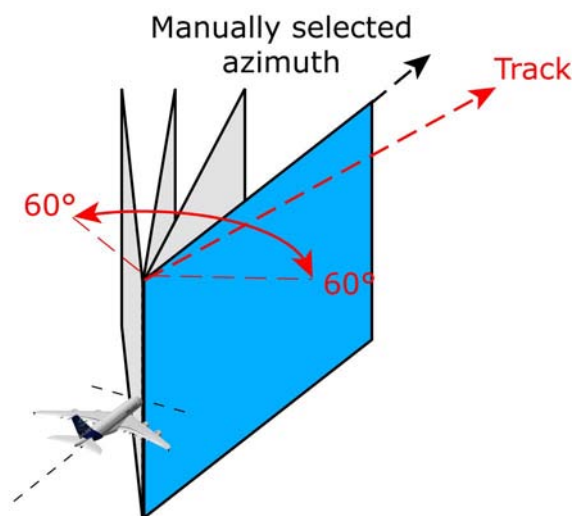


Figure 7-31: Generation of vertical weather view along FMS flight plan



Laser cut along track

Figure 7-32: Generation of vertical weather view along track

Laser cut along azimuth

Figure 7-33: Generation of vertical weather view along azimuth

- **Image generation in manual modes**

In tilt and elevation modes, the WXR function makes the laser cut as illustrated in 7.1.4.1.3 – Manual Modes.

7.1.7.3. INTERPRETATION OF WEATHER AND TERRAIN 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 7-34 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 7-34) 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 7-34).

The same interpretation can be made for weather information.

Do **not** directly read weather and terrain elevations on VD as they depend on local atmospheric conditions.

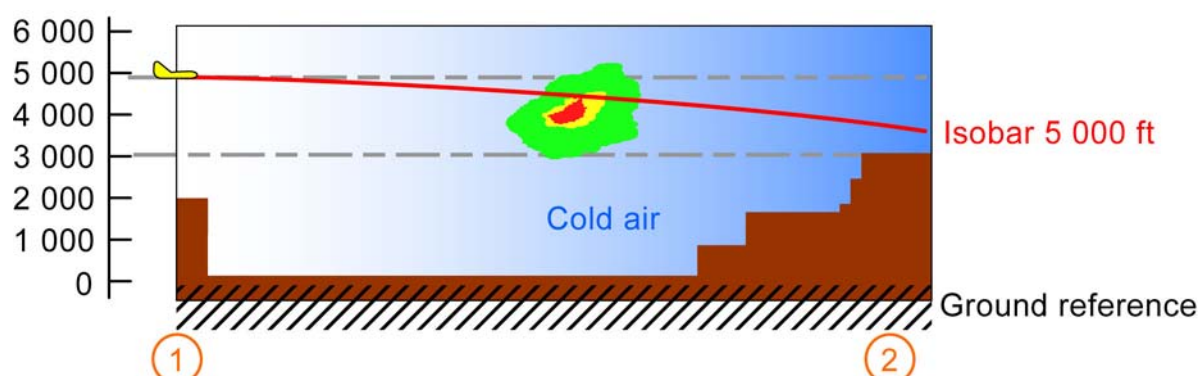


Figure 7-34 – Interpretation of weather and terrain information on VD

7.1.8. AES INDICATIONS

7.1.8.1. NAVIGATION DISPLAY (ND)

Captain and First Officer ND displays are independent. Each flight crewmember can display the desired information (terrain or weather) in the desired mode (tilt, elevation, azimuth, or automatic).

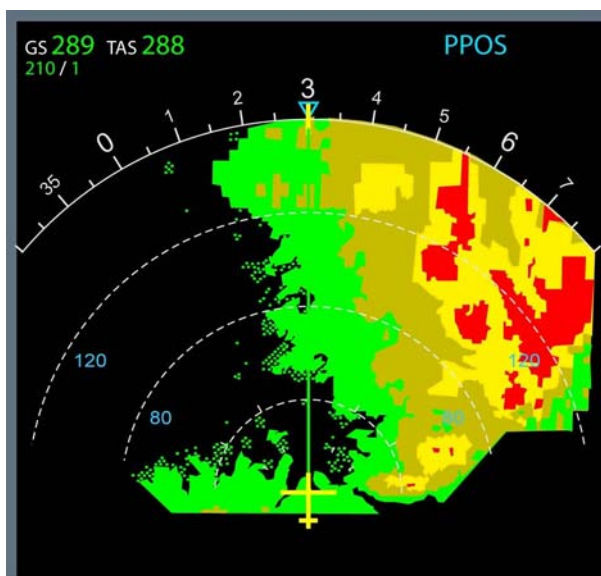


Figure 7-35: A380 ND TAWS view



Figure 7-36: A380 ND WXR view

AESS displays turbulence indications on ND within:

- 40 NM ahead of the aircraft
- 20 NM on either side of the aircraft centerline
- 4 000 ft above or below the aircraft altitude.

Refer to [Figure 7-24](#) for AESS radar coverage.

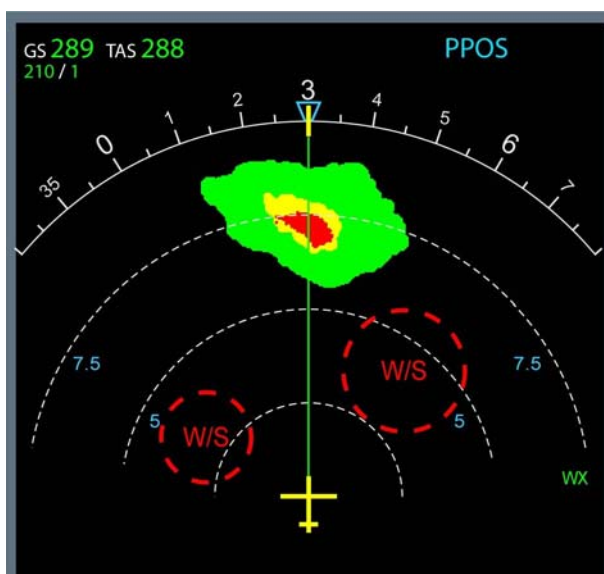


Figure 7-37: Wind shear icons for ND range of 10 NM

To enhance awareness of wind shears, the WXR function highlights sectors where wind shears occur in yellow for ND range greater than 10 NM.

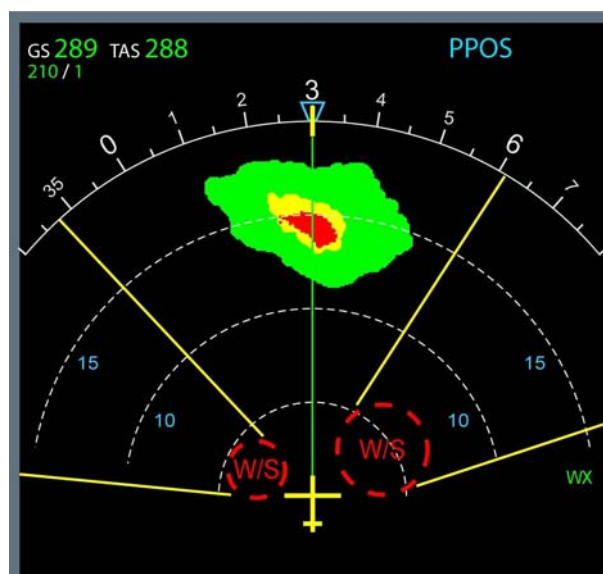


Figure 7-38: Wind shear icons for ND range greater than 10 NM

7.1.8.2. VERTICAL DISPLAY (VD)

- **VD image on aircraft track**

When the VD image is on aircraft track and the aircraft is under specific conditions⁴, the white indication **VIEW ALONG ACFT TRK** is displayed at the bottom of VD.

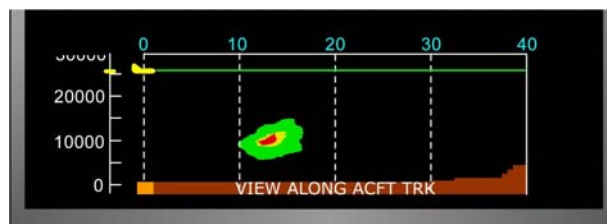


Figure 7-39: VD image on aircraft track

- **VD image on FMS flight plan path**



Figure 7-40: VD image on FMS flight plan path

- **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.



Figure 7-41: VD image on manual selected azimuth

⁴ For instance, in managed mode, when the aircraft deviates from the flight plan or the XLS approach course. Refer to your FCOM for details.

The AESS also displays a white reference line on ND to illustrate the manually selected azimuth (refer to Figure 7-36).

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 $\pm 60^\circ$ limits, the white reference line sticks to the limit until the aircraft turns in the opposite direction.

Figure 7-42 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.

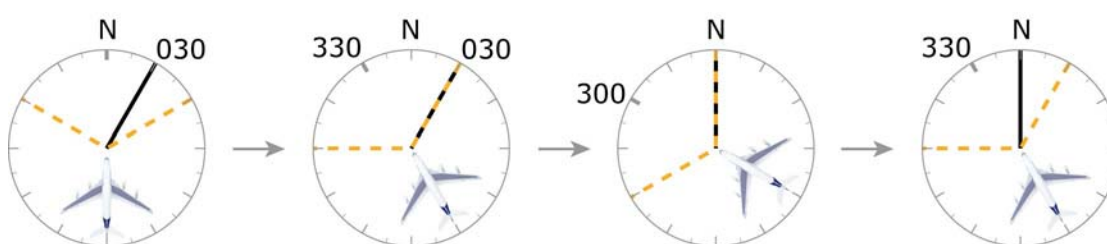


Figure 7-42: Behavior of the reference line during turns

The following table compares the surveillance data displayed on ND and VD.

	Navigation Display ND	Vertical Display VD
TAWS – Terrain	Yes	Yes
WXR – Ground mapping	Yes	No
WXR – Weather	Yes	Yes
WXR – Wind shear (PWS)	Yes	No
WXR – Turbulence	Yes	No
TCAS – Traffic	Yes	No

7.1.8.3. PRIMARY FLIGHT DISPLAY (PFD)

AESS displays on PFD:

- Wind shear alerts (amber W/S AHEAD caution or red W/S AHEAD warning) from the weather radar function
- Terrain alerts from the TAWS function
- TCAS orders on VSI.

Note: AESS provides terrain indications on PFD contrary to EGPWS or T2CAS that illuminates the PULL UP/GPWS pushbutton.

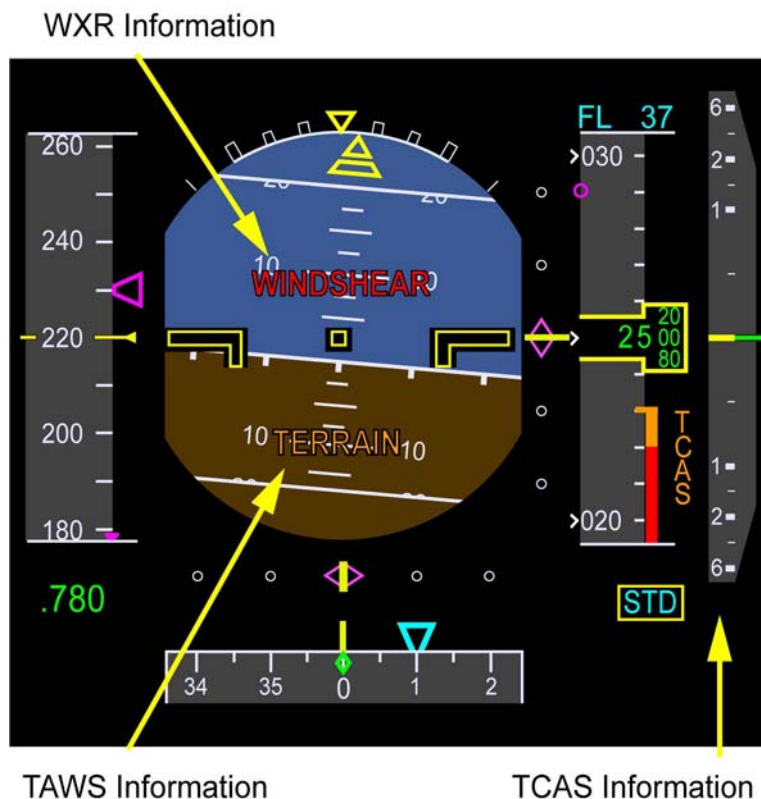


Figure 7-43: AESS indications on A380 PFD

7.1.8.4. AURAL ALERTS

AESS provides the same aural alerts as the ones provided by stand-alone systems:

- For TCAS alerts, refer to 3.1.7.2 – TCAS Aural Alerts
- For TAWS alerts, refer to 4.1.5 – TAWS Indications (see EGPWS)
- For WXR alerts, refer to 6.1.7 – Weather Radar Indications.

7.1.9. AESS CONTROLS

All AESS controls are common to Captain and First Officer, **except the following** that are limited to onside displays:

- **KCCU:** SURV key
- **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.

7.1.9.1. KCCU SURV KEY



Figure 7-44:
KCCU SURV key

The KCCU SURV key is a shortcut to the MFD SURV page. Refer to Figure 5-15 for the global KCCU picture.

7.1.9.2. EFIS CONTROL PANEL (EFIS CP)



Figure 7-45: EFIS Control Panel

With the EFIS CP, in addition to the range selection, the flight crew can select the information to be displayed on ND and VD (if available):

- WX: Weather, or
- TERR: Terrain, or
- TRAF: Traffic.

The flight crew cannot simultaneously select WX and TERR.

7.1.9.3. SURV PANEL



Figure 7-46: AESS Control Panel

With the SURV panel, the flight crew can:

- **TCAS⁵**: Select TCAS modes (ABV, BLW or NORM, and TA only or TA/RA)
- **TAWS**: Deactivate the visual and aural alerts of the TAWS Mode 5 – Excessive glide slope deviation
- **WXR**: Manually set the elevation/tilt⁶, gain or VD azimuth (these settings for CAPT and F/O are independent) or activate the WXR AUTO mode⁷
- **AESS**: Select the function groups (WXR/TAWS 1 or 2, XPDR/TCAS 1 or 2).

7.1.9.4. SURV PAGES ON MFD

Two pages relative to AESS are available on MFD:

- The SURV CONTROLS page
- The SURV STATUS & SWITCHING page.

⁵AESS does not support the THRT function (refer to 3.1.8 – TCAS Controls).

⁶ The flight crew uses the WXR ELEVN knob to manually set an elevation or tilt value. Refer to FCOM for more details.

⁷ The flight crew pushes the WXR ELEVN knob to activate the WXR AUTO mode.

7.1.9.4.1. CONTROLS Page

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 modify the SQWK code. However, for routine SQWK code changes, the flight crew can easily modify the SQWK code and send the IDENT signal in the RMP SQWK page (refer to 7.1.9.5 – SQWK Page on RMP).

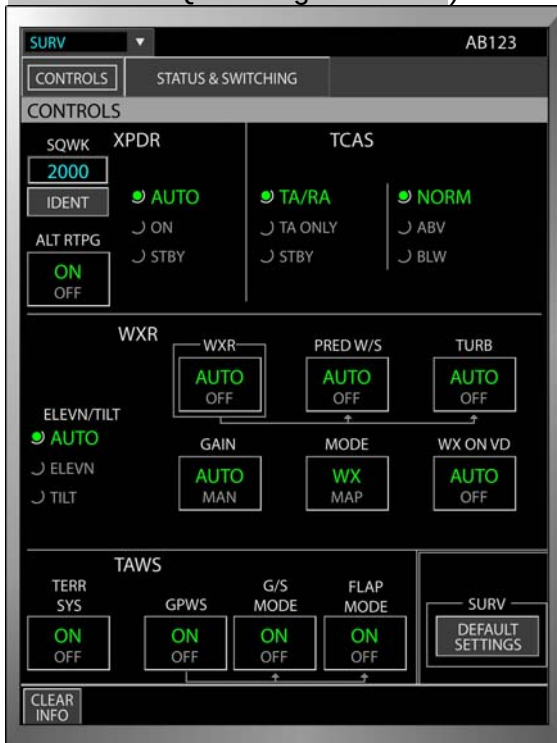


Figure 7-47: MFD SURV CONTROLS page

7.1.9.4.2. STATUS & SWITCHING Page

Through the MFD SURV STATUS & SWITCHING page (refer to Figure 7-49), the flight crew can dispatch the function groups on AESU 1 or 2 according to the detected failures.

This page is a back up of the AESS Control Panel for the selection of function groups.

At any time, the flight crew can reset the default settings (the ones shown in Figure 7-47) with the DEFAULT SETTINGS button in the bottom right corner. A dialog box pops up to confirm the reversion to default settings. When the flight crew resets the default settings, the AESS keeps the current SQWK code.

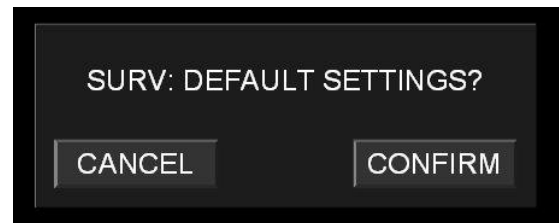


Figure 7-48: DEFAULT SETTINGS confirmation

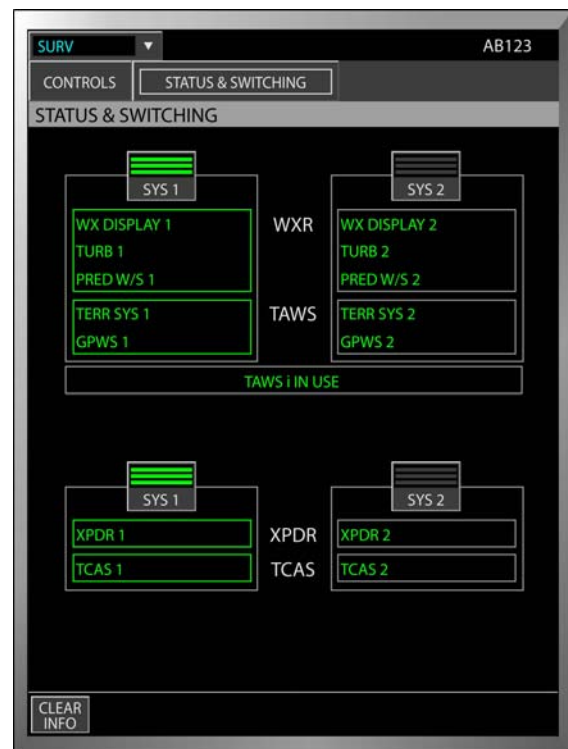


Figure 7-49: MFD SURV STATUS & SWITCHING page

7.1.9.5. SQWK PAGE ON RMP

On the RMP, the flight crew can:

- Modify the SQUAWK code in the SQWK page
- Activate the IDENT function from the SQWK page
- Check the transponder operating mode (AUTO, ON or STBY) either in the SQWK page or in the message line of the VHF, HF, or TEL page.

In compliance with the AIRBUS dark cockpit philosophy, the AUTO mode, which is the normal mode, is not indicated in the message line.



Figure 7-50: Transponder indications on RMP

7.2. OPERATIONAL RECOMMENDATIONS FOR AESS

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.

7.2.1. FOR THE AIRLINE

7.2.1.1. TRANSPONDER FUNCTION

Refer to 2.5 – Operational Recommendations for Transponder.

7.2.1.2. TCAS FUNCTION

Refer to 3.2 – Operational Recommendations for TCAS.

7.2.1.3. TAWS FUNCTION

In addition to recommendations provided in 4.2 – Operational Recommendations for TAWS, here are some recommendations specific to the A380 aircraft.

- During the training, pay special attention to the Vertical Display (VD) (e.g. automatic ground de-cluttering, generation of the vertical terrain view).

7.2.1.4. WEATHER RADAR FUNCTION

In addition to recommendations provided in 6.2 – Operational Recommendations for Weather Radar, here are some recommendations specific to the A380 aircraft.

- During the training, pay special attention to the Vertical Display (VD) (e.g. 3D buffering, generation of the vertical weather view).

7.2.2. FOR THE FLIGHT CREW

- Be aware of the automatic management of AESS functions per flight phase (e.g. WXR automatically turns off 60 s after touchdown). Refer to your FCOM for more details.

7.2.2.1. TRANSPONDER FUNCTION

Refer to 2.5 – Operational Recommendations for Transponder.

7.2.2.2. TCAS FUNCTION

Refer to 3.2 – Operational Recommendations for TCAS.

7.2.2.3. TAWS FUNCTION

In addition to recommendations provided in 4.2 – Operational Recommendations for TAWS, here are some recommendations specific to the A380 aircraft.

- Fly all flight phases with all TAWS settings to ON (i.e. DEFAULT SETTINGS) except when:
 - The airport is not in the TAWS database and the aircraft is within 15 NM from that airport, or
 - The approach procedure is known to produce erroneous TAWS alerts.
- **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)

7.2.2.4. WEATHER RADAR FUNCTION

In addition to recommendations provided in 6.2 – Operational Recommendations for Weather Radar, here are some recommendations specific to the A380 aircraft.

- Remember that it may take up to 30 seconds to build up the weather picture at the first weather radar activation (e.g. before take-off run or switching between SYS 1 and 2).
- **Be aware of the mechanism involved in the generation of the vertical weather view** (e.g. along flight plan, along track, along selected azimuth, on path and off path weather, atmospheric influences on barometric elevations).

7.3. REGULATIONS FOR AESS

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

The A380 AESS proposes an integrated solution for surveillance functions with some enhancements. Nevertheless, the AESS elementary functions are quite similar to the non-integrated surveillance functions described in the previous chapter (i.e. transponder, TCAS, TAWS, WXR). Therefore, the operational requirements are the same.

7.3.1. TRANSPONDER FUNCTION

Refer to 2.6 – Regulations for Transponder.

7.3.2. TCAS FUNCTION

Refer to 3.3 – Regulations for TCAS.

7.3.3. TAWS FUNCTION

Refer to 4.3 – Regulations for TAWS

7.3.4. WEATHER RADAR FUNCTION

Refer to 6.3 – Regulations for Weather Radar.

7.4. MANUFACTURERS FOR AESS

Honeywell and AIRBUS jointly developed the A380 AESS to integrate all surveillance systems in one. Figure 7-1 provides a simplified view of the AESS architecture. Functions supported by the AESS are derived from elementary Honeywell products:

- XPDR from TRA 67A Mode S transponder,
- TCAS from TPA 100A TCAS,
- TAWS from EGPWS,
- WXR from RDR 4000 weather radar.

7.5. FUTURE SYSTEMS

7.5.1. AIRBORNE TRAFFIC SITUATIONAL AWARENESS (ATSAW)

The A380 AESS is already capable to broadcast ADS-B OUT data, and is expected to implement the ATSAW application as described in 3.6 – Description of ATSAW. The ATSAW application makes the most of ADS-B IN data to improve the traffic awareness. The interactivity of the ATSAW application will be improved thanks to the interfaces provided by the A380 cockpit (i.e. KCCU).

Please bear in mind...**Description**

The AESS is an integrated surveillance system on A380 aircraft. It includes the transponder, the TCAS, the TAWS and the weather radar with PWS. The TAWS and the weather radar use the **Vertical Display (VD)** at best to enhance the flight crew awareness on terrain and weather.

Therefore, the AESS is also able to display on VD the terrain and weather along the path followed by the aircraft (flight plan, track) or the azimuth selected by the flight crew. The weather radar also introduces, thanks to the 3D buffer, the **on-path and off-path weather concept**, the weather view at a selected altitude (elevation mode).

The AESS controls are distributed on the AESS Control Panel, the EFIS CP, the MFD SURV page and the RMP SQWK page.

Operational recommendations

Operational recommendations regarding the AESS functions are the same as the ones provided for the elementary systems (i.e. XPDR, TCAS, TAWS, WXR). The VD introduces new logics and features. Therefore, **a special attention should be paid to mechanisms introduced by the VD.**

Refer to **7.2 – Operational Recommendations for AESS.**

Regulations

Regulations for the integrated AESS are the same as for elementary systems (i.e. XPDR, TCAS, TAWS, WXR).

Future systems

To keep pace with the deployment of the ADS-B technology, the AESS is expected to implement the ATSAW applications for enhanced traffic awareness.

APPENDICES



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Appendix H – Low level Wind shear effects on aircraft performances	H-1

APPENDIX A – WORLDWIDE ADS-B IMPLEMENTATION

This appendix provides a global view on the main implementation of ADS-B worldwide. ADS-B is an emerging technology and its implementation is concentrated in **Europe, USA, Australia and Asia** at the time of writing the brochure. Some local implementations exist where ADS-B is more profitable than SSR (e.g. the French La Réunion island, Indian Ocean).

Mandate dates for ADS-B are provided for information only. Refer to the appropriate Authority for the final dates.

A.1. THE EUROPEAN CASCADE PROGRAM

A.1.1. DESCRIPTION

- Europe progressively implements all ADS-B applications in the frame of the CASCADE program. The CASCADE program is one of the first bricks to found future ATM operations to be implemented in SESAR.

The first operational approvals for ADS-NRA were delivered late 2007. At the time of writing the brochure, standards for ADS-B RAD, ATSA VSA and ATSA ITP are being finalized before pre-operational validation. **EASA envisages an ADS-B mandate in 2015.**

A.1.2. WEBSITE

Details on SESAR may be found at <http://www.sesarju.eu>.

Details on the CASCADE program may be found at

http://www.eurocontrol.int/cascade/public/subsite_homepage/homepage.html

A.2. THE FAA SURVEILLANCE AND BROADCAST SERVICES PROGRAM

The FAA launched the program in 2005 for the implementation of ADS-B over the US territory. ADS-B is a crucial component of the US Next Generation Air Transportation system (NGATS or NextGen).

A.2.1. DESCRIPTION

The FAA deploys the ADS-B coverage in two segments:

- **Segment 1** includes Ontario (CA), Garden City (KS), North Platte (NE), Kansas City (KS), Louisville (KY), Gulf of Mexico, Philadelphia (PA), Bethel Area (AK), Anchorage (AK), and Juneau (AK). The first operational sites should start in Q3 2009, and the Segment 1 deployment should end in Q3 2010.
- **Segment 2** covers the entire US territory. The deployment of ADS-B in Segment 2 should start from 2010 and should end in 2013. An avionics equipage rate of 26% is expected by 2014 and a full equipage rate by 2020.

As proposed by the FAA NPRM released in October 2007, ADS-B would be mandatory in the following airspaces:

- Class A, Class B, Class C, Class E above 10 000 ft,
- From the surface to 10 000 ft within 30 NM of specified busy airports, and
- In the Gulf of Mexico above 3 000 ft, within 12 NM from the coast.

The FAA plans an ADS-B mandate in 2020.

A.2.2. WEBSITE

Details on NextGen may be found at <http://www.jpdo.gov/index.asp>.

Details on the Surveillance and Broadcast Services program may be found at http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/enroute/surveillance_broadcast/.

A.3. THE AUSTRALIAN ADS-B UPPER AIRSPACE PROGRAM (UAP)

A.3.1. DESCRIPTION

Airservices Australia is currently deploying ADS-B ground stations across Australia. Combined with existing SSRs, deployed ADS-B ground stations will provide an air traffic surveillance capability over the entire Australian territory. The air traffic surveillance will be available above FL 300 (refer to Figure A - 1). The objective of the program is to provide ADS-B equipped aircraft with increased safety and operational flexibility in non-radar airspace. ADS-B equipped aircraft will also be afforded operational priority in the ATC system.

The ADS-B UAP plans the installation of 28 ADS-B ground stations at remote locations in Australia, co-located with existing radio communication facilities.

The Australian Advanced Air Traffic System (TAAATS) is being upgraded to process 1000 ADS-B flights simultaneously from up to 200 ground stations. TAAATS will also use ADS-B technology to provide air traffic controllers with automated safety alerting capabilities and will continually monitor an aircraft's assigned route and altitude for any discrepancies.

Combined radar and ADS-B coverage with initial ADS-B deployment

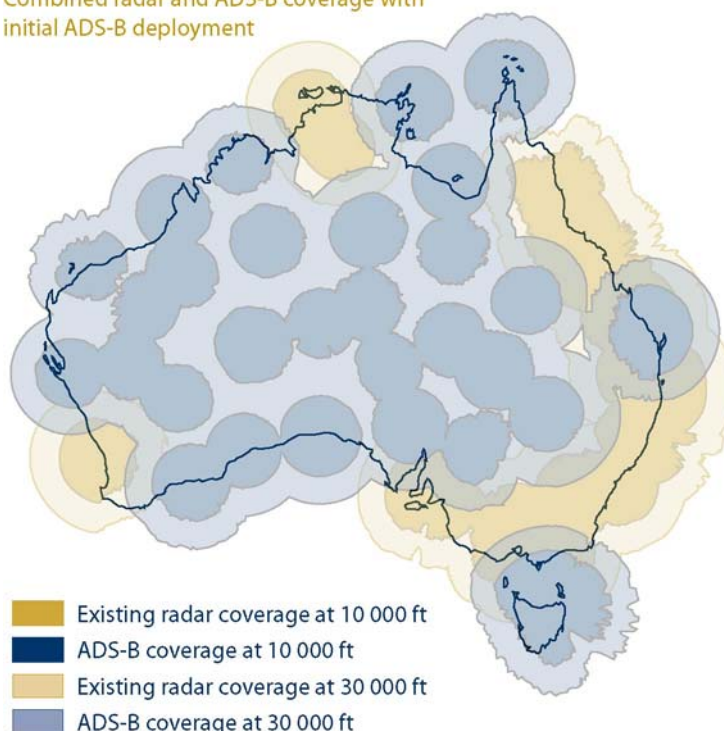


Figure A - 1: Australian ADS-B coverage

The ADS-B UAP also plans the purchase of a new Receiver Autonomous Integrity Monitoring (RAIM) system. The RAIM system will provide controllers with real-time information on Global Navigation Satellite System integrity.

The Upper Airspace Program may be expanded to provide additional ADS-B coverage and services below FL300 at a later date.

At the time of writing the brochure, Airservices Australia operates ADS-B on a voluntary basis. **CASA Australia mandates the carriage of ADS-B from December 12th 2013 at or above FL 290.**

A.3.2. WEBSITE

For more details, please refer to

<https://www.airservicesaustralia.com/projectsservices/projects/adsb/default.asp>.

A.4. DEPLOYMENT OF ADS-B IN ASIA

A.4.1. DESCRIPTION

In the Bay of Bengal and in the Asian regions, several trials are currently in progress. The following is some examples of activities in progress:

- **Fiji domestic airspace:** Procedural separations are in force. ADS-B is seen as a key enabler for an optimized management of traffic in the Fiji domestic airspace. Surveillance based on ADS-B should start in 2009-2010.
- **Chengdu-Lhasa route (China):** ADS-B is being implemented along the Chendu-Lhasa route to provide a reliable and continuous control service by 2015. Presently, procedural separations are applied. Four ADS-B stations are planned and should be validated in the course of 2009.
- **Incheon International Airport (South Korea):** ADS-B is intended to cope with the increasing traffic and to enhance the final approach and surface monitoring. ADS-B operations should start in the course of 2008. At the time of writing the brochure, 35 ADS-B transmitters had been installed on airport ground vehicles (e.g. fire and rescue, emergency, safety check, airline support, etc).
- **Pakistan airspace:** Most of the Pakistan airspace is radar covered. However, some gaps in the west and northern mountain regions, as well as in the south seaward part of the country, remain. ADS-B is considered to fill in these gaps. Trials are expected to start in late 2008 or early 2009.

A.4.2. WEBSITE

For more details, please refer to the materials of the *Automatic Dependent Surveillance – Broadcast (ADS-B) Seminar and The Meeting Of ADS-B Study and Implementation Task Force* available at <http://www.icao.or.th/welcome.html> (click on the desired year of the MEETING SCHEDULE frame in the middle of the left panel, then search for the ADS-B SITF meeting).

A.5. ADS-B NRA IN THE HUDSON BAY (CANADA)

A.5.1. DESCRIPTION

In July 2006, NAV CANADA announced its intention to implement ADS-B over the Hudson Bay by the end of 2008 (refer to Transport Canada AIC 18/07, see [References](#)). At the time of writing the brochure, 35 000 flights a year crossed the Hudson Bay without surveillance services. NAV CANADA retained ADS-B as the solution to fill in the surveillance gap in this area. ADS-B presents significant benefits compared to SSR in terms of quality, reliability and costs, but it also requires operators crossing this area to be equipped with appropriate avionics.

In 2007, 50 to 60% of the traffic over the Hudson Bay were technically capable to broadcast ADS-B data. IATA expects this portion of traffic to increase up to 90% in 2010.

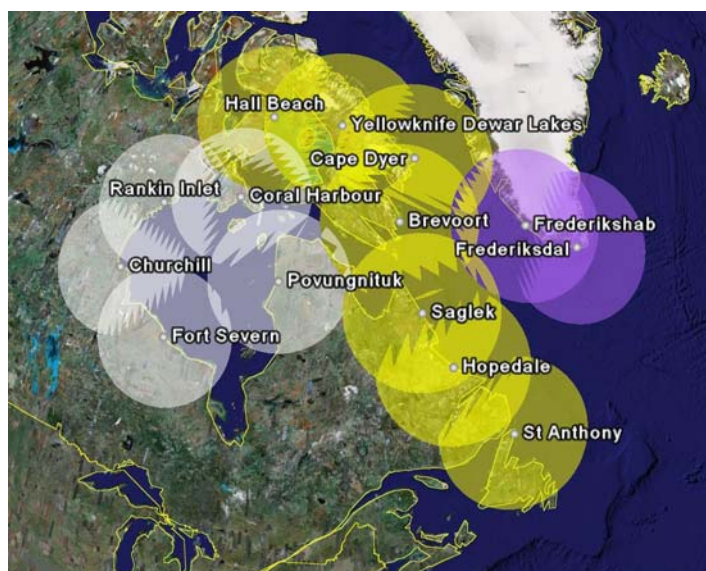


Figure A - 2: ADS-B coverage in Hudson Bay, Canadian Atlantic coast, and Greenland

NAV CANADA currently leads a consultation with its customers in order to prepare the implementation of ADS-B over the Hudson Bay. First operational ADS-B services started in January 2009. **Transport Canada plans an ADS-B mandate over the Hudson Bay in mid 2009 above FL 350.**

Five stations are planned in the Hudson Bay: Rankin Inlet, Churchill, Fort Severn, Povungnituk and Coral Harbor (white areas in [Figure A - 2](#)).

In the future, NAV CANADA plans to expand ADS-B to the Canadian Atlantic coast (yellow areas in [Figure A - 2](#)), the Gander airspace over Greenland (magenta areas in [Figure A - 2](#)), and eventually over the entire country.

A.5.2. WEBSITE

For more details, please refer to:

<http://www.navcanada.ca/NavCanada.asp?Language=en&Content=ContentDefinitionFiles%5CServices%5CANSPrograms%5CADS-B%5Cdefault.xml>

APPENDIX B – ADS-B PHRASEOLOGY

The following table provides an overview of the ADS-B phraseology as per the ICAO Doc 4444 – PANS ATM, 15th Edition, 2007, Chapter 12 – Phraseologies (see [References](#)).

Note: The implementation of ADS-B operations may locally change. Refer to AIP for specific regional procedures.

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*) <i>* As AIRBUS aircraft use the 1090 ES data link, TEN NINETY DATA LINK should be announced.</i> 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	RESET SQUAWK [(mode)] (code)	RE-ENTER [ADS-B or MODE S] AIRCRAFT IDENTIFICATION <i>Note: Not able to comply with some FMS standards (see note in 2.5.2.2 – For the Flight Crew). Refer to AIP for alternative</i>

Circumstances	Radar	ADS-B
Read back	RESETTING (mode) (code)	<i>procedures.</i> Not defined
12.4.3.7. To request the operation of the IDENT feature	SQUAWK [(code)] [AND] IDENT	TRANSMIT ADS-B IDENT <i>Note: Transponder and ADS-B transmitter are coupled on AIRBUS aircraft. Activate the IDENT function as in radar coverage.</i>
12.4.3.10. To request the termination of transponder or ADS-B transmitter operation	STOP SQUAWK [TRANSMIT ADS-B ONLY] <i>Note: Not able to comply with on AIRBUS aircraft. Refer to AIP for alternative procedures.</i>	STOP ADS-B TRANSMISSION [SQUAWK (code) ONLY]
12.4.3.11. To request transmission of pressure-altitude	SQUAWK CHARLIE	TRANSMIT ADS-B ALTITUDE <i>Note: Transponder and ADS-B transmitter are coupled on AIRBUS aircraft. Activate the altitude reporting as in radar coverage.</i>
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)] <i>Note: Transponder and ADS-B transmitter are coupled on AIRBUS aircraft. Refer to 2.5.2.2 – For the Flight Crew.</i>

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: <ul style="list-style-type: none"> - 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 <u>not</u> either the ITP aircraft or the Reference Aircraft.
Qualified data	ADS-B	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: <ul style="list-style-type: none"> - 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 to C.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).

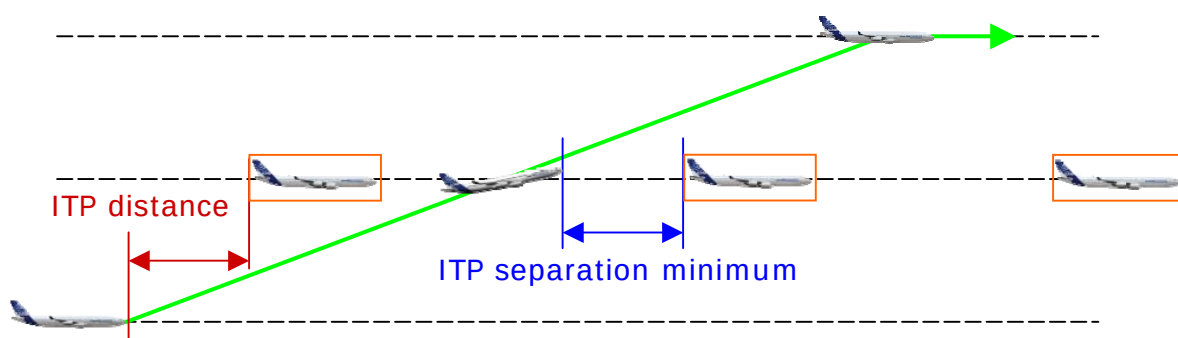


Figure C - 1: ITP separation minimum

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.

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](#).

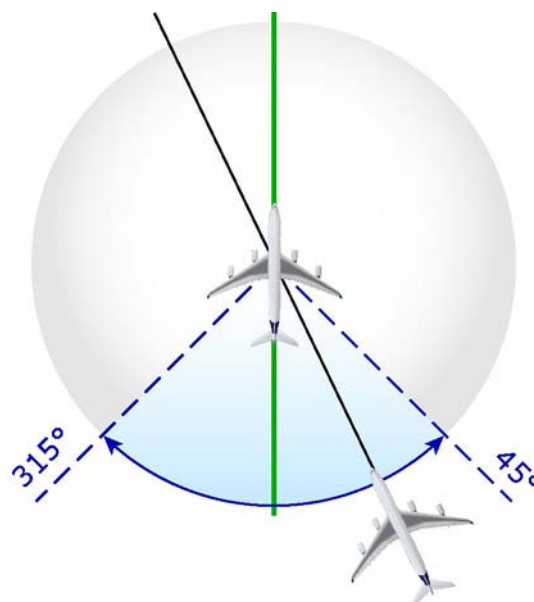


Figure C - 2: Same direction

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).

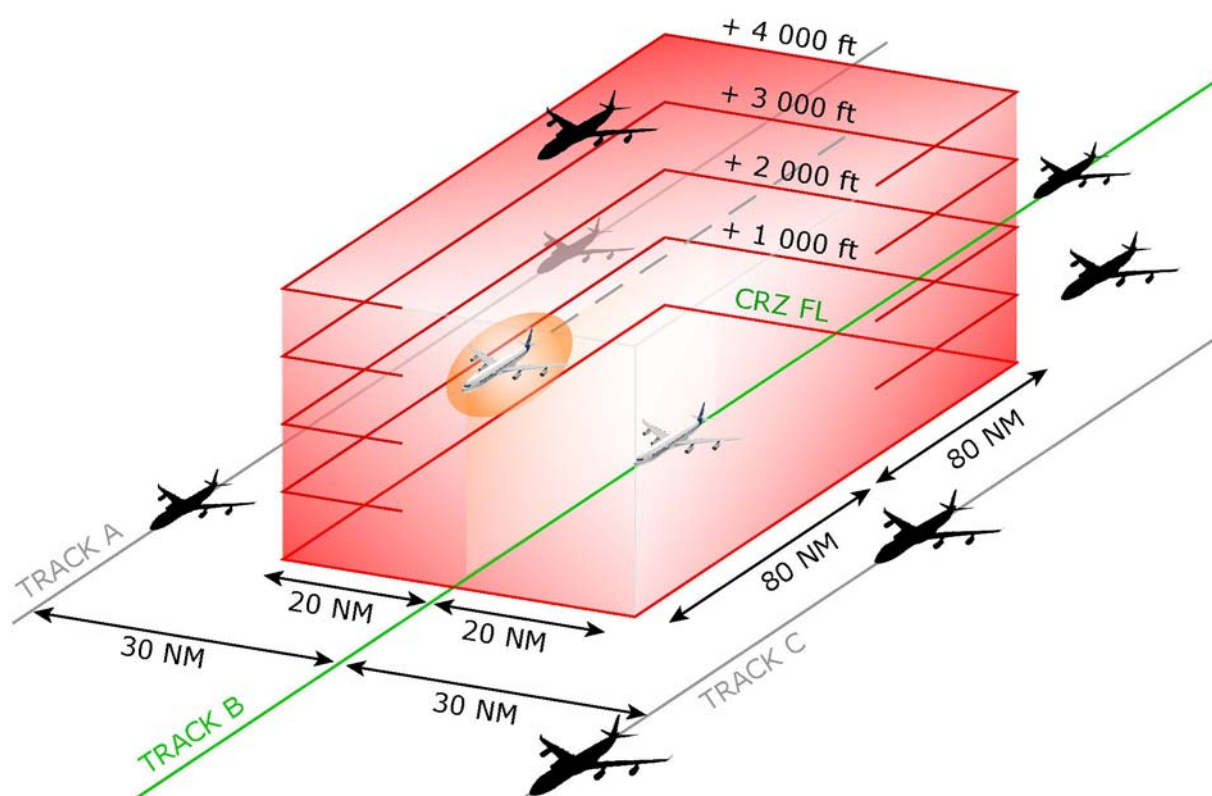


Figure C - 3: ITP volume

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.

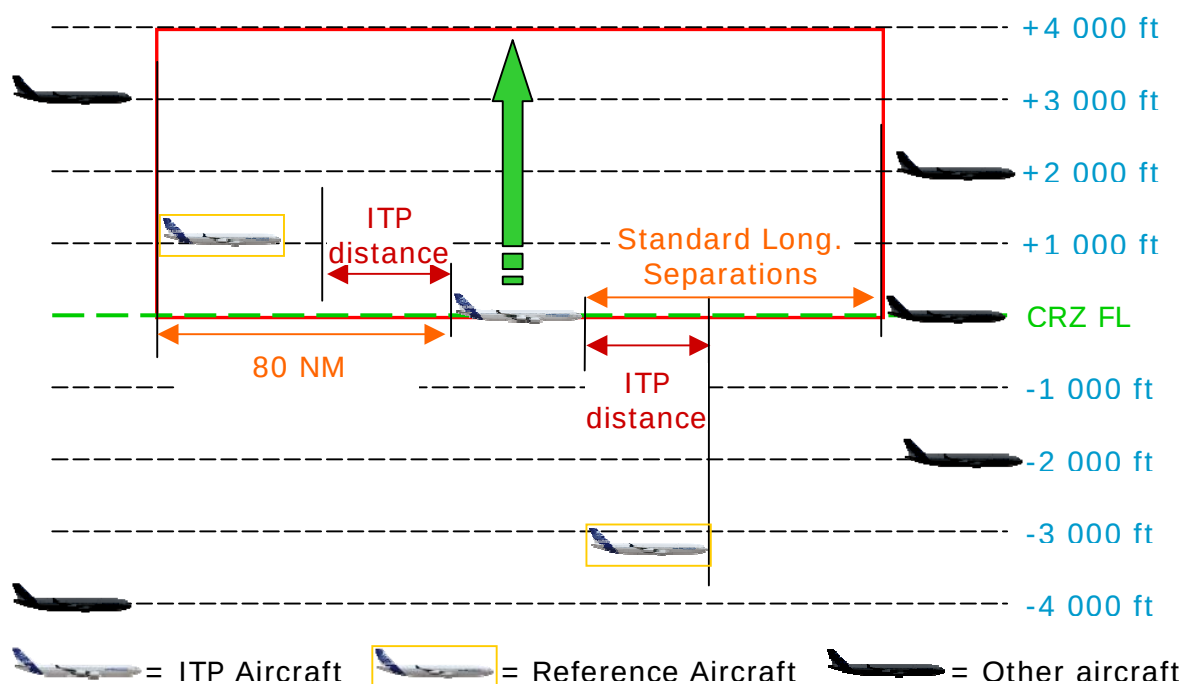


Figure C - 4: Side view of ITP volume

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.**

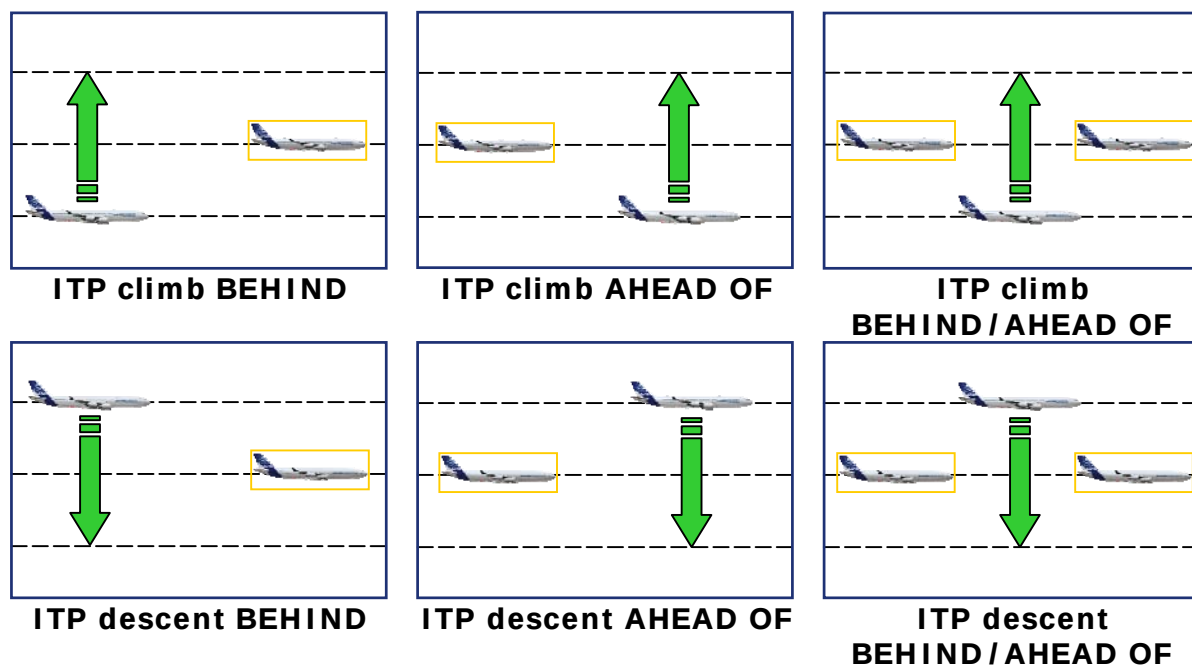


Figure C - 5: ITP geometries

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.

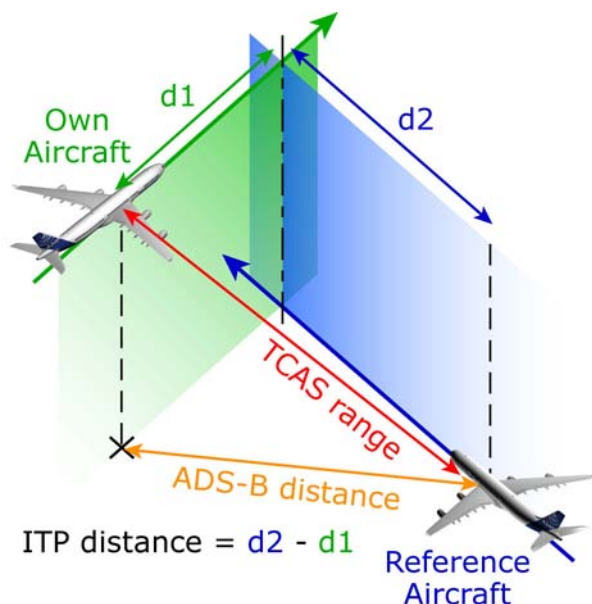


Figure C - 6: ITP distance

Note: It has to be noted that aircraft are separated by thousands of feet vertically and dozens of nautical miles horizontally. As a rough order of magnitude:

$$\frac{1\,000\text{ ft}}{10\text{ NM}} = 0.016. \text{ ADS-B distance does not differ much from TCAS range.}$$

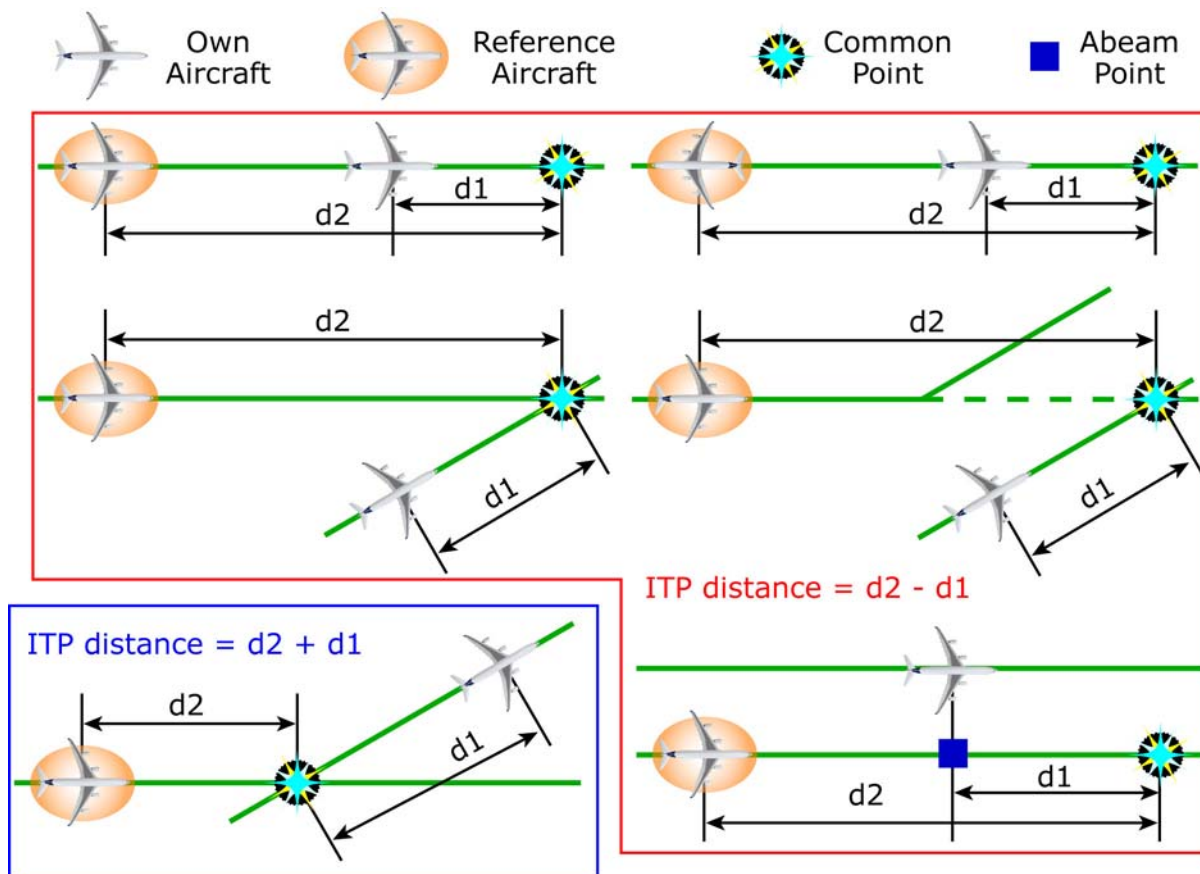


Figure C - 7: ITP distances with different geometries

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 3.6.4.2.4 – 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. PNF: REQUEST THE ATC CLEARANCE

PF informs PNF that ITP is possible and indicates the Reference Aircraft (ITP distance, position, and flight number).

PNF requests an ITP clearance to ATC by CPDLC. PNF applies a specific phraseology in the CPDLC message. **See notes below.**



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.

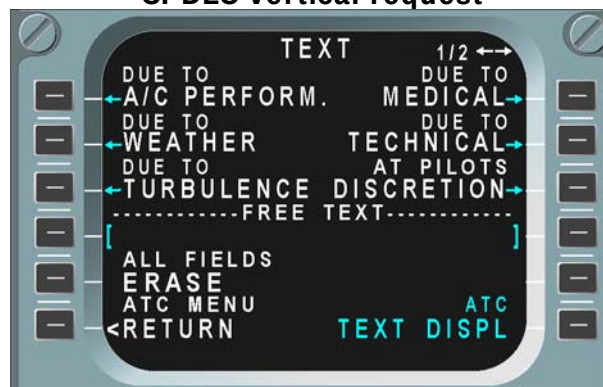


Figure C - 14: Go directly to the 2nd TEXT page with the SLEW keys (←→)



Figure C - 15: Enter ITP data and transfer the message to DCDU

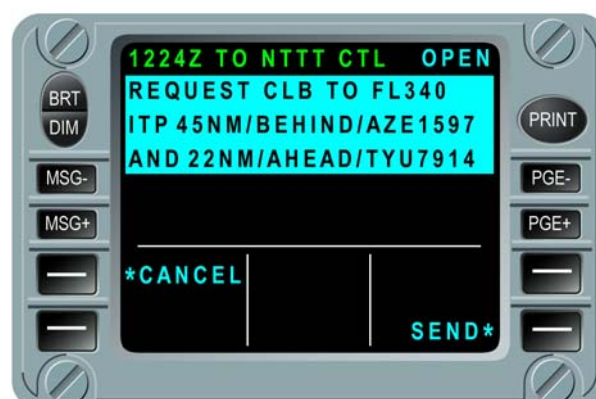


Figure C - 16: Send the message from DCDU

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: At the time of writing the brochure, the CRISTAL ITP consortium suggested an ITP phraseology to ICAO. ICAO evaluates the suggested ITP phraseology and should provide some recommendations. [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, PNF 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.

At the time of writing the brochure, CRISTAL ITP has proposed a PANS-ATM (ICAO Doc 4444) amendment to introduce ATSA ITP to be validated by ICAO.

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

<p>Current VSA procedure Basic VSA procedure <i>(Green italic is specific to the <u>basic</u> procedure)</i></p>	<p>Advanced VSA procedure <i>(Blue italic is specific to the <u>enhanced</u> procedure)</i></p>
<p><i>(Amber italic is specific to the <u>basic and advanced</u> procedure)</i></p>	
<p>Initiation by the ATC controller</p>	
<ul style="list-style-type: none"> ➤ 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. ➤ <i>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.</i> <ul style="list-style-type: none"> o Visual contact <ul style="list-style-type: none"> - <i>The flight crew checks the consistency between the visual contact, the ATSAW traffic information, and the ATC traffic information.</i> - The flight crew informs the ATC controller that the preceding aircraft is in sight (i.e. TRAFFIC IN SIGHT). Go to the next step. 	<ul style="list-style-type: none"> - 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 SIGHT¹). - 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. <ul style="list-style-type: none"> ✓ <i>If the flight numbers are consistent, go to the next step.</i> ✓ <i>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.</i>

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 <i>(Green italic is specific to the <u>basic</u> procedure)</i>	Advanced VSA procedure <i>(Blue italic is specific to the <u>enhanced</u> procedure)</i>
<i>(Amber italic is specific to the <u>basic and advanced</u> procedure)</i>	
<p>o No visual contact</p> <ul style="list-style-type: none"> - 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 - <i>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.</i> 	<ul style="list-style-type: none"> - <i>If the preceding aircraft is on ND, the flight crew</i> <ul style="list-style-type: none"> ✓ <i>Informs the ATC controller that the preceding aircraft is identified on ND (e.g. LOOKING OUT AIB1234²)</i> ✓ <i>Continues to search the preceding aircraft with the support of the ATSAW traffic information.</i> - <i>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:</i> <ul style="list-style-type: none"> ✓ <i>If the flight numbers are consistent, the ATC controller waits the flight crew reports the traffic in sight.</i> ✓ <i>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.</i>
<ul style="list-style-type: none"> - The flight crew informs the ATC controller that the preceding aircraft is finally in sight. 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).

Current VSA procedure Basic VSA procedure <i>(Green italic is specific to the <u>basic</u> procedure)</i>	Advanced VSA procedure <i>(Blue italic is specific to the <u>enhanced</u> procedure)</i>
Initiation by the flight crew	
<ul style="list-style-type: none"> ➤ The flight crew achieves a visual contact with the preceding aircraft with visual information, <i>ATSAW traffic information</i>, and party line (transmissions from the controller and other flight crews on the frequency). ➤ <i>When the preceding is in sight, the flight crew checks the consistency between the visual contact and the ATSAW traffic information.</i> ➤ If the visual contact can be maintained, the flight crew: <ul style="list-style-type: none"> o Informs the ATC controller that the preceding aircraft <i>with its flight number displayed on ND</i> is in sight (<i>e.g. PRECEDING TRAFFIC AIB1234 IN SIGHT</i>). o Requests a clearance for VSA procedure. Go to the next step. 	

D.1.2. CLEARANCE FOR THE MAINTENANCE OF THE VISUAL SEPARATION WITH THE PRECEDING AIRCRAFT

Current VSA procedure Basic VSA procedure <i>(Green italic is specific to the <u>basic</u> procedure)</i>	Advanced VSA procedure <i>(Blue italic is specific to the <u>enhanced</u> procedure)</i>
<i>(Amber italic is specific to the <u>basic and advanced</u> procedure)</i>	
<ul style="list-style-type: none"> ➤ The ATC controller clears the flight crew: <ul style="list-style-type: none"> o To maintain a visual separation with the preceding aircraft o If needed, to continue on a visual approach. ➤ The flight crew accepts or refuses the clearance. <i>The flight crew can better assess the ATC clearance with ATSAW.</i> ➤ 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 <i>(Green italic is specific to the <u>basic</u> procedure)</i> <i>(Amber italic is specific to the <u>basic and advanced</u> procedure)</i>	Advanced VSA procedure <i>(Blue italic is specific to the <u>enhanced</u> procedure)</i>
<ul style="list-style-type: none"> ➤ The flight crew: <ul style="list-style-type: none"> o Flies the approach o <i>Looks at the preceding aircraft on ND with the traffic display enabled.</i> o Looks at the preceding aircraft out the window o Decides if a maneuver is required based on visual information <i>or ATSAW traffic information</i> o 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: <ul style="list-style-type: none"> o Interrupts the approach o Executes a missed approach o 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

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.

[illegible]

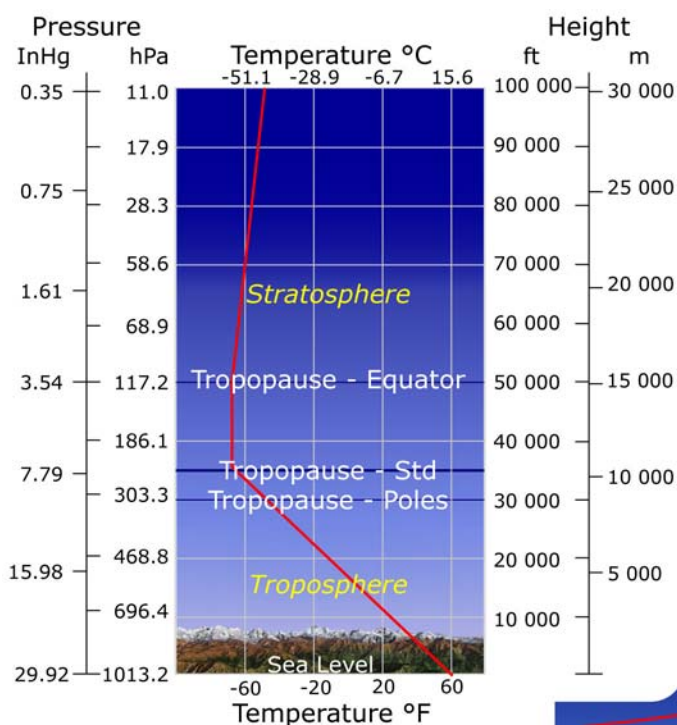
ICAO	AIRBUS	Examples
available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.	(transponder)	format)
Call Sign ICAO telephony designator for the operating agency followed by the flight identification.		"AIRBUS ONE TWO THREE FOUR" for AIB1234
ICAO 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](#)).

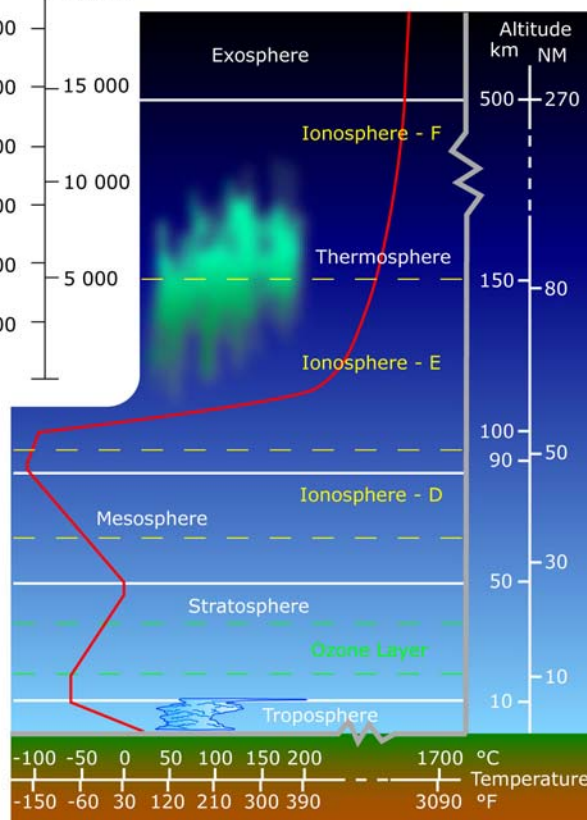
APPENDIX G – AVIATION METEOROLOGY REMINDERS

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).

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 is 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.2.2. 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.

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).

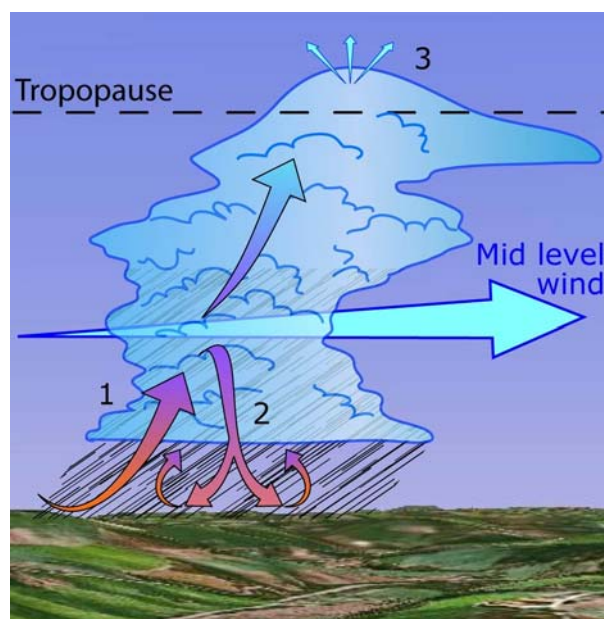


Figure G - 2: Super cell development

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.

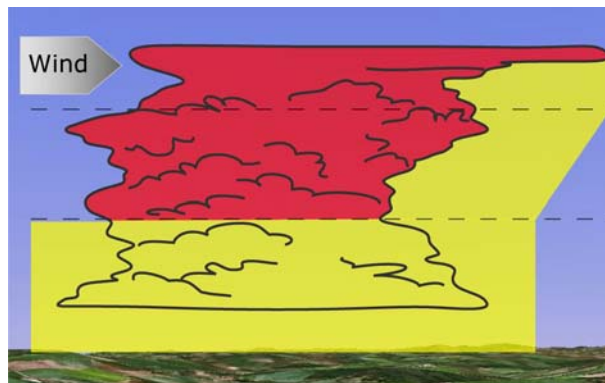


Figure G - 3: Probability of hail encounter

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 instability 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 **Figure 6-27**.

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**.

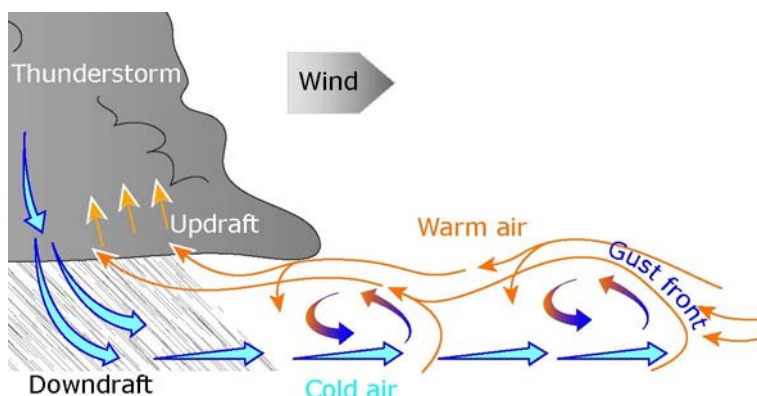


Figure G - 4: Downdraft development

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:
 - o A cumulus or cumulonimbus with virga (precipitation that evaporates before reaching the ground),
 - o 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.

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.

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.4.7. 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 (cold 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 contain enough water. Weather radars may not detect them due to their weak reflectivity. Nevertheless, this kind of clouds may produce light to moderate turbulence.

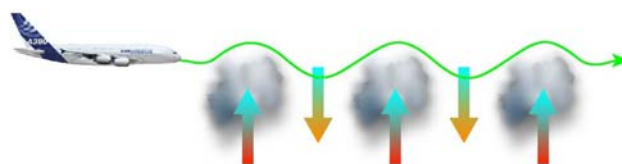


Figure G - 5: Turbulence due to cumulus

The turbulence is due to the alternation of updrafts that form the clouds and downdrafts between the clouds.

APPENDIX H – LOW LEVEL WIND SHEAR EFFECTS ON AIRCRAFT PERFORMANCES

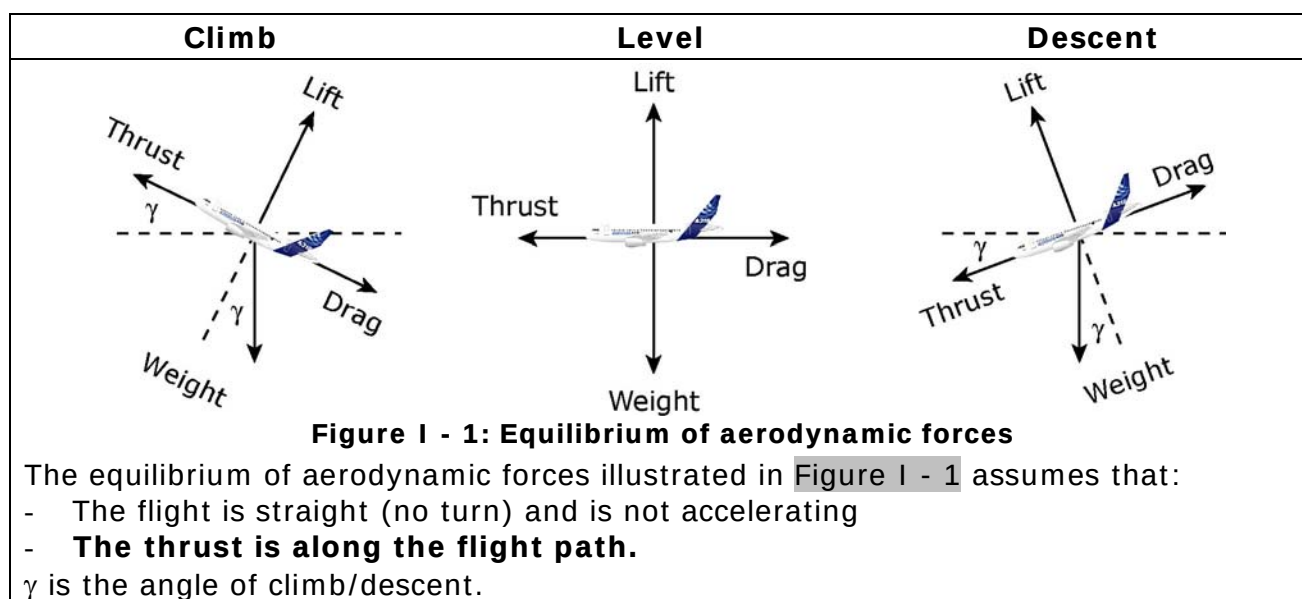
This appendix provides a summary of wind shear effects on aircraft performances at low level. For a more detailed analysis of these effects, refer to the **ICAO Manual on Low Level Wind Shear and Turbulence, Doc 9817** (see **References**).

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



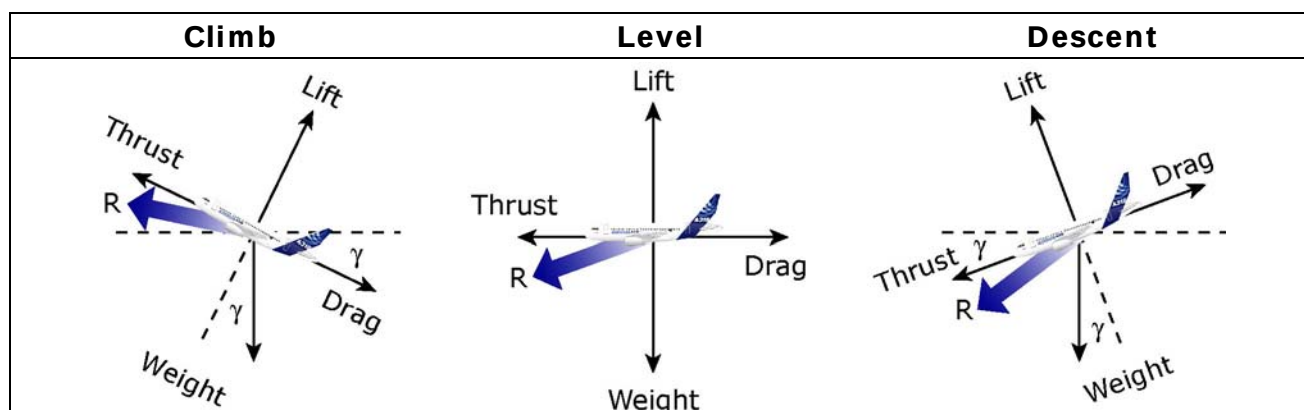


Figure I - 2: Resultant flight path vector – Decreasing headwind / Increasing tailwind

Figure I - 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.

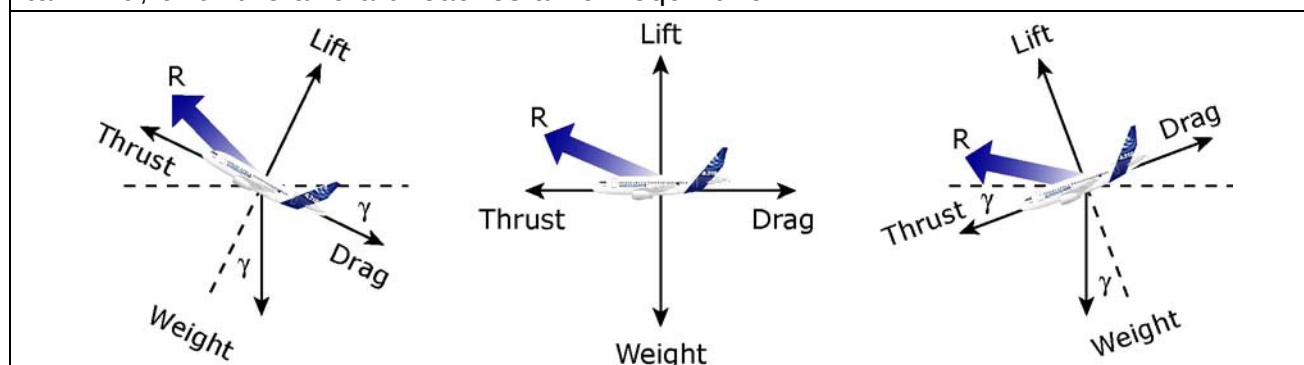


Figure I - 3: Resultant flight path vector – Increasing headwind / Decreasing tailwind

Figure I - 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 I - 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 I - 5).

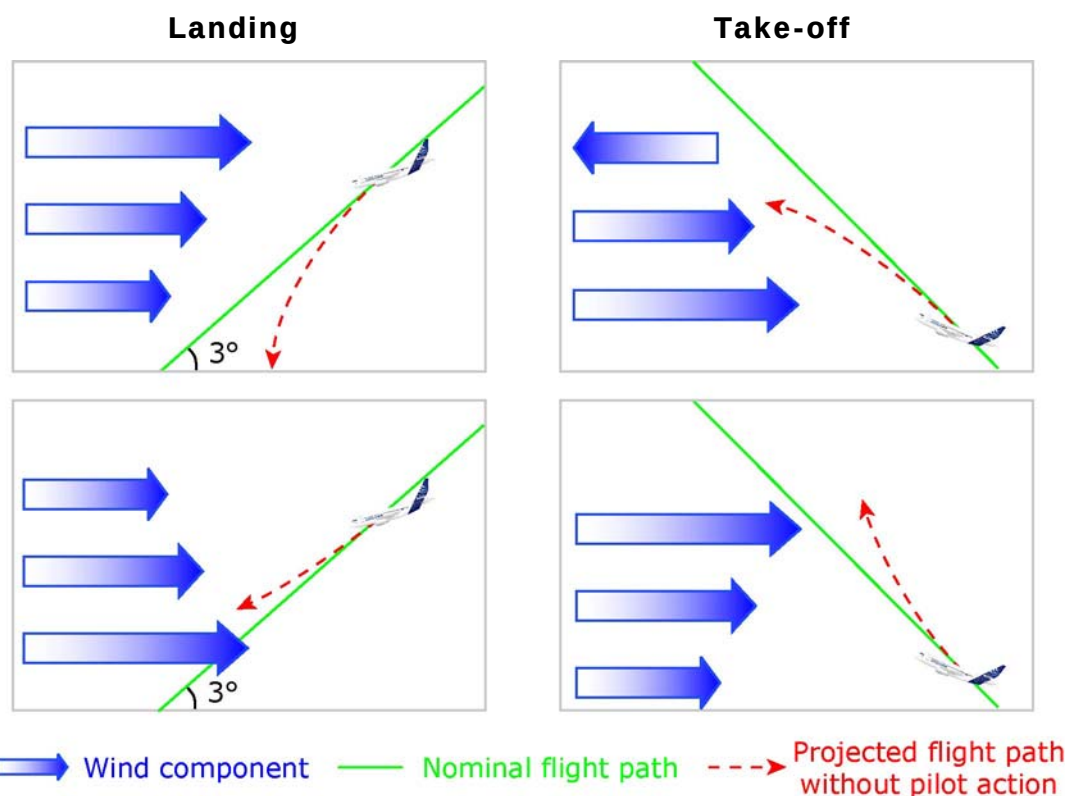


Figure I - 4: Effects of longitudinal wind shears on flight path

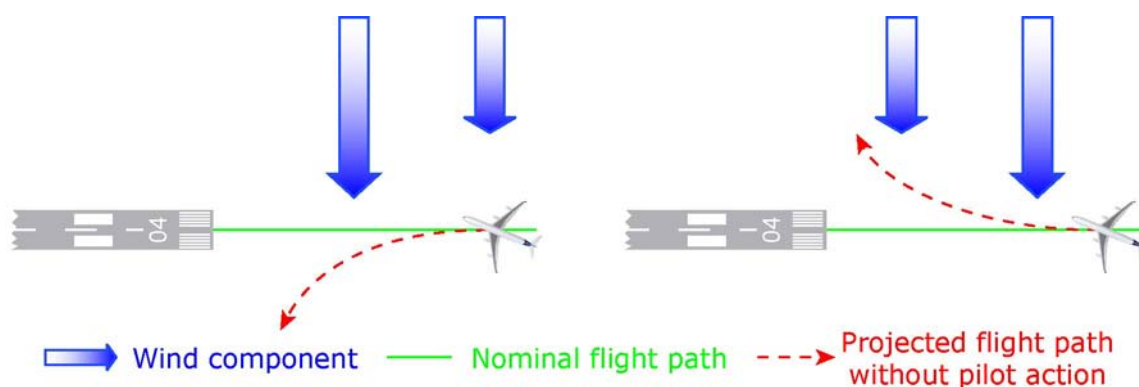


Figure I - 5: Effect of crosswind shears on flight path

H.2. VERTICAL WIND SHEARS

H.2.1. EFFECT ON ANGLE OF ATTACK

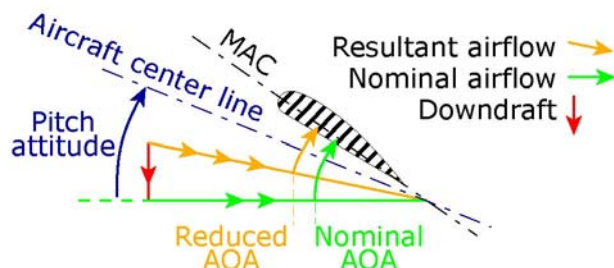


Figure I - 6: Wing aerofoil view - Vertical wind shear effect

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.

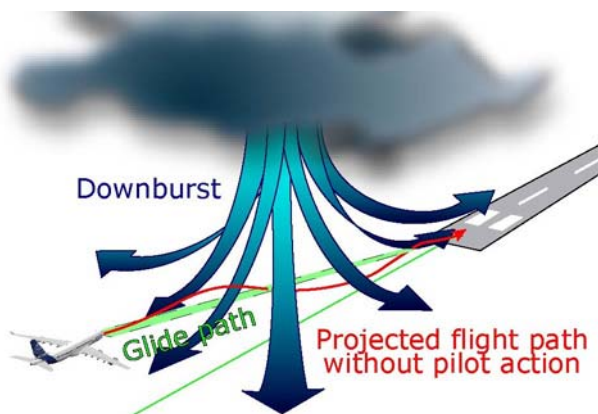


Figure I - 7: Downburst effect

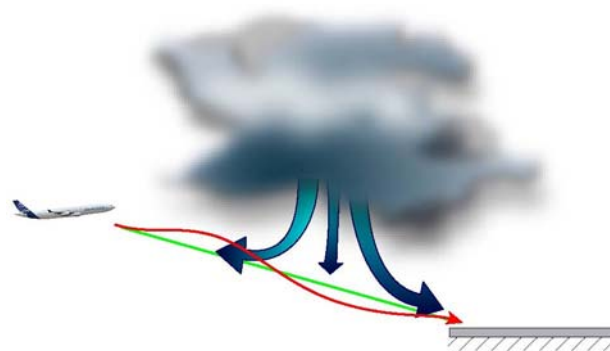


Figure I - 8: Downburst side view

Figure I - 7 and Figure I - 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 I - 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 I - 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 I - 4).

A downburst centered on the glide path is the worst wind shear case when approaching 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 I - 9.

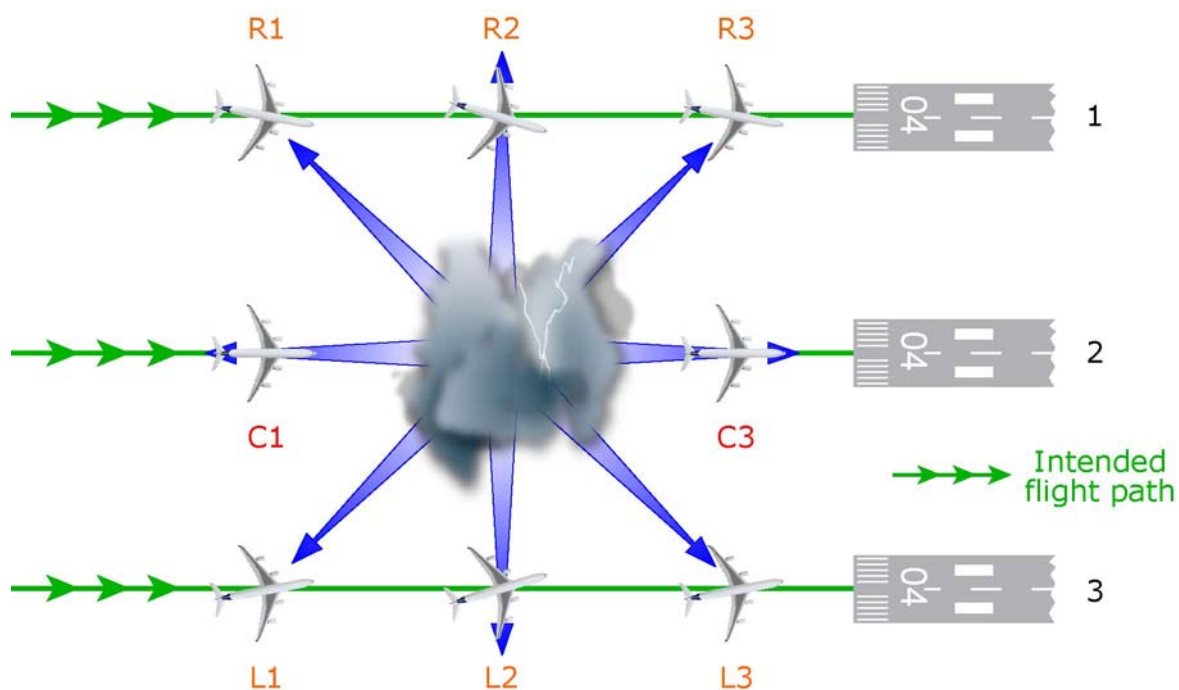


Figure I - 9: Downburst effect – Top view

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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