AIR TRAFFIC MANAGEMENT

A GUIDE TO GLOBAL SURVEILLANCE

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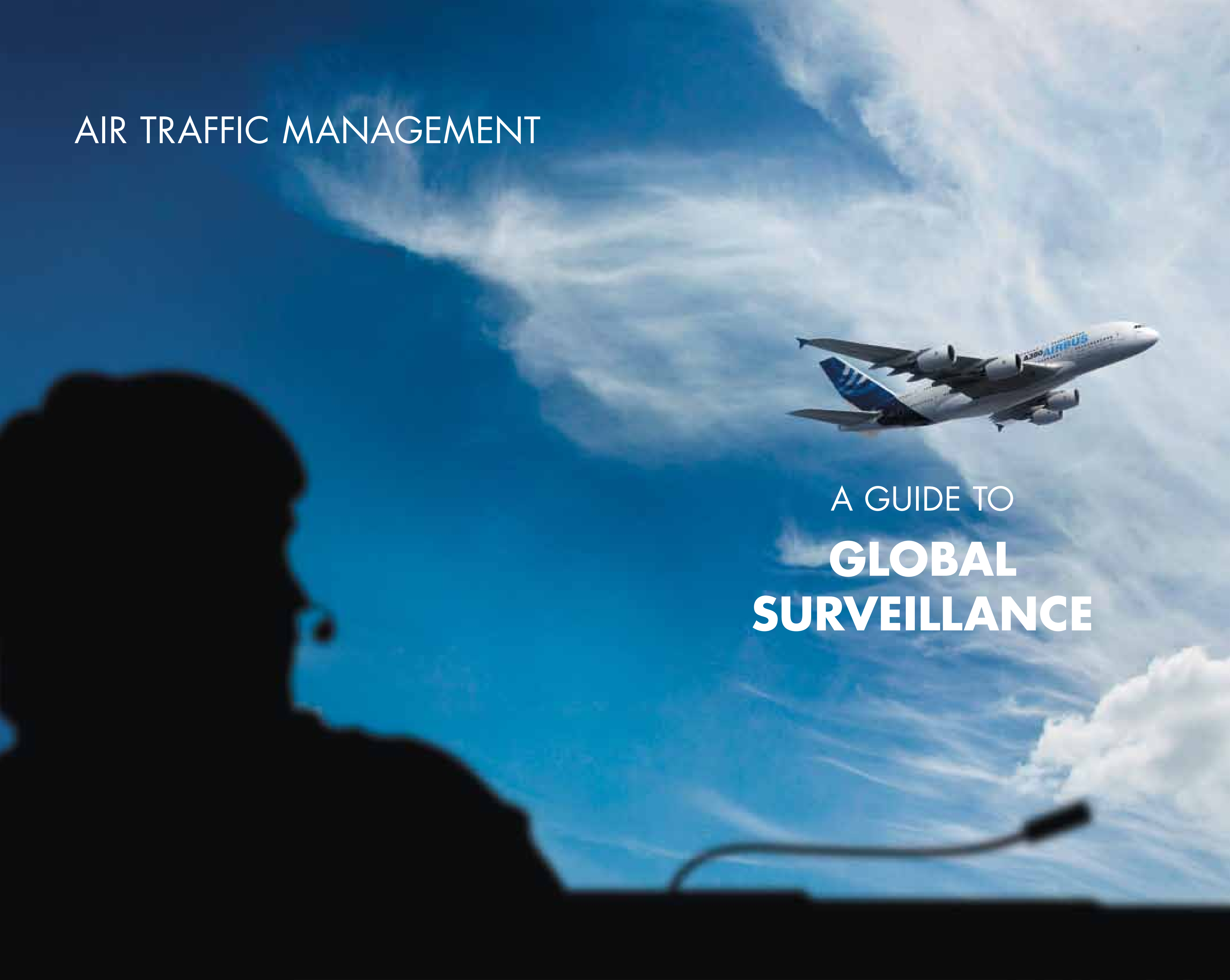
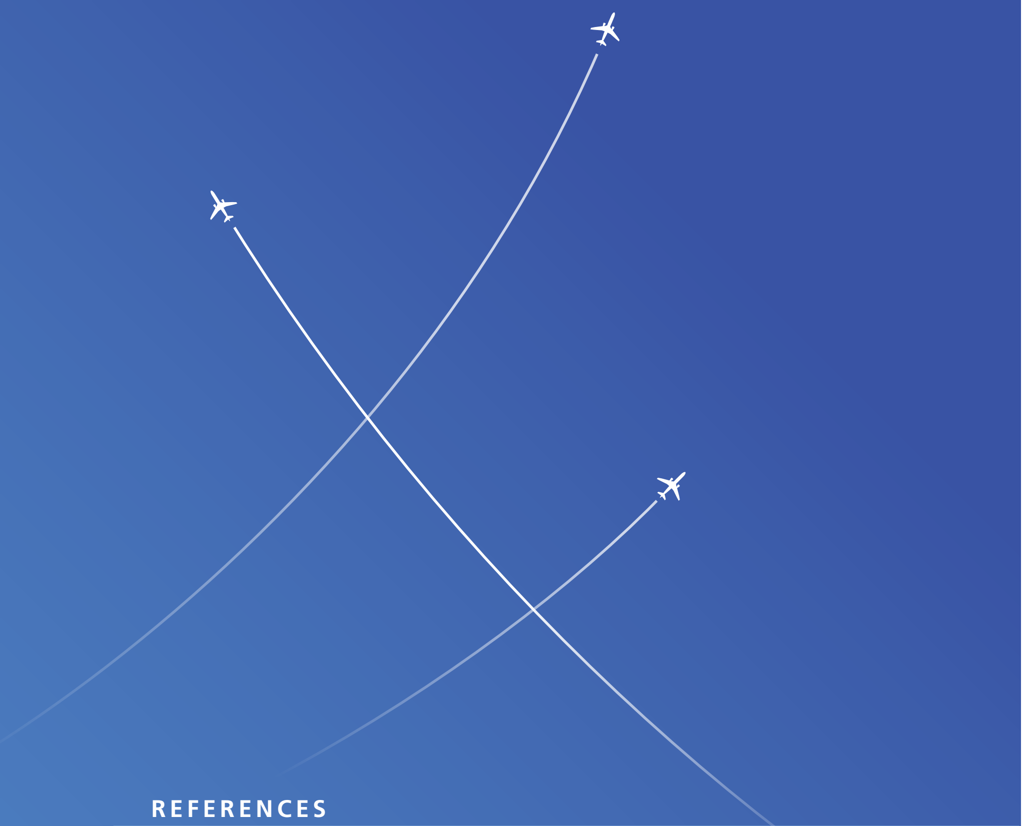


INTRODUCTION

EVERY DAY MILLIONS OF PLANES TAKE TO THE SKIES. THAT MEANS MILLIONS OF PASSENGERS ON-BOARD EXPECTING TO ARRIVE AT THEIR DESTINATION SAFELY, QUICKLY AND WITHOUT DELAYS.

Air traffic controllers on the ground make sure these millions of planes fly safely and efficiently together. Surveillance solutions are the “eyes” of air traffic controllers, illuminating the skies to show what and who is there.
Surveillance is not what it used to be a few years ago. Solutions exist today that make surveillance possible in the most difficult of environments, solutions that are making air traffic control more accurate, safer and efficient.
Today you can choose from traditional radar solutions as well as new surveillance technologies such as multilateration and automatic dependent surveillance. Although you may hear that some solutions outweigh others, the truth is that no one solution fits all. A solution that delivers exceptional results in a complex approach area may prove to be less effective for mountainous areas. You may even find that it is in combining surveillance technologies that you will achieve optimal results.

You need a surveillance solution adapted to your environment, your traffic (current and forecast) and your budget. A solution ready to meet tomorrow’s traffic flows whilst meeting your quests for higher safety, enhanced efficiency and lower costs.
This booklet will introduce you to global surveillance. Discover the different technologies that are out there; what they do well and what they are less good at. Take a look at how some countries are already getting the best from their surveillance solution. And rest assured, you don’t have to be an expert to understand. This booklet is plain and simple; no fancy technical words, no complicated diagrams, just plain English and pictures.
Get the global picture on surveillance and make sure your choice is a wise one.



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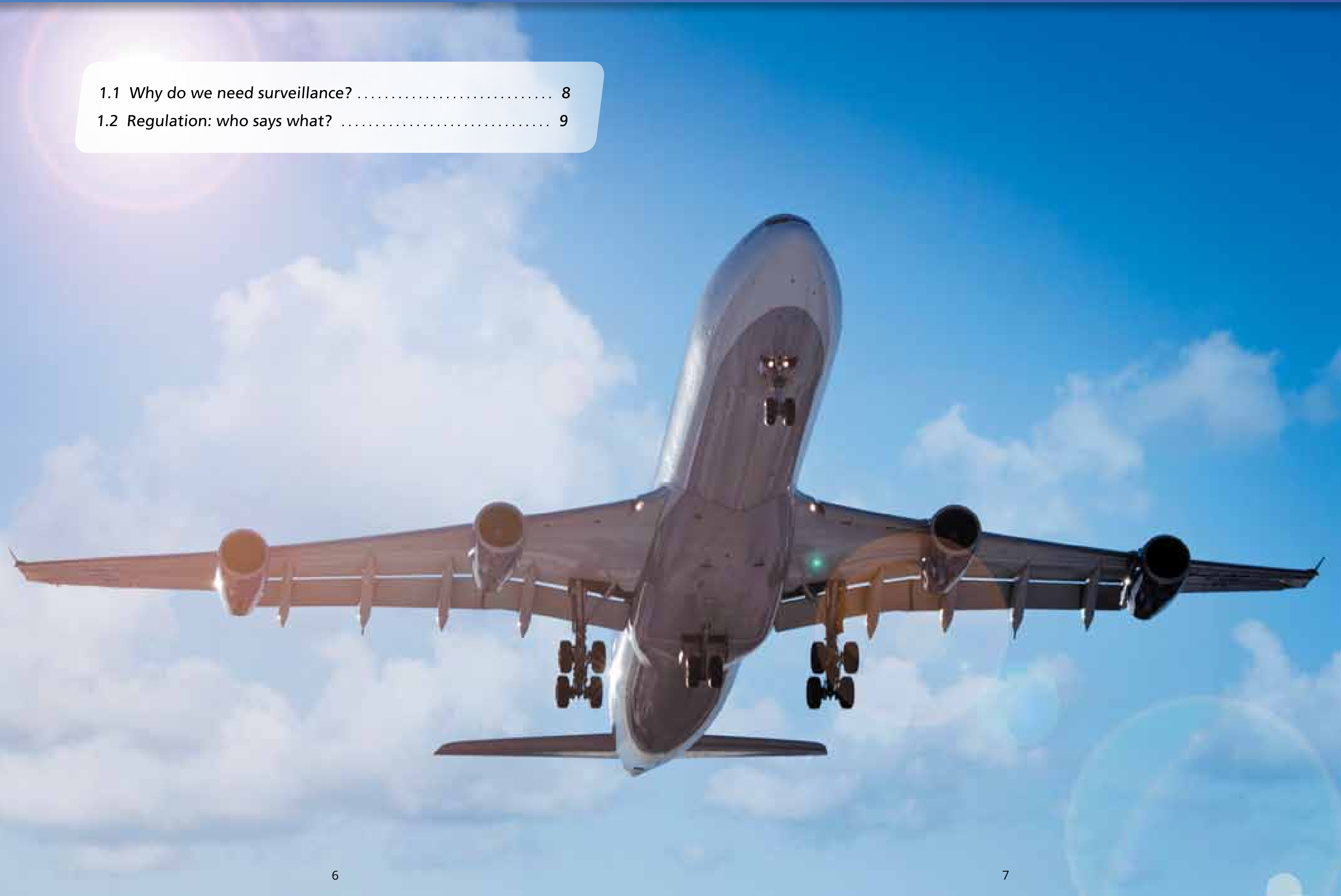


1 SURVEILLANCE NEEDS & REGULATIONS

1.1 Why do we need surveillance?

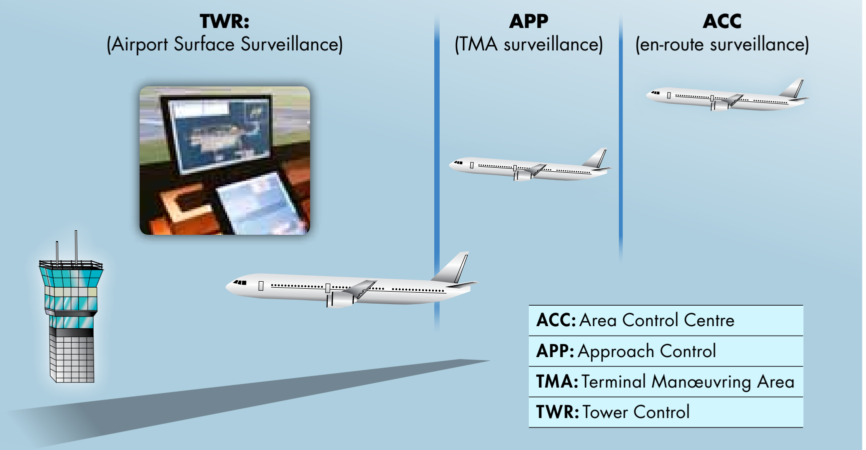
Air Traffic Control is a service that regulates air traffic, preventing collisions between aircraft, collisions between aircraft and obstructions on the ground, and expediting and maintaining the orderly flow of traffic. Air Traffic Control is provided by Air Traffic Controllers who rely on air traffic control systems to safely and efficiently guide aircraft from gate to gate.

The airspace can be divided into the following different divisions of control:

- Ground/Aerodrome control: Control Tower
- Terminal/Approach: aircrafts landing and taking-off. Controllers work in the Terminal/Approach Control Centre.
- En-route: aircrafts at a medium to high altitude. En-route controllers work in an Area Control Centre (ACC).

Surveillance is a key function of air traffic control. Surveillance systems are the “eyes” of air traffic controllers; they show who is in the sky, where they are and when they were there. They are at the beginning of the air traffic control process. Surveillance systems detect aircraft and send detailed information to the air traffic control system allowing air traffic controllers to safely guide the aircraft. Air traffic control is not possible without surveillance systems mainly in highly dense air traffic areas.

Surveillance is most widely provided by primary and secondary radars. However new surveillance technologies such as GPS-based ADS systems and multilateration are progressively being deployed.



The Fundamentals of Surveillance:

Operational Aim

ENSURE AIRCRAFT ARE SAFELY SEPERATED:

- E.g. 5 NM Seperation for En-Route surveillance areas, 3NM Seperation for Approach, 50 NM in Oceanic En-routes without surveillance means...

Technical Requirements

DETECT, LOCALISE, IDENTIFY ALL AIRCRAFT:

- With a given probability: e.g.>0.97%
- With a given horizontal accuracy: e.g. <50m
- With a specified update rate: e.g. <4 sec

1.2 Regulation: who says what?

The International Civil Aviation Organization (ICAO) defines an aeronautical surveillance system as one that “provides the aircraft position and other related information to ATM and/or airborne users” (ICAO Doc 9924 (Ref Doc. 25)).

The traditional ICAO approach is to “define the signal in space for various technical systems to ensure interoperability and leave to States to decide which system(s) should be implemented in their airspace.”

IATA has outlined the following surveillance requirements:

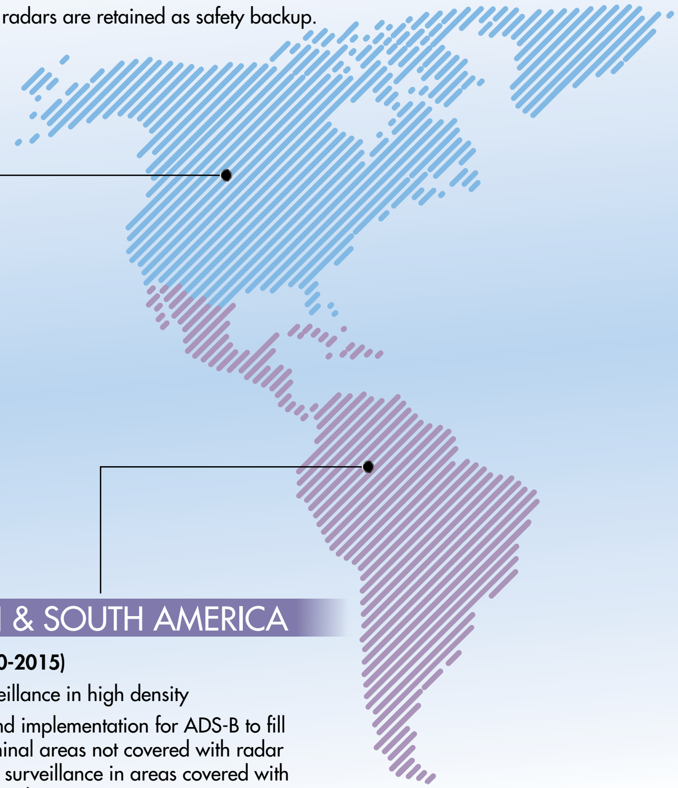
- No airline requirement for using Primary Surveillance Radar (PSR)[1] technology
- Multilateration will be a superior replacement for Secondary Surveillance Radar (SSR)[2] in terminal airspace.
- Support SSR Mode S over SSR Mode A/C[3] where radar must be established or replaced.
- Support implementation of ADS-B OUT[4] based on Mode S Extended Squitter (1090ES) data link to supplement and eventually replace radar, and in non-radar airspace if traffic could benefit from ATC surveillance.

[1] Refer to Chapter 2.1 [2] Refer to Chapter 2.2 [3] Refer to Chapter 2.4 [4] Refer to Chapter 2.4

IATA has also outlined regional requirements as follows:

NORTH AMERICA

- Existing surveillance infrastructure will remain in place until 2020
- Migration to ADS-B as primary means of surveillance by 2020
- Reduced secondary surveillance network (after 2020)
- Retain all en route beacons
- Retain limited set of terminal beacons at OEP/High Density Terminals
- Terminal primary radars are retained as safety backup.



CARIBBEAN & SOUTH AMERICA

Medium term (2010-2015)

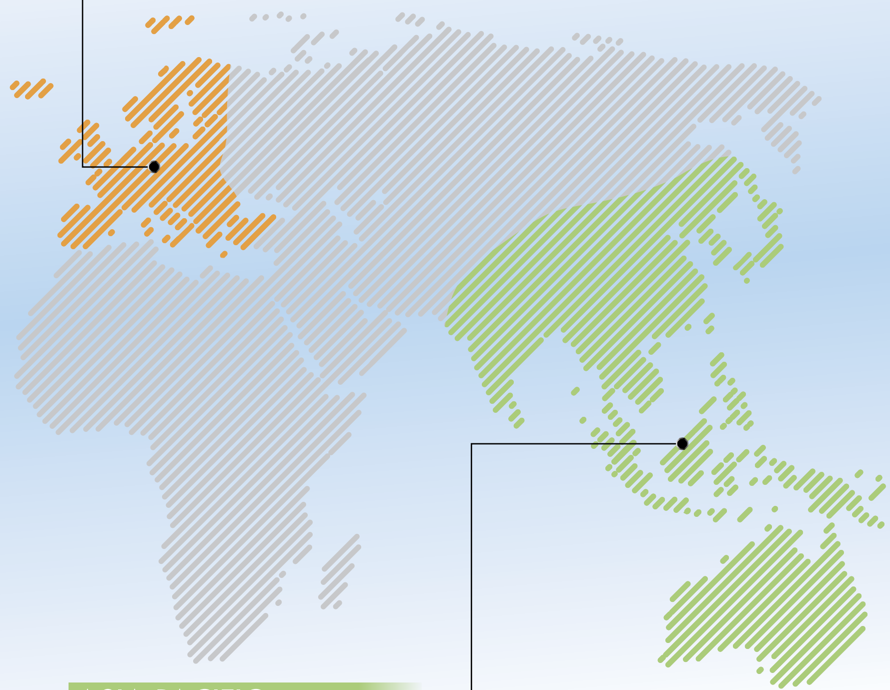
- SSR Mode S surveillance in high density
- Increase of Ground implementation for ADS-B to fill en route and terminal areas not covered with radar and to strengthen surveillance in areas covered with SSR Modes A/C and S.
- Wide area multilateration (WAM) implementation as a possible transition path to ADS-B environment in a shorter timeframe.
- ADS-C surveillance in all oceanic and remote airspace.

Long term (until 2015-2025)

- Old SSR Mode A/C radars won't be replaced anymore.
- ADS-B or multilateration systems will fully replace those decommissioned SSRs.

EUROPE

- Until 2020+, at least one layer of ATM ground surveillance should be an co-operative independent surveillance to meet safety requirements
- PSR is required in TMAs to cater for failed avionics in a critical phase of flight.



ASIA PACIFIC

- Maximise the use of ADS-B on major air routes and in terminal areas, use of ADS-B for ATC separation service;
- Reduce the dependence on Primary Radar for area surveillance;
- Air routes: using ADS-B and Mode S SSR based on operational requirements;
- Make full use of SSR Mode S capabilities where radar surveillance is used
- Make use of ADS-C where technical constraint or cost benefit analysis does not support the use of ADS-B, SSR or Multilateration;
- Make use of Multilateration for surface, terminal and area surveillance where appropriate as an alternative or supplement to other surveillance systems.

2 SURVEILLANCE TECHNOLOGIES

2.1 Primary Surveillance Radar (PSR)

The PSR is used mainly for Approach and sometimes for En-route surveillance. It detects and position aircraft.

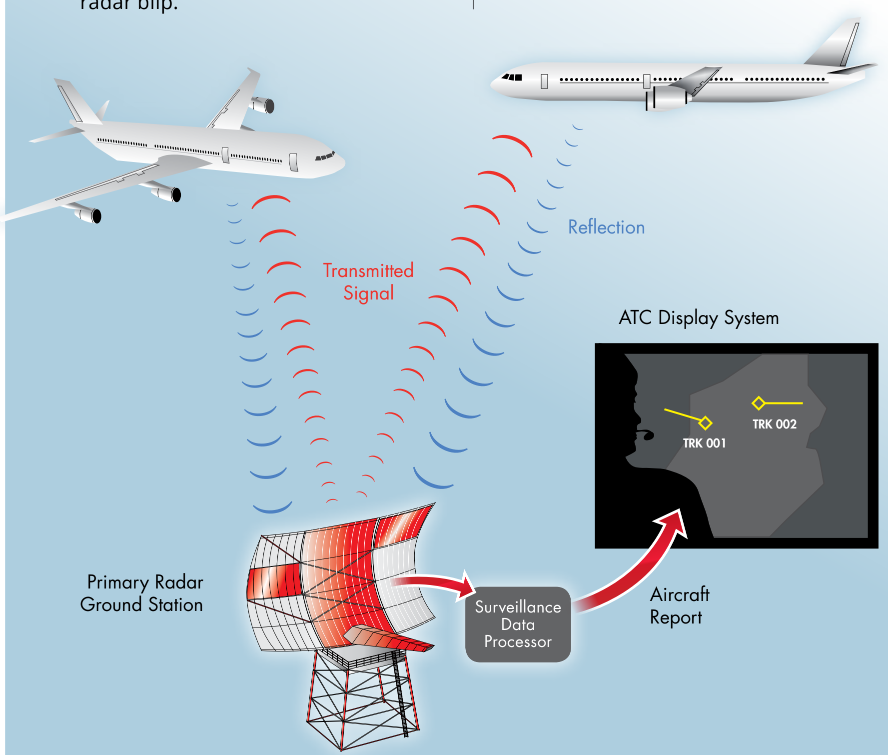
The PSR is used mainly for Approach and sometimes for En-route surveillance. It detects and position aircraft.

Think of a PSR as working in the same way as an echo. Equipped with a continually rotating antenna, the PSR sends out a beam of energy. When that beam of energy hits an aircraft, it is reflected back to the radar, like an echo. By measuring the time it takes for the beam to be reflected back and the direction the reflection comes from, the primary surveillance radar can determine the position of the aircraft. The position is sent to the air traffic control system where it is displayed to the air traffic controller as a radar blip.

Only the position of the aircraft can be determined. The aircraft is not identified.

Used mainly around airports, the radar is also used in certain countries for en-route surveillance.

The undisputable advantage of the PSR is that it detects all aircraft in range regardless of aircraft on-board equipment. This is referred to as independent surveillance. This means that no aircraft can remain invisible to air traffic controllers. This is the only type of technology today to offer this level of safety and security.



“We are investing in what we believe is the most advanced technology available on the market today. The new radar systems are fully compliant with International Standards and will further strengthen the safety of the Belarussian airspace.”

Leonid Churo, DG Belaeronavigatsia, 09/02/2011

PROS

- No additional onboard equipment is required for detection
- Can be used for ground surveillance
- High data integrity level
- Low infrastructure costs = one site installation
- Weather information

CONS

- Aircrafts not identified
- Limited range
- Low update rate
- Mountainous areas to be avoided
- Equipment Cost

A GLANCE AT STAR2000 AND TRAC2000N

Thales’s STAR2000, primary surveillance radar and TRAC2000N, primary en-route radar, provide independent surveillance for approach, extended approach and en-route areas.

Designed for the densest of air traffic situations, Thales’s primary radars guarantee an extremely high availability. Detection range capabilities reach up to 100NM and 230NM for the STAR2000 and TRAC2000N respectively.

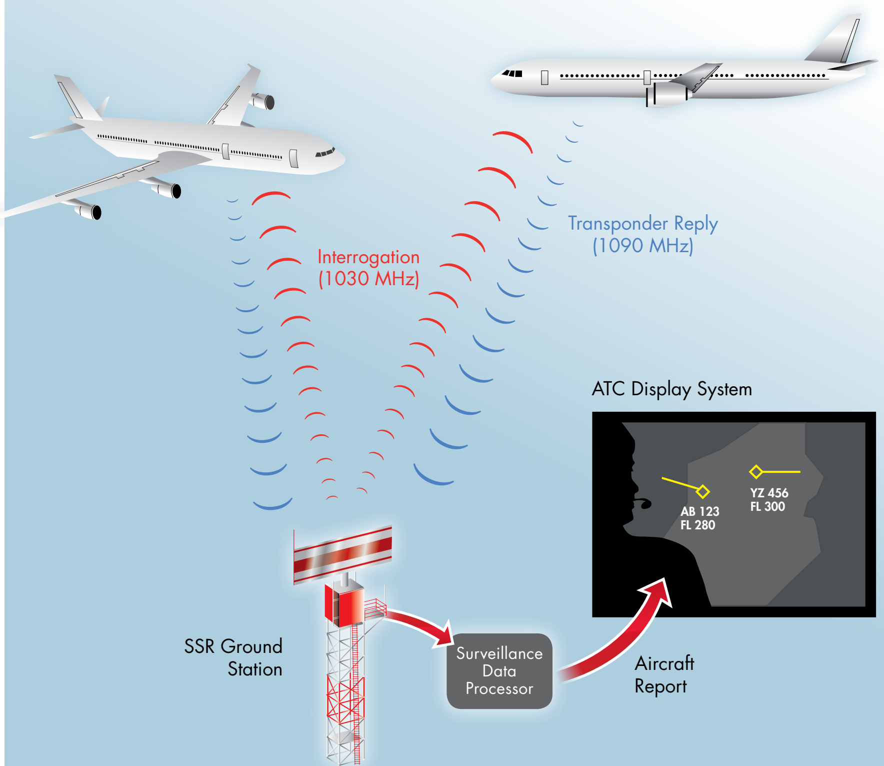
Proven technology operational in over 100 countries worldwide, the STAR2000 and TRAC2000N can be deployed stand-alone or co-mounted with a secondary surveillance radar.

2.2 Secondary Surveillance Radar (SSR)

The SSR is used for Approach and En-route surveillance. It detects and positions aircraft and receives additional information such as their identity and altitude.

Contrary to the PSR, the SSR requires aircraft to be fitted with a transponder onboard. With its continually rotating antenna, the SSR will send out an energy beam which will interrogate aircraft. When the energy beam hits an aircraft, a coded reply will be sent back to the radar. This reply contains the aircraft's identification, its altitude and, depending on the type of transponder on board, additional information. However, the SSR does not rely on the transponder for the position of the aircraft. It determines this itself by measuring the time it takes for the beam to be reflected back to the radar and the direction the reflection comes back from. The SSR then transmits all this information to the air traffic control system where it is displayed as an aircraft label. Secondary radars transmit pulses on 1030 Mhz to trigger transponders installed in aircraft to respond on 1090 Mhz.

> *“… Nigeria's airspace is now totally covered by radar as a result of the Total Radar Coverage of the Nigerian Airspace Project (TRACON). What this means is that we now have the technology to reduce air disasters to the barest minimum and to police and protect Nigeria's airspace from unauthorized entry.”*
>
> **Goodluck Jonathon,** President of the Federal Republic of Nigeria, 22/10/2010



PROS

- Identity and altitude of targets are detected as well as the range and azimuth
- Less sensitive to interferences than primary radar
- Covers a larger range than the primary radar
- Mode S introduces the air-to-ground data link
- Medium data integrity level

CONS

- Does not work for ground surveillance
- Confusion issues related to the use of Mode A/C
- High latency and low update rate

A GLANCE AT RSM970S

With more than 250 operational references in over 50 countries, the RSM 970 S secondary surveillance radar is the cutting-edge of radar technology, giving controllers total support in dense air traffic situations.

Thirty years of experience in the field of MSSR/Mode S give Thales the unique capability to propose the RSM 970 S, the higher performance sensor that gives controller total support in severe air traffic situations. The Mode S functions cover the selective interrogation, the elementary/enhanced surveillance and full data link.

The RSM970S has full Mode S functionalities, validated by ICAO and Eurocontrol, making Thales 'radar solution a secure investment for ANSPs.

Mode A/C/S

The information sent by an aircraft depends on the transponder onboard. If an aircraft has a Mode A/C transponder, the coded reply will contain the aircraft's identification and its altitude. This was all good and well until air traffic increased and radars were getting mixed up due to overlapping signals. With Mode A/C, when a radar sends out an interrogation, all aircraft in range reply. Therefore, Mode S was introduced which gives each aircraft its own unique worldwide address (24-bit aircraft address) for selective interrogation and to acquire downlinked Aircraft Identification (commonly referred to as Flight ID). This fundamental concept is called Mode S Elementary Surveillance (ELS). Mode S also allows aircraft to send more information to the radar.

A more recent concept for Mode S is the Mode S Enhanced Surveillance (EHS). It consists of Mode S ELS supplemented by the extraction of downlink aircraft parameters (DAPs) for use in the ground air traffic management (ATM) systems.

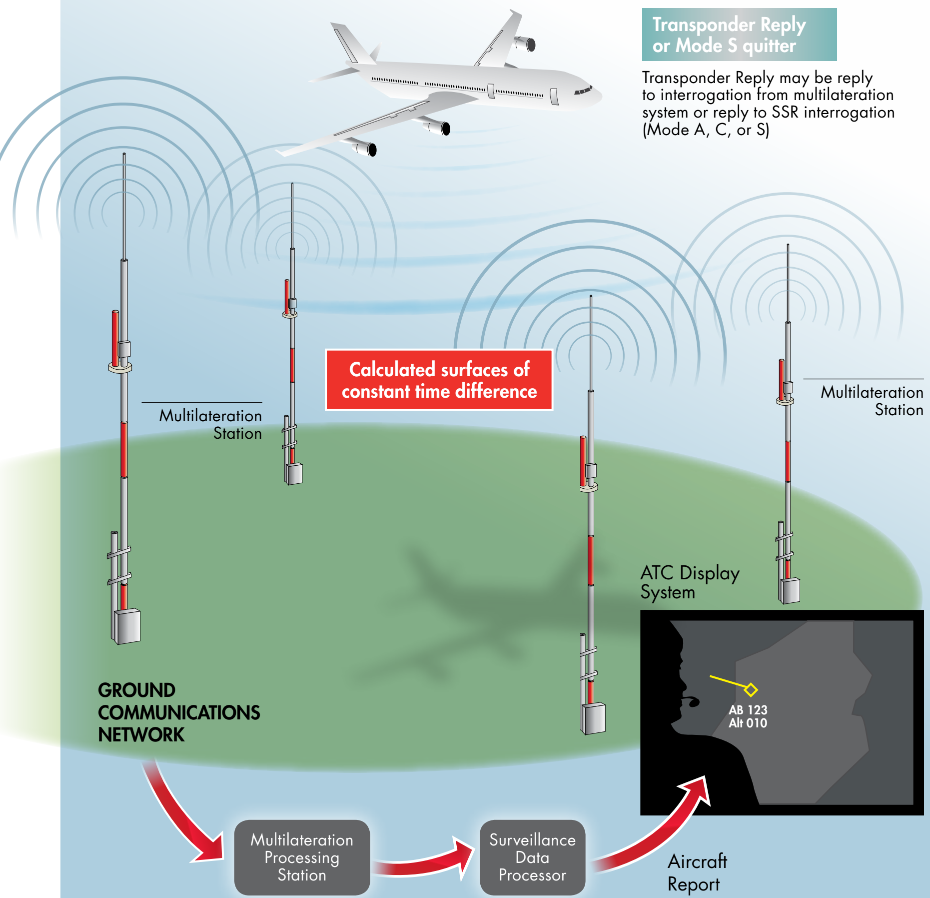
2.3 Multilateration

Multilateration can be used for ground, terminal approach and en-route surveillance. It detects positions and identifies aircraft and can receive additional information.

A multilateration system is composed of several beacons which receive the signals which are emitted by the aircraft transponder.

These signals are either unsolicited (squitters) or answers (conventional Mode A/C and Mode S) to the interrogations of a multilateration station. Localization is performed thanks to the Time Difference Of Arrival (TDOA) principle. For each beacons pair, hyperbolic surfaces whose difference in distance to these beacons is constant are determined. The aircraft position is at the intersection of these surfaces.

Multilateration is used for ground movement's surveillance, for the airport approaches (MLAT) and for en-route surveillance (Wide Area Multilateration (WAM)).



"This new surveillance sensor technology supplies enhanced surveillance data to controllers to ease their daily operational work," "It provides more flexibility to feed aircraft into the approach area around Frankfurt Airport, which helps to fulfil the demand to reduce noise over densely populated areas."

DFS chairman and CEO **Dieter Kaden**, 17 September 2012

PROS

- No additional aircraft equipment is required
- System flexibility to easily expand coverage
- Suitable for difficult environments as ground stations can be mounted in all locations
- Installations go unnoticed thanks to small system size
- Quick and easy installation
- Fit for complex airspace and congested airports with high accuracy and update rates
- Built-in ADS-B capability providing a potential transition solution before ADS-B implementation in aircraft
- Covering different flight levels including low flying aircraft
- Low ground equipment cost
- Low lifecycle costs
- Stable accuracy
- Update rate per second
- No rotating part
- High reliability: redundancy and N-1 system design

CONS

- Costly for large regions
- Numerous sites required which may result in high infrastructure cost
- Complex system to manage: numerous sites, synchronization across system, multiple interrogations

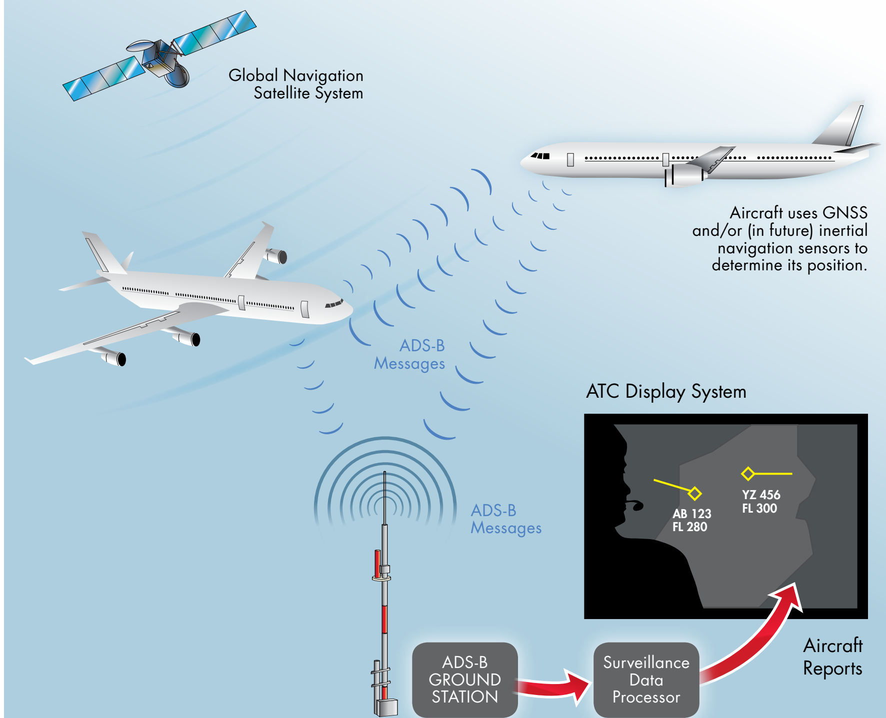
A GLANCE AT MAGS

MAGS, the Wide Area Multilateration system designed and built by Thales Air Systems is a single versatile system to fulfil surface, precision approach monitoring to en-route cooperative surveillance needs. The system has a great flexibility and scalability to tailor performances according to any customer needs and can operate in the most stringent environments. Highly efficient and safe, the main purpose of the WAM system is to provide high precision, high update rate secondary surveillance to Air Traffic Controllers (high accuracy, refresh rate, degraded modes, dual synchronisation, SWAL3 software qualification). It has been tested & qualified by German DFS, UK NATS and French DGAC.
After a rigorous testing program, DFS awards Site Acceptance for the Thales WAM system for Frankfurt TMA, one of the most complex and busy airspaces in Europe and the world.

2.4 Automatic Dependent Surveillance – Broadcast (ADS-B)

Aircraft tell everybody who can listen who they are, where they are, where they are going and at what speed.

An aircraft uses Global Navigation Satellite System (GNSS) to determine its position, which it broadcasts together with other information to ground stations. The ground stations process and send this information to the Air Traffic Control system which then displays the aircraft on air traffic controllers' screens. ADS-B equipped aircraft broadcast once per second their position and other information without any intervention from ground systems. As well as their position, aircraft broadcast their altitude, speed, aircraft identity and other information obtained from on-board systems. Once received by ground stations, the information is processed and sent to the Air Traffic Control Centre for display on controllers' screens. ADS-B broadcasts can be received and processed by any receiving unit, which means ADS-B can be used for both ground and airborne Air Traffic Control surveillance applications.



> *Thales ADS-B in Australia is delivering economical, environmental and safety benefits.*
>
> Airservices Australia

PROS

- Acquisition and installation cost is the lowest for a single ADS-B site than other surveillance system
- Minimal infrastructure requirements as ground station can be installed on existing infrastructure such as navigation aid, radar or VHF radios sites
- Used for both ground-based and airborne surveillance applications
- High refresh rate (1second)
- Air/ground datalink available
- Small latency
- High update rate (1 second)
- High accuracy (GPS accuracy)
- Very low lifecycle cost
- Intent available (level-off altitude, next waypoint etc.)
- Each position report is transmitted with an indication of the integrity associated with the data – users can determine which applications the data can support
- Immune to multi-path

CONS

- Requires all aircraft to be equipped with Mode S extended squitter
- Relies exclusively on Global Navigation Satellite System (GNSS) for position and speed
- Aircraft position is determined onboard without independent system validation
- Ionospheric effects around the Equator affect GNSS

A GLANCE AT AX/BX680

Thales ADS-B ground stations have been selected by service providers in Australia, Asia Pacific, Europe and North America to enhance surveillance in both radar and non-radar airspace. The company has also participated in several trials to demonstrate how ADS-B data can be used to improve situational awareness, and enhance safety. In the largest ADS-B contract to date, Thales is delivering up to 1,200 systems to provide a nationwide network across the US.

Thales is drawing on expert teams in the US, France, Germany and Italy to meet the FAA requirement, which includes a dual link ground equipment, containing both 1090 MHz and UAT datalink capabilities.

ADS-B datalink technologies

Three ADS-B datalink technologies have been developed and these are the 1090 MHz Mode S Extended Squitter (1090ES), Universal Acess Transceiver (UAT) and VHF Digital Link Mode 4 (VDL Mode 4).

ADS-B IN or OUT ?

ADS-B requires equipment on the aircraft to broadcast its position and other information (ADS-B OUT Function) and equipment on the ground (ADS-B IN Function) to receive this information.

2.5 Automatic Dependent Surveillance – Contract (ADS-C)

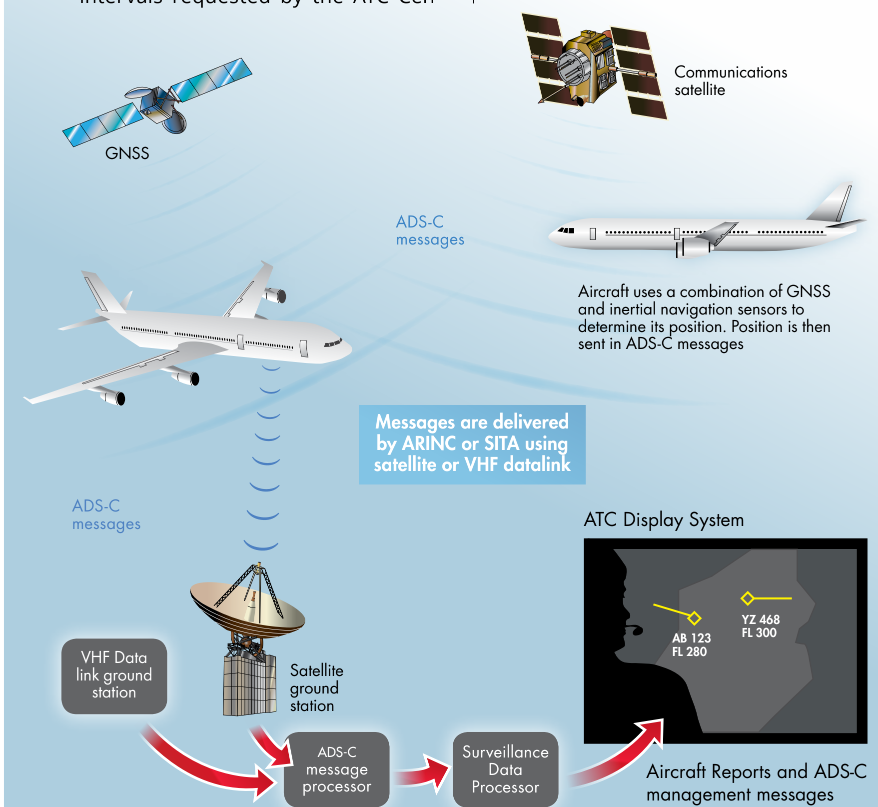
Aircraft report to the ATC Centre when requested.

An aircraft uses Global Navigation Satellite System (GNSS) or on-board systems to determine its position and other information. The Air Traffic Control (ATC) Centre sets up a contract with the aircraft asking it to provide this information at regular intervals. Aircraft will send this information to the ground station which will process and send it to the ATC Centre for display on Air Traffic Controller screens.

Equipped aircraft will send their position and other information at the intervals requested by the ATC Centre through point-to-point communications to the ground station. This means that only the ATC Centre that set up the contract will receive the information.

Aircraft will send their speed, meteorological data and expected route in addition to their position.

ADS-C provides surveillance in areas where other means of surveillance are impractical or impossible, such as oceanic and desert areas.



PROS

- Surveillance coverage for areas impractical or impossible for other surveillance systems, such as oceanic or desert areas
- Information “expected road” available
- Datalink between the aircraft and the ground

CONS

- Requires additional aircraft equipment
- Information is delivered to ground stations by a service provider which bears cost
- Relies partly on GNSS to determine aircraft position and speed, which may experience outages
- Aircraft Surveillance Applications are not supported as information is no directly available to other aircraft
- Surveillance performance is determined by the communication media
- Aircraft position updated less frequently than other surveillance systems
- Global Navigation Satellite System errors: Clock errors of the satellites’ clocks, Ionospheric effects
- ADS-C does not support 3 nautical mile or 5 nautical mile separation standards

A GLANCE AT TOPSKY - DATALINK

The risk-free TopSky – Datalink solution, put in place by Thales, enables clients to completely provide air surveillance in oceanic or desert areas . Thales is able to deliver ADS-C through FANS1/A+ and ATN (aeronautical telecommunication network). Worldwide deployed across Australia, Singapore, China, France, Chile, South Africa, ASECNA, Ireland, Indonesia, Taiwan, TopSky – Datalink is a field proven and key datalink solution for oceanic and continental operations. TopSky – Datalink integrates the major technological and functional evolutions resulting from SESAR and NextGen, which will bring visible improvements to the automation products.

2.6 Summary of sensor surveillance technology

		RADAR-BASED TECHNOLOGY		SATELLITE-BASED TECHNOLOGY		OTHER
		PSR	SSR	ADS-B	ADS-C	Multilateration
Independent or Dependent Aircraft position is measured from the ground (Independent) or aircraft position is determined onboard (Dependent)		Independent	Independent	Dependent	Dependent	Independent
Cooperative or Non-Cooperative Surveillance requires aircraft equipment (Cooperative) or surveillance does not depend on aircraft equipment (Non-Cooperative)		Non-Cooperative	Cooperative	Cooperative	Cooperative	Cooperative
	No Aircraft Transponder	Detection	–	–	–	–
AIRCRAFT TRANSPONDER	Mode A	Detection	Detection & Identification	–	–	Detection & Identification
	Mode C	Detection	Detection & Identification	–	–	Detection & Identification
	Mode S	Detection	Detection & Identification	–	–	Detection & Identification
	ADS-B	Detection	–	Detection, Identification & Position	Detection, Identification & Position	–
Major Pro		Non cooperative targets detection as no on-board equipment is required. Can be used for ground surveillance. High data integrity level.	Identity and altitude determination as well as range and azimuth. Less sensitive to interferences than PSR. Its range is more important than the PSR (as the interrogation and the answer have only one-way distance to cover) Mode S introduces the air-to ground datalink.	Use for ATC, vehicule tracking and for on-board surveillance applications. High refresh rate (1s at least). Air/ground data link available. Small latency. High update rate. Position accuracy.	Use of surveillance area with no radar coverage. Information "expected road" available. Air/ground data link available.	SSR technology can be used (does not need any evolution of onboard equipments). Suitable for ground surveillance. Small latency. High update rate. Position accuracy. High reliability.
Major Con		Targets cannot be identified. Target altitude cannot be determined. High power emission is required which limits its range. High latency and low update rate.	Does not work for the ground surveillance High latency and low update rate.	Depends only on the aircraft (equipped or not) and on the data correction that it sends. Time stamping errors. GPS outages.	Depends on the aircraft only (equipped or not) and on the data correction which is sent. Not all the aircrafts are equipped at this time. Time stamping errors. GPS outages.	High demand on reliable data communication infrastructure.

2.7 Applications of sensor surveillance technology

PSR

- Surface movement radar application
- Terminal area surveillance
- En-route surveillance.

SSR

- Terminal area surveillance
- En-route surveillance
- Precision Runway Monitor (PRM): Special SSR ground stations are used by a number of states to support precision runway approach monitoring to parallel runways.

ADS-B

- Surface mouvement
- Terminal Maneuvering Area (TMA) surveillance
- En-route surveillance
- PRM: ADS-B shows promise for use in PRM applications when aircraft are equipped because ADS-B meets the accuracy, velocity vector performance and update requirements of PRM. However, at this time, no safety case nor ICAO approval has been obtained to use ADS-B for this application.

Multilateration

- ASMGCS: Multilateration has been deployed at numerous locations for surface surveillance to detect and provide position/identity to these systems. Typically 10-20 ground stations are used to provide multilateration coverage over the whole airport surface.
- Terminal Maneuvering Area (TMA) surveillance: Multilateration shows promise for “wide area” application and a number of states have projects to deploy multilateration for this purpose.
- En-route surveillance: Multilateration is able to be used in “very wide area” applications.
- PRM: Multilateration shows promise for use in PRM applications when aircraft are equipped because multilateration meets the accuracy and update requirements of PRM.

ADS-C

- En-route surveillance in remote or oceanic areas.

2.8 Data provided by each surveillance technology

The following provides a brief overview of the information that may be received and processed by the relevant surveillance technologies

	PSR	SSR Mode A/C	SSR Mode S
No transponder	Position, calculated velocity vector	No data is able to be provided by this sensor	No data is able to be provided by this sensor
Mode A/C transponder	No data is able to be provided by this sensor	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector
Mode S transponder with Downlink Aircraft Parameters (DAPs)	No data is able to be provided by this sensor	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector	Position, flight level (barometric), 4 digit octal identity, 24 bit unique code, selected altitude, Flight ID, Selected Altitude, Roll Angle, Track Angle Rate, Track Angle, Ground Speed, Magnetic Heading, Indicated Airspeed/Mach No, Vertical Rate, calculated velocity vector

	Multilateration	ADS-B	ADS-C
No transponder	No data is able to be provided by this sensor	If ADS-B equipped: Current aircraft: Position, flight level (barometric), position integrity, geometric altitude (GPS altitude), 24 bit unique code, Flight ID, velocity vector, vertical rate, emergency flags, aircraft type category. Fully compliant DO260A will add a number of data fields.	If ADS-C equipped: Position, altitude, flight ID, emergency flags, waypoint events, waypoint estimates, limited “intent data”
Mode A/C transponder	Position, flight level (barometric), calculated altitude, 4 digit octal identity, calculated velocity vector		
Mode S transponder with Downlink Aircraft Parameters (DAPs)	Position, flight level (barometric), 4 digit octal identity, 24 bit unique code, selected altitude, Flight ID, Selected Altitude, Roll Angle, Track Angle Rate, Track Angle, Ground Speed, Magnetic Heading, Indicated Airspeed/Mach No, Vertical Rate, calculated velocity vector		

2.9 Tracking system

An ATC automation centre shall take integrate data sent by numerous surveillance sensors.

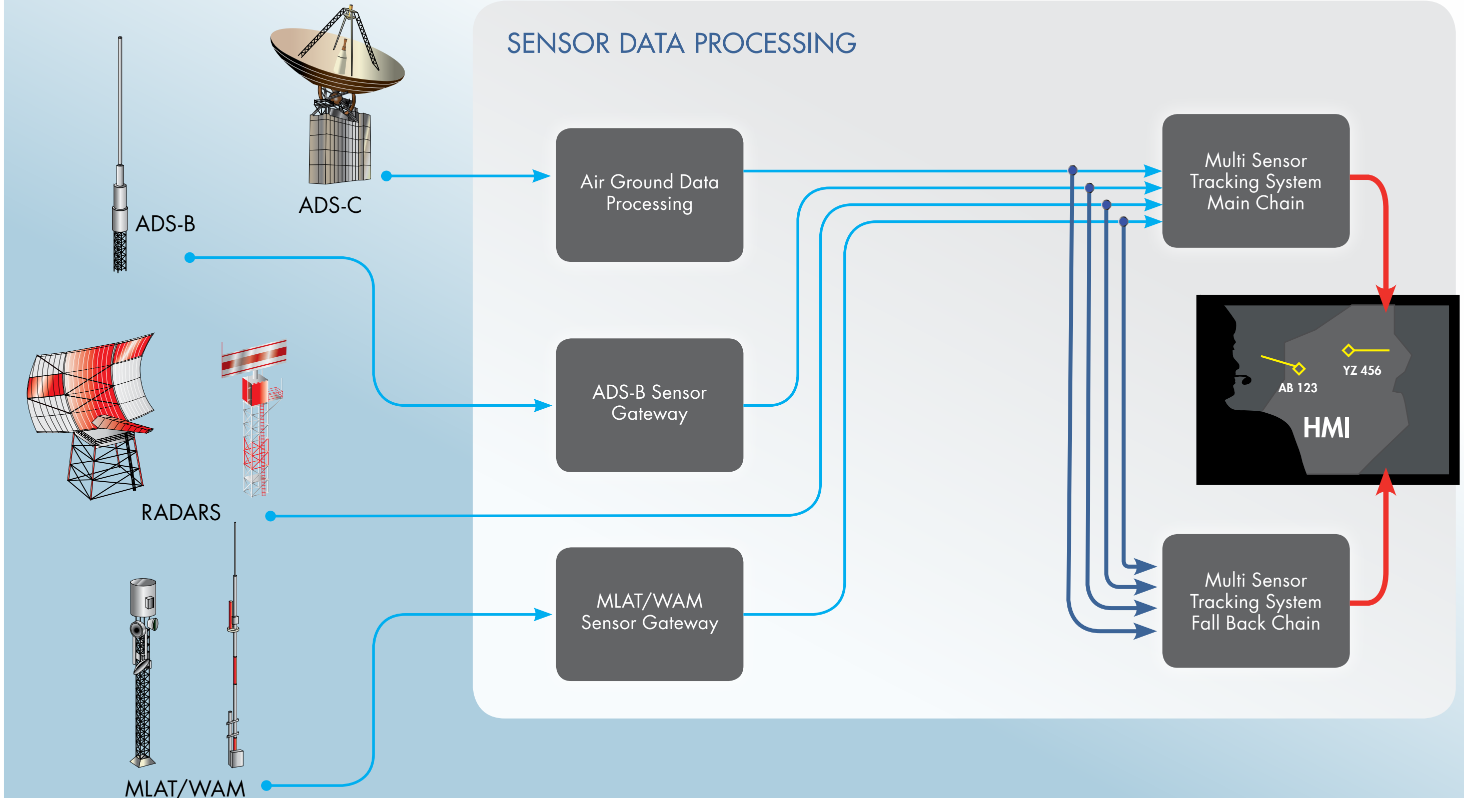
The rule of a tracking system is then to process and to unify all types of surveillance data, in order to provide fused information to the visualisation and the safety nets systems.

The definition of a new set of surveillance standards has allowed the emergence of a post-radar infrastructure based on data-link technology.

The integration of this new technology into gate-to-gate architectures has notably the following purposes:

- fluxing air traffic which is growing continuously,
- increasing safety related to aircraft operations,
- reducing global costs (fuel cost is increasing quickly and this seems to be a long-term tendancy), and
- reducing radio-radiation and improving the ecological situation.

The Multi Sensor Tracking system combines received data pertaining to a single aircraft into a single surveillance track, taking advantage of the best contribution from each surveillance source and eliminating the influence of their respective drawbacks.



A GLANCE AT TOPSKY-TRACKING

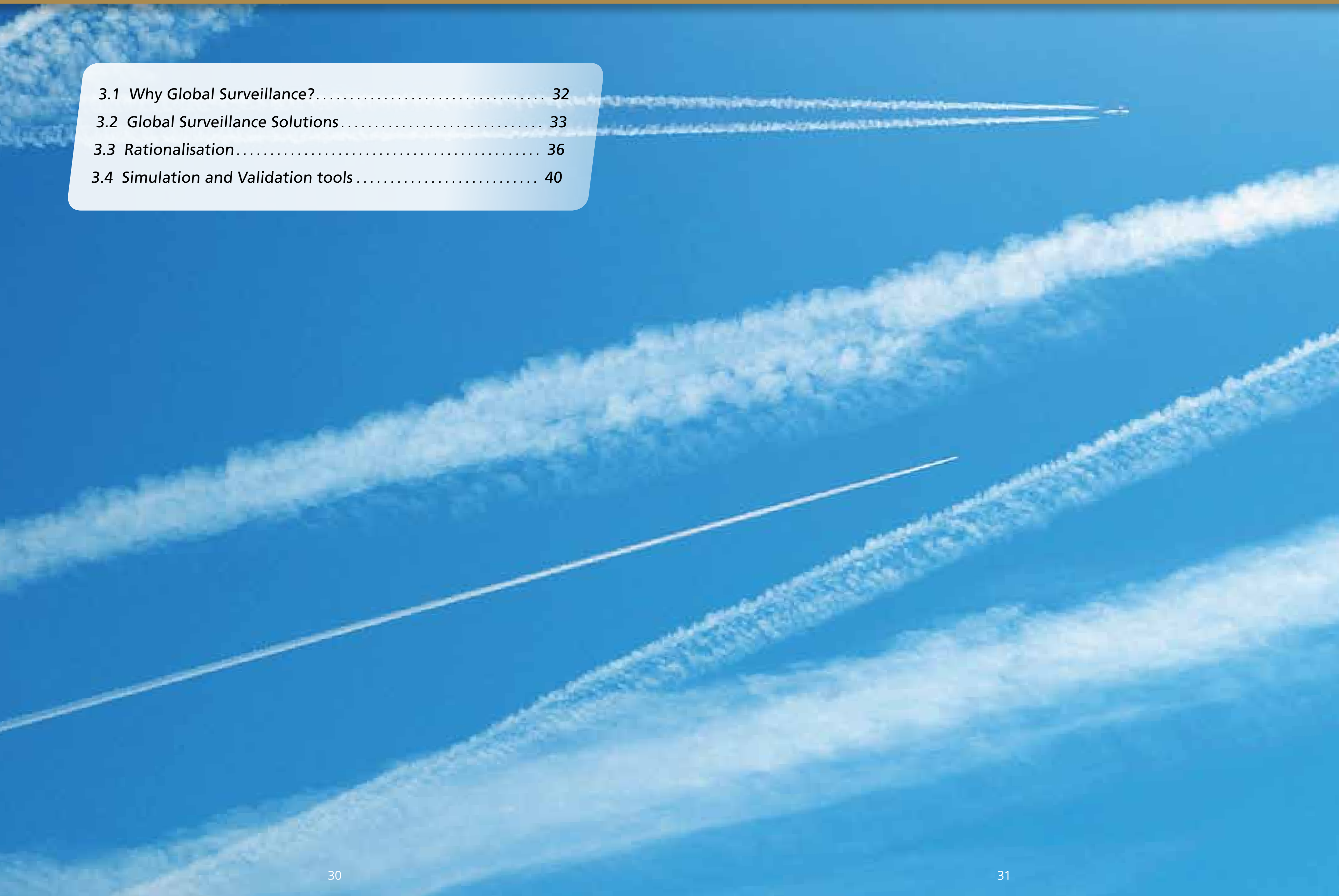
With more than 20 years experience, Thales TopSky-Tracking system is field proven with the highest number of operational systems in the world.

The system receives and processes all types of surveillance data from PSR, SSR, Mode S, Mode A/C, ADS-B, Wide Area Multilateration (WAM) and surface sensors (SMR, Airport Multilateration, SMGCS tracks).

For cooperative aircraft, significant information is supplied as Downlink Aircraft Parameters (DAPs) from the aircraft avionics. DAP data is processed by the TopSky-Tracking function and is also stored in the output messages for use by downstream data-processing functions.

The data fusion technique used within the TopSky-Tracking function is based on the use of extended Kalman filter (EKF) algorithms that make up an Interacting Multiple Model (IMM) filter. The Kalman filter features are particularly adapted for an aircraft trajectory assessment and integrate the capability to predict the aircraft motion.

3 GLOBAL SURVEILLANCE

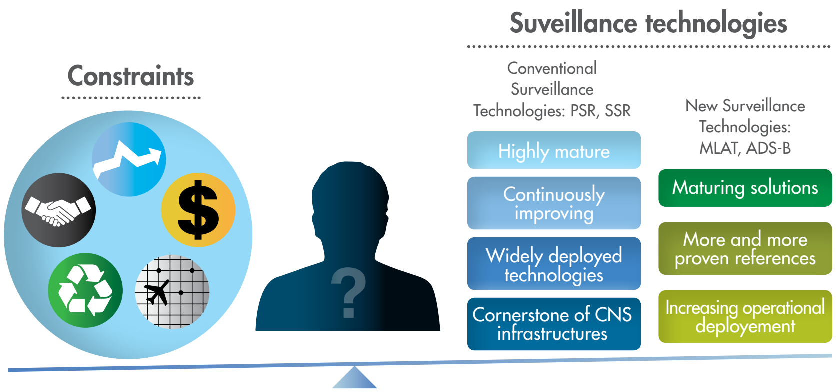


3.1 Why Global Surveillance?

ANSPs are today faced with a dilemma: choosing between conventional surveillance technologies and new surveillance technologies.

On one hand, conventional technologies, typically primary and secondary radars, are highly mature, widely deployed and continuously improving.

On the other hand, new surveillance technologies such as ADS-B, ADS-C and Multilateration are maturing with increasing operational deployment.



A surveillance infrastructure is to provide the required functionality and performance to support a safe, efficient and cost-effective Air Traffic Control service.

In the recent past the Surveillance infrastructure was composed of Secondary Surveillance Radar (SSR) and Primary Surveillance Radars (PSR). The requirements placed upon the infrastructure were based on the use of radars achieving radar-specific performance requirements.

Recently technological developments such as Automatic Dependent Surveillance –Broadcast (ADS-B) and Multilateration (MLAT) have reached maturity for operational deployment for surveillance applications and relevant standards were defined.

Due to the nature of these new technologies the technical requirements cannot continue to be expressed in terms of radar-specific performance requirements.

In parallel, new performance targets and associated operational requirements are emerging from Single European Sky initiatives.

The environment in which ANSP's provide a surveillance service is, in all regards, under continual pressure.

There are numerous factors which can be considered in the scope of any rationalisation exercise.

Methodology and tools have been developed to support ANSPs on decision making and to optimize surveillance infrastructure regarding the attributes of various surveillance technologies: This is the concept of Global Surveillance Solutions.

3.2 Global Surveillance Solutions

A global surveillance solutions provider will combine state-of-the-art technologies to find the composite surveillance solution best matching the ANSPs' needs.

Whatever the geographical constraints or traffic level, ANSP must have the most adapted surveillance capability:

- First focus on needs, not on products ;
- Complete airspace security & safety offer, from ground to en-route must be considered;
- Performance excellence and costs efficiency through optimised solution is mandatory;
- Multiple outputs to ease interface to any ATM system are required;
- Specially designed and tested multi sensor simulation and validation tools help to optimize system design.

Global Surveillance solutions provider has to assist the customers in defining the best solution to meet their requirements.

- Definition of the desired surveillance coverage
- Identification of site-related constraints: Complicated coverage - terrain restrictions / Gapfiller
- Identification of operational restraints: accessibility of sites, existing systems, limited com
- Modeling of surveillance infrastructure to cover new routes.

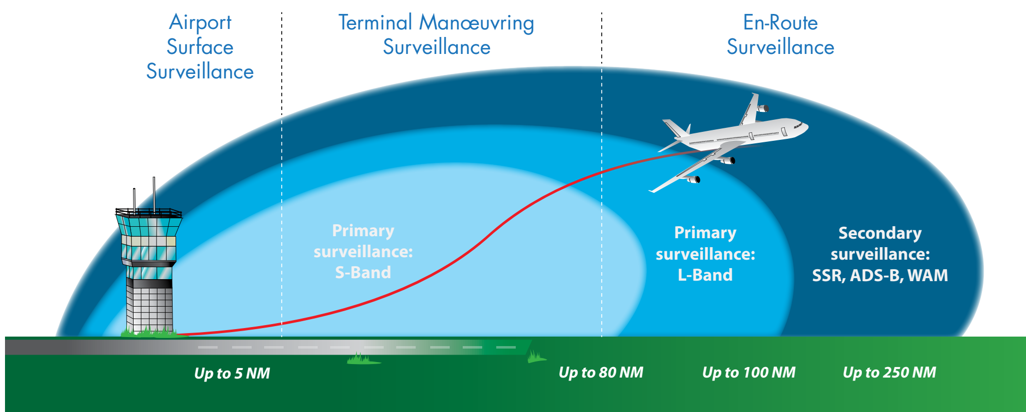
Several criteria have to be considered in order to provide the optimal solution, such as operational requirements, average/peak traffic density, budget (current and future), environment (terrain, propagation...) as well as safety & security objectives.

The Global Surveillance system optimization is based on several assessments:

- Performance indexes (Probability of detection / correct identification, Localization accuracy)
- Cost evaluations (Equipment acquisition, Operations, Maintenance)
- External footprint (Spectral occupancy, Environmental impact).

Global surveillance systems are an efficient way to combine various technologies and share between surveillance layers a part of the burden of "ancillaries" such as:

- Infrastructure (tower, masts, ...)
- Energy sources (power supply,...)
- Communication links



PSR and SSR are often installed in a “co-mounted” installation. Alternative technologies could be deployed in an integrated infrastructure too.

One can typically consider:

- the integration of an ADS-B receiver into an SSR
- the integration of an ADS-B capability into a WAM station
- the integration of an PSR station and an ADS-B + WAM into a common system

ADS-B + SSR Mode S

Various approaches can be considered to integrate an ADS-B receiver into an SSR, and different solutions are available on the market depending on the system manufacturer. They differ according to the position of the ADS-B antenna vs the SSR antenna.

The benefit of an “SSR-ADS-B” system compared to a standard (or Mode S) SSR is to provide improved acquisition and tracking performances on ADS-B equipped aircraft (due to the higher update rate of ADS-B). It provides also a way to assess the integrity of ADS-B data, or -in a transitional period- to monitor the quality and equipage ratio of aircraft transponders.

ADS-B + WAM

Integration of ADS-B and WAM can be very easily achieved as both systems may use the same and single antenna, RF reception and digitisation hardware. A dual functionality of ADS-B and Multilateration ground station is a big advantage. Such a capability is recognized in Eurocae standardization documents such as ED-142. It is recognised that a WAM system may also provide ADS-B data reception and handling capability.

ADS-B capability can hence be offered as a simple software addition to WAM equipments.

Some system manufacturers offer this capability as embedded in their WAM offer.

The consequence is the ability to offer ADS-B service and application at a marginal additional cost, when a WAM surveillance system has been deployed.

Conversely, it allows for a seamless service extension from ADS-B to WAM, when an ADS-B ground configuration has been deployed. Such an extension will imply:

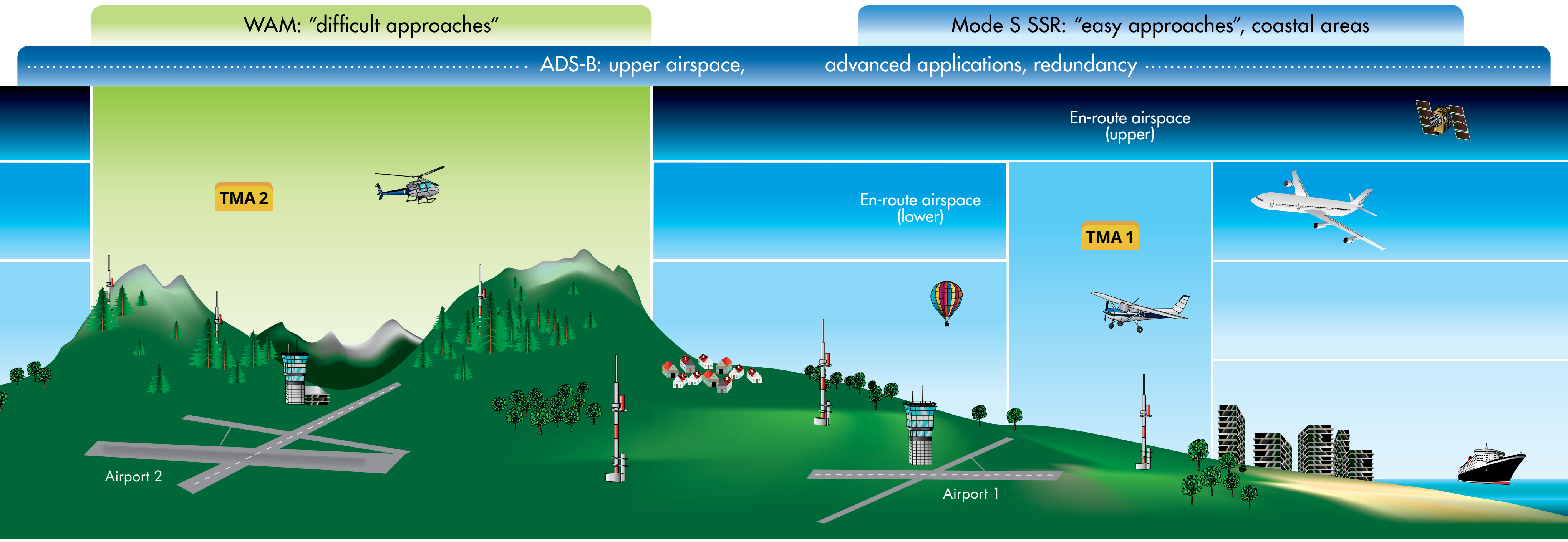
- the deployment (if needed, depending on terrain and required coverage) of additional WAM stations to ensure the proper level of performance, e.g. accuracy,
- the software upgrade of existing ADS-B stations- to make the WAM capable.

ADS-B + WAM + PSR

Further integration of PSR and WAM-ADS-B capabilities into a common system, is an attractive concept which would offer the service of a global surveillance (non-cooperative, cooperative independent, and cooperative dependent).

The deployment of such a Global Surveillance Systems could be envisioned:

- either as an upgrade of surveillance systems based on WAM-ADS-B technologies, providing them with the additional capability of non-cooperative surveillance
- or in a direct deployment, for the equipment of new airspaces / new airports.



3.3 Rationalisation

Measuring or quantifying how much rationalisation is needed or, if assessed after the event, how much rationalisation was achieved is a necessary step for ANSP.

Rationalisation activities may focus upon improving a whole range of Key Performance Areas (KPA).

There are currently no published standardised metric definitions or commonly agreed ATM performance figures for the surveillance infrastructure rationalisation. ANSP's can assess their surveillance infrastructure against these generic KPA and define targets for their improvements that contribute to the overall ATM targeted improvement.

The Key Performance Areas cover:

- **CAPACITY:** The future ATM System should provide the capacity to meet the demand at the times when and where it is needed.
- **COST EFFECTIVENESS:** The price of the air traffic services provided by the future ATM System should be cost-effective with respect to meet the individual needs of the relevant airspace user.
- **EFFICIENCY:** Efficiency addresses the operational and economic cost-effectiveness of flight operations from a single-flight's perspective and will be central to achieving the environmental performance targets, which will be placed upon the future ATM System.
- **ENVIRONMENTAL SUSTAINABILITY:** The future environmental system performance will be a requirement and the future ATM System must meet their obligations in this respect.
- **FLEXIBILITY:** Flexibility addresses the ability of the system to meet all modification of surveillance requirements in dynamic manner.
- **INTEROPERABILITY:** The functionality and design of the future ATM System must be based upon the use of global standards and uniform principles to ensure technical and operational interoperability.
- **PREDICTABILITY:** Predictability refers to the ability of the future ATM System to enable the airspace users to deliver consistent and dependable air transport services.
- **SAFETY:** Safety requires the highest priority in aviation and the provision of air traffic services. It plays a key role in ensuring overall aviation safety. Society will always expect zero accidents from the aviation industry as a whole and performance from this perspective sets the end customers' confidence in air transport.
- **SECURITY:** Security refers to the protection against both direct and indirect threats, attacks and acts of unlawful interference to the ATM System.
- **HUMAN PERFORMANCE:** An efficient and capable surveillance system leads to improved Air Traffic Controller efficiency.

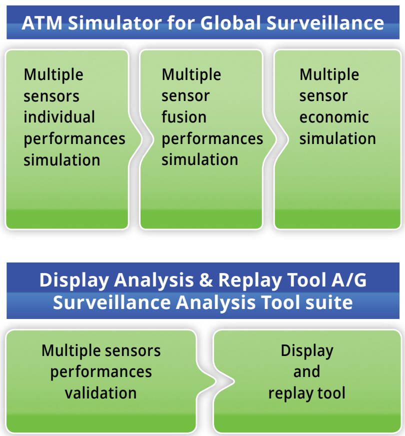
KPA	PSR	SSR	ADS-B	WAM	Hybrid solution
CAPACITY	• **PSR meets the current and expected future capacity needs**	• **Mode S can improve vertical capacity**	• **Support reduced separation, hence increased capacity in low altitude / dense airspace**	• **Support reduced separation, hence increased capacity in low altitude / dense airspace**	• **Support reduced separation, in a homogeneous performance, hence increased capacity in any part of the covered airspace**
COST EFFECTIVENESS	• **Proven technology, limited non recurring costs** • Still costly life cycle compared to other Surveillance technologies	• **Proven technology, limited non recurring costs**	• **Highly cost effective**	• **Generally improved cost due to improved flexibility**	• **Highly improved cost effectiveness vs PSR + SSR**
EFFICIENCY	• **Amplifier transition from tubes to solid-state improved the Radio Frequency footprint** • **Use of digital processing to continuously improve performance** • Overlapping coverage at high altitudes • High power transmission still impacts Radio Frequency footprint and deployment constraints	• **No loss of information.** • **Mode S (EHS, ELS) improve the SSR efficiency**	• Neutral on surveillance efficiency & spectrum efficiency	• **Improved surveillance efficiency** • Potential negative impact on spectrum efficiency in some areas due to increased interrogations	• **Improved surveillance efficiency & spectrum efficiency**
ENVIRONMENTAL	• Significant required infrastructure • Potentially impacted by Wind Turbines	• Significant required infrastructure • Potentially impacted by Wind Turbines	• **Enabler to trajectories with reduced fuel consumption and noise impact. Much less visual footprint than radars**	• **Enabler to trajectories with reduced fuel consumption and noise impact** • **Much less visual footprint than radars**	• **Enabler to trajectories with reduced fuel consumption and noise impact.** • **Less visual footprint than radars**
FLEXIBILITY	• **Best suited for long range and high altitude Surveillance** • Limited adaptability to changing of air routes due to its significant required infrastructure	• **Best suited for long range and high altitude Surveillance** • Limited adaptability to changing of air routes due to its significant required infrastructure	• **Distributed system allows flexible deployment** • **High update rate allows flexible trajectory management**	• **Distributed system allows flexible deployment** • **High update rate allows flexible trajectory management**	• **Distributed system allows flexible deployment.** • **High update rate allows flexible trajectory management**
INTEROPERABILITY	• **Use of ASTERIX format** • Required frequency/distance separation between two PSRs	• **Use of ASTERIX format** • **Clustering of SSR Mode S**	• Limited Interoperability due to limited aircraft equipage, and to dual standard in some regions of the world (eg 1090/ UAT)	• **Positive impact on Interoperability , as WAM able to track any transponder equipped target**	• **High impact on Interoperability, as being able to track any air target**
PREDICTABILITY	• **Proven technology through experience** • **Not dependent on on-board transponders** • Performance depends on propagation effects	• **No false tracks** • Dependent on on-board transponders • Performance depends on propagation effects	• Predictability may be not optimal in the transition period due to persistence of «non certified» transponders with poor performance • Performance depends on propagation effects	• **Improved predictability due to graceful degradation, spatial diversity,...** • Performance depends on propagation effects	• **Improved predictability due to graceful degradation, space & frequency diversity,...** • Performance depends on propagation effects
SAFETY	• **Not dependent on on-board transponders** • **Redundant system in its design** • Poor coverage at low altitude for some configurations	• **High added value system (Use of Mode S EHS ans DAPs)** • **Redundant system in its design** • Dependent on on-board transponders • Poor coverage at low altitude for some configurations	• Subject to GPS outage or jamming, and avionics failure	• **Improved safety due to graceful degradation, spatial diversity,...** • However still some limitations (against transponder failures)	• **Highly improved safety, as no more identfied weaknesses**
SECURITY	• **Non Cooperative Surveillance technology** • Poor coverage at low altitude for some configurations	• **Non Cooperative Surveillance technology** • Poor coverage at low altitude for some configurations	• Subject to multiple threats e.g. GPS jamming, spoofing, deliberate swith off of transponders,...	• Equivalent to SSR. However still major issues remaining against various kind of threats, as relying on aircraft cooperation	• **Highly improved security, as no more identfied weaknesses**
HUMAN PERFORMANCE	• **Proven efficient HMI** • Require skilled ATC controllers	• **Proven efficient HMI with high added value information**	• **Allows better anticipation of conflicts or loss of adherence in contract trajectories, hence reduces ATM workload**	• **Allows better anticipation of conflicts or loss of adherence in contract trajectories, hence reduces ATM workload**	• **Reduces ATM workload through a better anticipation of any critical situation**

3.4 Simulation and Validation tools

Availability of validated technical and economic modelling and evaluation tools is mandatory to offer safe and optimal surveillance solutions.

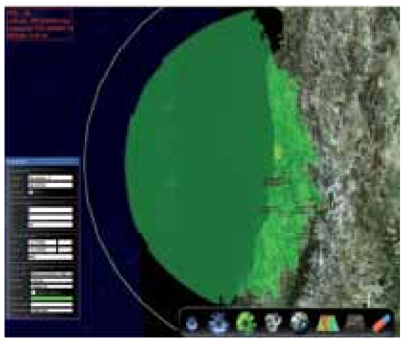
To support any ANSP wanting to develop its surveillance architecture, comprehensive suite of simulation tools have been developed with the following functions:

- Implementation of the ANSP surveillance needs and its environment
- Definition of scenario and performance indexes
- Development of potential solution, independent of manufacturers
- Cost evaluations (Acquisition and operation)

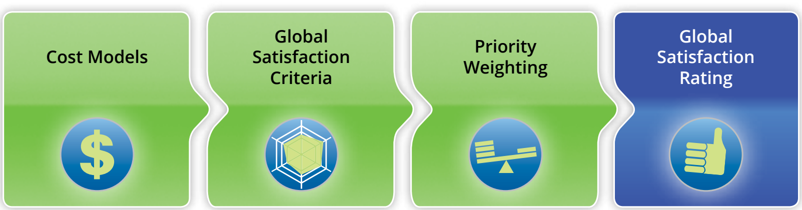


Performance Modelling Tools

A performance modelling tool computes the performance indexes of multi sensor systems such as WAM or MSPSR or mono sensor systems such as PSR/SSR/ADS-B. The tool is able to compute the non cooperative coverage merging the data given by different PSR and MSPSR system and cooperative coverage merging the data given by different SSR, ADS-B and WAM system. Then, the system simulates the multi-sensor tracking process and data fusion. The user can also view and display the selected configuration.



Economical Modelling Tools: Cost & Solution Global Valuation

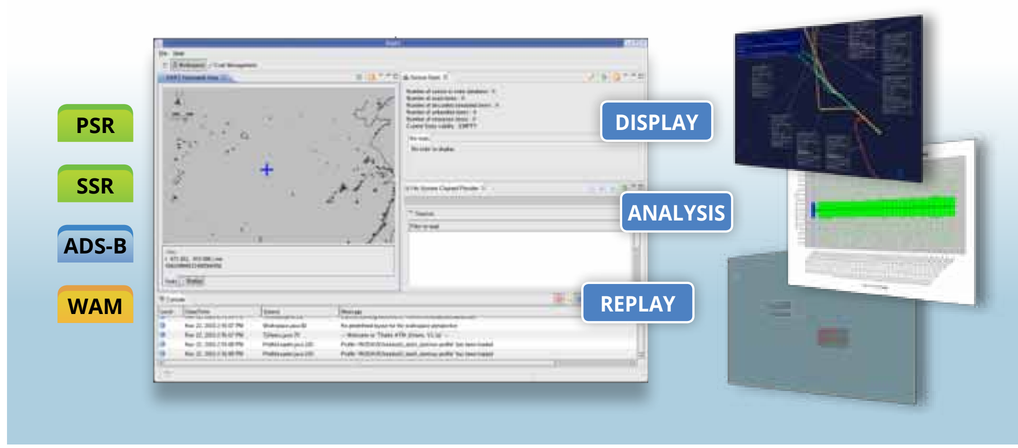


Display Analysis and Replay Tools

These tools validate and monitor the global surveillance solution through the analysis of recorded air traffic situations based on three major features:

- Display : Tracks/plots from different sources, ASTERIX and specific radar formats, Air situation and tabular display, Data filtering upon different criteria, Image (JPEG, PNG, PS), xml and csv data export
- Complete replay capabilities and Speed selection
- Analysis: Bias and noise estimation, Track characteristics and bias value chart display, Sensor statistics and Tracking performance assessment results

Display analysis and replay tool functionalities (DART developed by Thales)



Air and Ground surveillance Analysis Tools Suite

1/ Trajectory Generation based on

- Mobile scenario: 3D mobile template simulation
- Sensor scenario (standard characteristics & specific per kind of sensor)
- Environment scenario (airport layout management, shadowing areas, multipath,...)
- Trajectory scenario

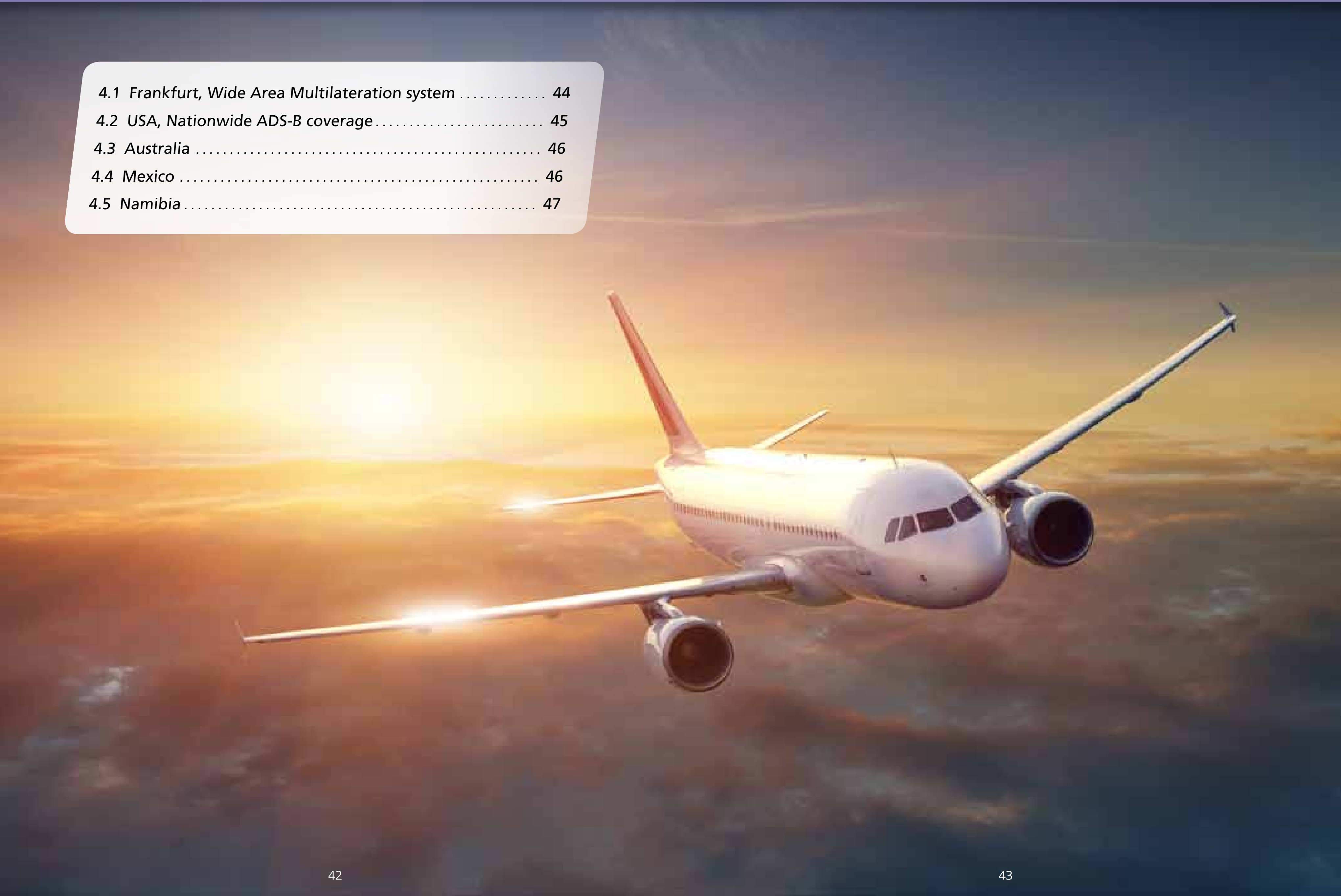
2/Trajectory Reconstruction

- Sensor reports and/or track updates chaining
- Gap filler processing
- Trajectory smoother

3/ Sensor and Tracker Performance Assessment

- Sensor performance computation for approach & en route radars (PSR, SSR, CMB, Mode S), surface movement radar (SMR), MLAT / WAM system, ADS-B ground station
- Tracker performance assessment (Accuracy, latency, continuity and integrity metrics according to ESSASPs rules)
- Verification of International Standards such as EUROCONTROL, MIT, EUROCAE, FAA, ANSPs specific.

4 CASE STUDIES



4.1 Frankfurt am Main TMA, WAM system

The Precision Approach Monitoring (PAM) system is the first operational WAM system in Germany, and is designed specifically for highly congested environments. It delivers almost five times higher update rates than conventional radar and provides controllers with enhanced situational awareness and more flexibility to feed aircraft into the approach area around Frankfurt Airport. The WAM PAM comprises 37 ground stations, 15 transmitters, and 37 receivers, set up around 34 individual sites. High precision surveillance data is provided throughout a 128 by 80 nm coverage area starting as low as Frankfurt am Main Airport ground and reaching beyond cruising altitude. Around the airports of Frankfurt and Hahn, the lowest detection limit is 500 feet above ground, increasing to 1,000 feet above ground within the terminal approach area. The remaining area is covered from 3,000 feet above ground.

DFS approved its final site acceptance in early September 2012. It is planned to go operational by April 2013, after approval by the German Federal Supervisory Authority for Air Navigation Services (BAF). ■

4.2 USA, Nationwide ADS-B coverage

Approximately 87,000 flights crisscross America's skies each day. According to the FAA, that number is projected to rise to over 128,000 flights per day by 2025. Unfortunately, the current ground-based radar air traffic control system that's served America so well for the last 60 years has hit the ceiling of its growth capacity. It simply cannot keep pace with expected demand.

NextGen is transforming the US National Airspace System (NAS) to meet future needs and avoid gridlock in the sky and at airports. The FAA has embarked on a continuous roll-out of new capabilities and technologies that will reduce delays, make air traffic more efficient and minimize aviation's impact on the environment. Travel will become more predictable, quieter, cleaner and more fuel-efficient, and more importantly, safer.

As a key member of the ITT team, Thales is providing some 1,600 ADS-B stations for nationwide coverage across the US, as well as TopSky–Tracking, the multi-sensor tracker for reliable fusion of radar and ADS-B targets.

This satellite-based surveillance system will bring improved precision and reliability to US skies. Pilots will benefit from improved situational awareness. Controllers will be able to reduce aircraft separation and increase airspace capacity. Aircraft will fly more direct routes, reducing fuel burn.

ADS-B is already supporting the 9,000 daily helicopter operations in the Gulf of Mexico allowing flights to continue even in poor visibility conditions. UPS is using ADS-B at its hub in Kentucky and expects to achieve an annual fuel reduction of 800,000 gallons, a 30% decrease in noise and 34% reduction in emissions when ADS-B will be fully implemented. ■

4.3 Australia

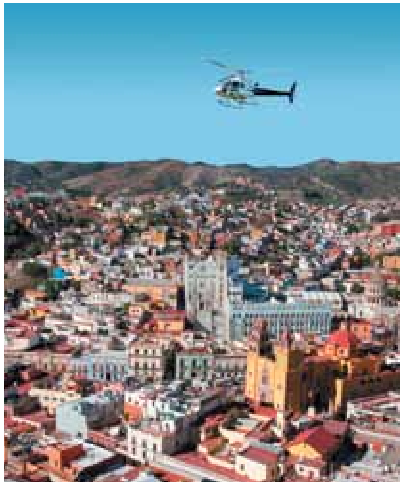
The airspace controlled by TAAATS (The Australian Advanced Air Traffic System) covers 56 million square kilometers and controls more than three million air traffic movements per year. While almost full radar coverage exists along the east coast of Australia and the majority of commercial air traffic in Australia is currently under radar coverage, over 90% of Australian airspace is outside radar coverage. The Automatic Dependant Surveillance Broadcast (ADS-B) system has provided extensive coverage in non-radar airspace and complements the existing en-route and terminal radar RASPP network

The ADS-B system is fully integrated with TAAATS flight plan, radar data and Automatic Dependant Surveillance Contract (ADS-C) data display and allows Airservices Australia to provide radar-like separation services in the current non-radar airspace. TAAATS has been upgraded to process up to 1,000 ADS-B flights simultaneously from up to 200 ground stations. The UAP ADS-B programme is the first operational large scale ADS-B system. ■

4.4 Mexico

Thales radars provide over 80% of the radar coverage in the country.

Thales has modernised and improved Mexico's surveillance capabilities, helping SENEAM to meet the NextGen initiatives and to enhance air traffic management capabilities. FAA and SENEAM are working together for ADS-B on Gulf of Mexico Project.



ADS-B Equipment based on Thales Ground Station AS680 is been installed at Mexico City International Airport and at within Mexico Valley. It is considered one of the most complex operational area. The complexity is increased by the elevation of the city, by the mountains around it and because the city is one of the most heavily populated on the world (Airport location almost in Town). The Valley of Mexico is perfectly covered by ADS-B antenna pattern. The ADS-B equipment is integrated to TopSky – Tracking, a Multi sensor tracking system. This equipment mixes the radar data with ADS-B data for delivering one fusioned track. ■

4.5 Namibia

Since early 2010, the surveillance of the entire Namibian Airspace above the FL 145 and the approach of Hosea Kutako International Airport is ensured by a combination of primary and secondary radar for the Windhoek TMA as of the rest of airspace is covered by means of primarily WAM made of 36 receiving and 24 transmitting stations complemented by data from ADS-B equipped aircraft and ADS-C capability at Eros ACC automation system. A multi-sensor surveillance processing system is implemented within the Eros Area Control Centre to fuse the data from the miscellaneous sensors. ■

5 SUPPORT SERVICES

Global Surveillance Solution also include support and services by providing a complete Integrated Logistics Support package, by optimising maintenance, documentation, training and supportability from the earliest design phase, to reduce the life cycle costs of the equipment provided.

Maintenance requirements are fed into the design process to develop easily maintainable equipment delivered with a comprehensive logistics package. It is adapted to take into account customer specific requirements, priorities and organisations.

Documentation and training are designed to streamline preparations to deploy on operational missions as quickly as possible.

After delivery, support capabilities have to include factory and on-site maintenance, calibration, software updates and other services.

With a full range of services to support the surveillance solution all over the world at all levels of maintenance, surveillance experts should be available to carry out corrective or preventive maintenance task on site.

Based on analysis of customer's feedback, Global surveillance solutions build on lessons learned to deliver better, faster and more cost effective services.

Delivering global, long-term Support and Services

Maintenance

- Repair services
- Spare parts
- Integrated logistic support
- Technical assistance
- Software support
- Overhaul
- Test benches
- Contractor Logistics Support (CLS)

Upgrade & System life extension

- Functional & capacity improvements
- System life extension

Extended services

- Full life support
- All level maintenance
- Support prime contractorship
- Maintenance operator

6 MAJOR R&D PROGRAMMES

NextGEN

MEMBER OF SESAR JOINT UNDERTAKING

The Air Traffic Management system is currently facing a drastic need for change in order to increase capacity and safety ad to reduce cost and environmental impact.

NextGen ADS-B Program

Automatic Dependent Surveillance-Broadcast (ADS-B) system is the cornerstone program of the FAA's Next Generation Air Transportation System (NextGen) initiative to modernize from a ground-based system of air traffic control to a satellite-based system of air traffic management. This program leading by ITT will have a huge impact on the entire aviation industry, affecting, to a certain degree, every aircraft in U.S. airspace. As a key member of the ITT team, Thales is providing some 1600 ADS-B stations for nationwide coverage across the US as well as the multi-sensor tracking function.

NextGen Data Communications

Data Comm will allow digital information to be exchanged between air traffic control (ATC) and pilots, enabling the auto-load of information directly into the aircraft flight management system. This will allow aircraft to receive departure clearances and airborne reroutes digitally. Thales is working with the FAA to develop Data Comm Avionics and support its validation and verification efforts with simulation equipment.

NextGen Surveillance and Weather Radar Capability (NSWRC)

The FAA currently operates four distinct radar systems for terminal aircraft surveillance and airport hazardous weather detection in the nation's terminal airspace. These radar systems, Airport Surveillance Radar (ASR) models 8, 9, and 11 and Terminal Doppler Weather Radar (TDWR), are nearing the end of their life cycle and will require Service Life Extension Programs (SLEPs) to continue operational service. Sustainment and upgrade programs can keep these radars operating in the near to mid-term. For the long term, the FAA recognizes that replacement of these radars is the best option. One of the potential alternatives is multifunction phased-array radar (MPAR) alternative that uses active electronically scanned phased array technology. It is possible to reduce the total number of radars required by approximately one-third.

There are major R&D programmes such as the Single European Sky ATM Research (SESAR) and the NextGen in the United States, that have been initiated with the aim to develop new operational concepts and enabling surveillance technologies that will be able to support the implementation of a new ATM system:

SESAR WP 15.04.01 - Rationalisation of the Surveillance Infrastructure

The objectives of the SESAR WP 15.04.01 project were twofold:

- Methodology to promote a rationalisation and adaptation of the Surveillance infrastructure.
- Roadmap to support the introduction of changes to the Surveillance infrastructure that are identified in the ATM Masterplan.

The Team is composed of representatives from Thales Air Systems SA, DFS Deutsche Flugsicherung GmbH, EUROCONTROL, NATMIG and INDRA.

SESAR WP 15.04.05 a & b: Ground system enhancements for ADS-B

The objective of SESAR WP 15.04.05a is to enhance the ground Surveillance systems in support of ADS-B applications.

The main activity is the development of update for specification for ADS-B ground station on Surveillance Data Processing and Distribution (SDPD) and ASTERIX interface.

High level objective of WP 15.04.05b is to develop a ground-based prototype to support Airborne Separation Assistance Systems (ASAS) applications (En-Route and TMA). The work consists in evaluation of DO260B/ED102A Ground Station.

SESAR WP12.02.02 "Runway Wake Vortex Detection, Prediction and Decision Support Tools"

The objective of SESAR WP 12.02.02 is to safely reduce wake vortex separations for arrival & departures and define, analyze, develop and verify a Wake Vortex Decision Support System (WVDSS) in order to:

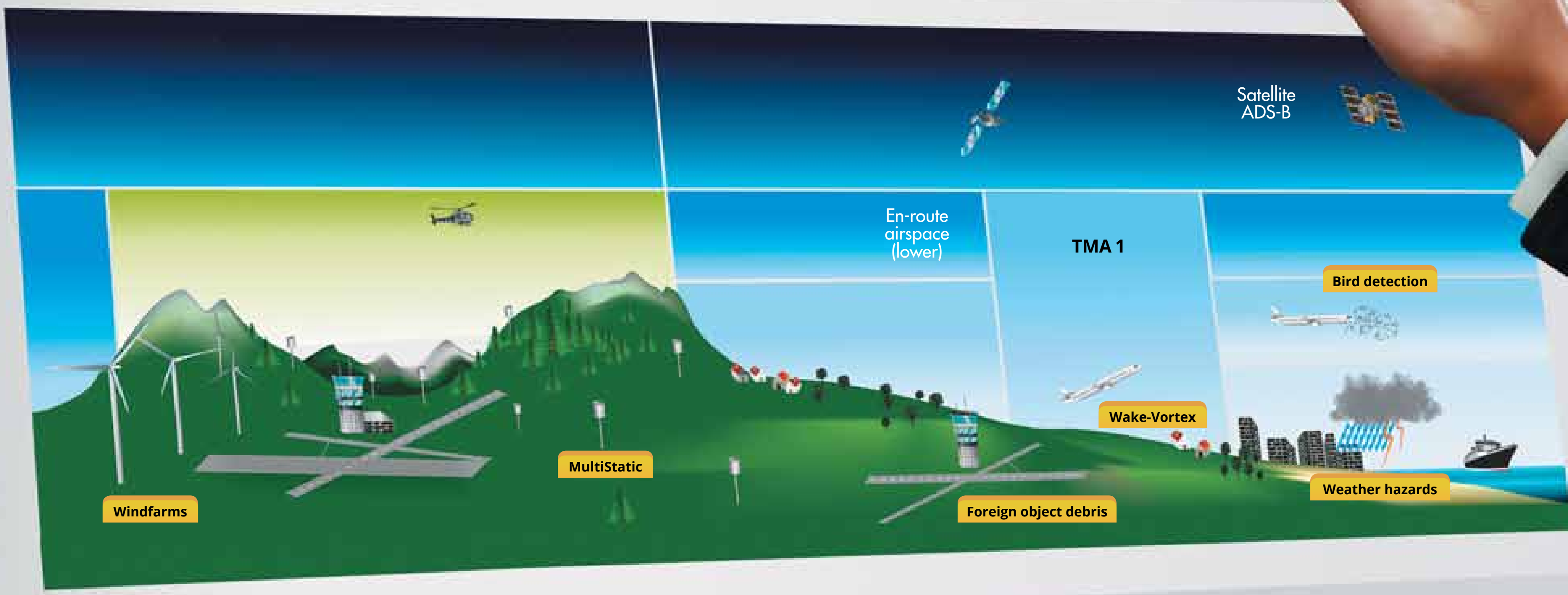
- satisfy SESAR WP 06.08.01 operational concept
- deliver position & strength of wake vortices
- predict wake vortices behavior and impact on safety & capacity
- advise stakeholders (Air Traffic Controllers, Supervisors ...)

WVDSS has to be able to bring solutions to Wake Vortex concerns, taking into account airport infrastructure, layout and weather conditions.

The Team is composed of representatives from Thales Air Systems SA, DFS Deutsche Flugsicherung GmbH, EUROCONTROL, NATMIG and INDRA.

7 INNOVATION

Extended solutions for tomorrow: Global Surveillance Solutions making the best use of the new technologies to face new operational needs.



7.1 Windfarm Compliant Radars

The development of renewable energy is now a priority all over the World, and among emerging technologies, wind energy is one of the most promising solution.

As an example, in Europe, the EWEA (European Wind Energy Association) forecasts that electricity production from wind turbines will be multiplied by 6 within the next 20 years.

However, windturbines can disturb Air Traffic Services, and in particular Primary Surveillance Radars (PSR). Practical disturbances are the generation of false plots and tracks by the windturbines, the loss of detection of real targets (aircraft) flying over the windfarm and the masking of low level aircraft behind the windfarm.

Mitigation solutions are developed in order for the radar to become "Windfarm Compliant", which will prevent blocking wind energy development because of radars.

As an illustration, Thales has installed a STAR 2000 PSR in Scotland at Inverness, an airport which is surrounded by many windfarms. This was a good opportunity to make recordings on real situations and to analyse the capacity of a windfarm filter to cancel a large amount of windturbine echoes. Such a solution is an attractive alternative to the more conventional NAI (Non Automatic Initiation) process, which prevents from initiating new tracks in windfarm areas.

Thales has identified three development axis, depending on the type of situation to tackle:

- the upgrade of existing radars: software processing can be improved, in particular by adding windfarm filters which allow to filter out the windturbine spurious signals once they are classified as such,
- gap-filler radars: in the case of existing radars for which such an upgrade is not envisaged or yet for solving specific issues such as masking, then Gap-Filler radar solutions (e.g. installed on the windturbine itself) can be proposed,

- next generation radars: windfarm "clutter" will be considered as a requirement, and new architectures are already studied for proposing the best solutions. Among these architectures, MSPSR (Multi-Static PSR)[5] shows built-in nice features for mitigating windfarm effects.

Thales also contributes to dedicated groups, and shares its knowledge with world experts' communities (such as the Eurocontrol Wind Turbine Task Force), therefore participating to a common effort towards a greener planet.

[5] Refer to Chapter 7.5

7.2 Bird detection

Bird strikes with aircrafts are a wellknown problem in the aviation world related to both civil and military communities.

Bird ingestion is causing major damages to aircrafts, sometimes leading to fatal crashes.

- 7320 bird strike on civilian aircraft in the US in 2008, 72% below 500 ft AGL, 92% below 3000 ft, 2/3 on landing, 1024 with significant damages on aircraft, 49 aircraft destroyed
- Total cost of bird strike (Commercial aviation) is 1255 M$, 65$ per flight

Avian radar systems use available marine or coastal radars (CW100 & CW10)

Avian Radar

Avian radar systems are adding to airport technologies providing information needed for strategic and tactical management of wildlife hazards.

Radar provides an opportunity to extend observational capabilities to 24/7 time frames and the ability to expand spatial coverage in both distance and altitude. Specific radar-based detection systems have been developed to address an airport's critical wildlife management and bird strike hazard warning requirements. The most common avian radar systems use readily available marine or coastal band radars (S-band and X-band) with scan configurations and digital processing of sensor data optimized for wildlife target detection and tracking. Unlike other radars used at airports, avian radars are a new addition to the technological capabilities of airports.

Bird detection at 0 feet Above Ground Level (AGL)

Automated Foreign Object Debris (FOD) detection solutions like FODetect have been specifically designed to detect birds on airports travel surfaces. Numerous hazardous birds on travel surfaces have been encountered with the installed systems all over the globe.

7.3 Foreign Object Debris Detection

Foreign Object Debris (FOD) events at airports, which occur on a daily basis, present a risk to passenger lives and safety, disrupt airport service and cause billions of dollars in aircraft damage annually.

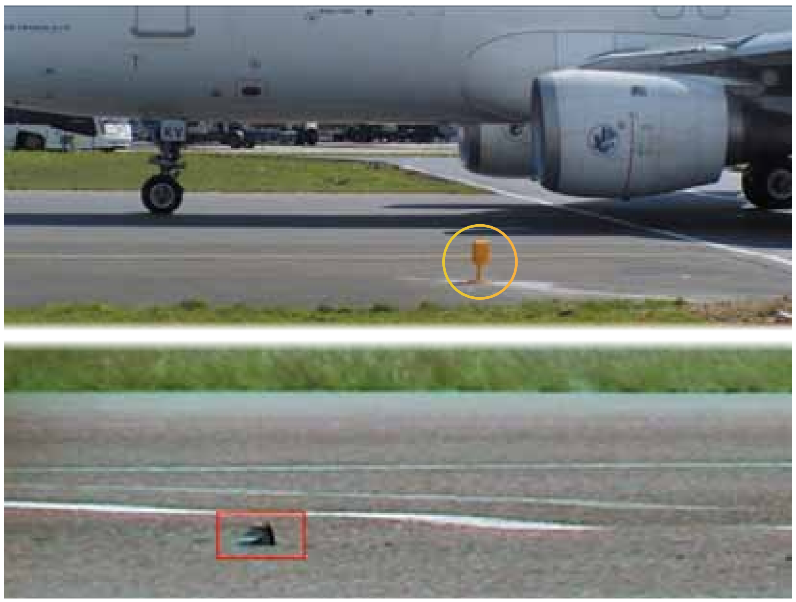
Direct damage to airplanes resulting from FOD is estimated to cost the aerospace industry $4 billion a year, while the indirect damages result in significantly higher figures.

Crashes of several aircraft in the last few years jolted the aviation industry and highlighted the need for continuous checking of the runway between takeoffs and landing, a requirement that necessitates an automated, technological solution. This approach is supported by the Federal Aviation Authority (FAA), EUROCONTROL and by the International Civil Aviation Organization (ICAO).

FODetect have been specifically designed to detect Bird, Wildlife and FOD on airports travel surfaces.

FODetect is an automated FOD detection solution with superb detection capabilities deriving from a unique integrated optical-radar sensing technology, advanced image processing software and close range detection.

The system is embedded in Surface Detection Units (SDUs) that are co-located with the runway edge lights.



7.4 Wake-Vortex detection

Aircraft creates wake vortices in different flying phases. To avoid jeopardizing flight safety by wake vortices encounters, time/distance separations have been conservatively increased, thus restricting runway capacity.

The concern is higher during taking off and landing phases, as aircraft are less easy to maneuver.

Wake vortices are a natural by-product of lift generated by aircraft and can be considered as two horizontal tornados trailing after the aircraft.

Enquiries have shown that highest occurrence of wake-vortex encounters are:

- At the touchdown (behind 100 feet in altitude)
- At Turn onto glideslope (between 3500-4500 feet in altitude)

A trailing aircraft exposed to the wake vortex turbulence of a lead aircraft can experience an induced roll moment (bank angle) that is not easily corrected by the pilot or the autopilot.

However these distances can be safely reduced with the aid of smart planning techniques of future Wake Vortex Decision Support Systems based on Wake Vortex detection / monitoring and Wake Vortex Prediction (mainly transport estimation by cross-wind), significantly increasing airport capacity.

Radar and Lidar Sensors are low cost technologies with highly performing complementary wake-vortex detection capability in all weather conditions compared to others sensors that suffer of limited one.

Thales Radar for Wake Vortex Detection (SESAR project)

7.5 Weather hazards detection

75% of all air traffic delays is due to weather and weather has contributed for high percentage of all aircraft accidents in the world.

Main weather hazards with impact to safety are: Storms (Cumulonimbus) & heavy rain (Gust fronts), Wake Vortex, Severe Weather turbulences (CAT), Wind-shear & microburst,...

Development of weather aviation systems for Terminal Approach & Airport Controls is necessary to improve safety in adverse conditions and to reduce flight delays & optimize airport capacity.

Existing surveillance equipments are not optimized for weather airport services: Weather radars from National Met Offices are localized far from the airport, Weather channel of Primary ATC Radar has poor quality, Terminal Weather Radars have not been deployed in Europe and are based on old technology in US...

Some R&D programmes (US FAA/ NEXTGEN MPAR) are working on innovative evolution based on electronic Multi-Function Approach that allow rapid & adaptive scanning, increase lead time for weather hazard warning, better data quality for national numerical weather prediction, high resolution / high refresh rate for hazards monitoring (wake vortex, wind shear,...). Several solutions are explored: Networked short range sensors, Rotating Phased Array Radar (PAR), fixed face PAR...

7.6 MultiStatic Primary Surveillance Radar

MultiStatic Primary Surveillance Radar (MSPSR) is an innovative independent non-cooperative civil and military Surveillance for Terminal Approach Control and en-route purposes.

It is based on a sparse network of stations able to transmit and receive omni-directional and continuous waveforms.

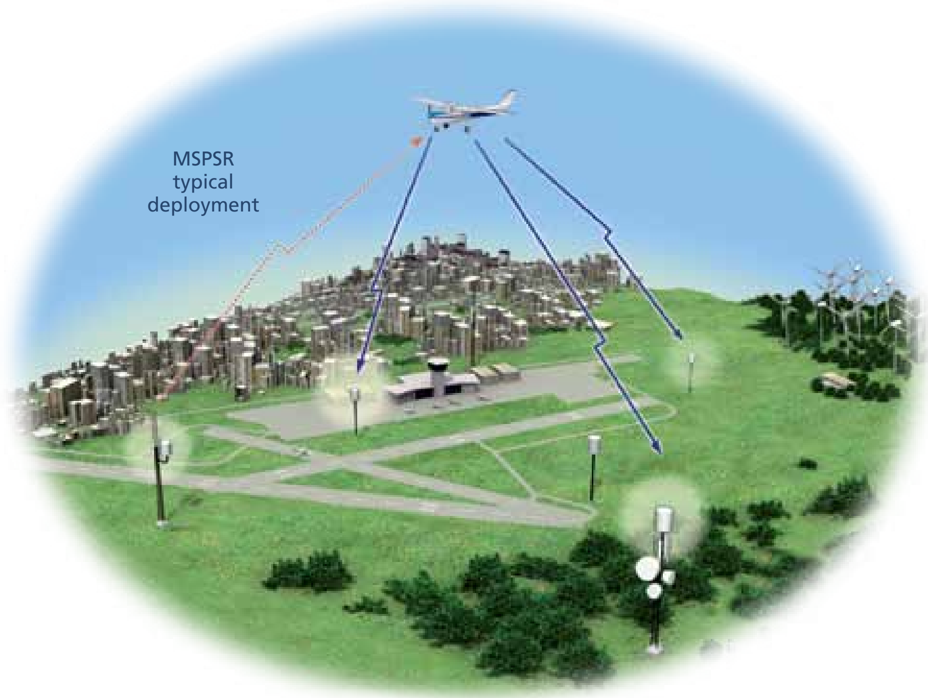
Two system types are derived from this concept:

- "active" MSPSR with dedicated ("controlled") transmitters,
- "passive" MSPSR relying on transmitters of opportunity, identified as "PCL" (Passive Coherent Location).

The strength of this technology is such that localisation of aircraft is now available in the three dimensions and with a faster renewable rate compared to current PSR. Existing transmitters (opportunity transmitters as radio or TV broadcast) can be used by PCL. Dedicated transmitters of active MSPSR will use current PSR frequency bands.

MSPSR offers several improvements compared to a conventional Primary Surveillance Radar: 3D detection, higher renewal rate (1.5 s instead of 4-5 s), resistance to wind-farms effects, and lower energy consumption.

The configuration is adaptable to the environment and can be reconfigured. It re-uses existing infrastructures such as communication masts. The coverage can be extended by adding transmitters (Tx) and receivers (Rx) as necessary in order to respond to various applications.



Acronyms and Terminology

TERM	DEFINITION
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
ANSP	Air Navigation Service Provider
ASTERIX	All-purpose Structured Eurocontrol Radar Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Air Traffic Network
ATS	Air Traffic Service
CAA	Civil Aviation Authority
ELS	ELementary Surveillance
ES	Extended Squitter
ESARR	EUROCONTROL Safety Regulatory Requirement
FAA	Federal Aviation Administration
FOD	Foreign Object Detection
FRUIT	False Replies Un-synchronised In Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GS	Ground Station
ICAO	International Civil Aviation Organization
ID	IDentification
KPA	Key Performance Areas
MLAT	MultiLATeration
MSPSR	Multi Static Primary Surveillance Radar
MSSR	Monopulse secondary surveillance radar
MTBCF	Mean Time Between Critical Failures
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NM	Nautical Mile
PoD or PD	Probability Of Detection
PCL	Passive Coherent Location
PMR	Precision Runway Monitor
PSR	Primary Surveillance Radar
R&D	Research and Development
RF	Radio Frequency
Rx	Receiver
SAP	System Access Parameter
SESAR	Single European Sky ATM Research Programme
SMR	Surface Movement Radar
SSR	Secondary Surveillance Radar
STCA	Short Term Conflict Alert
TDOA	Time Difference Of Arrival
TIS-B	Traffic information services-broadcast
TMA	Terminal Manoeuvre Area
TOA	Time Of Arrival
TWT	Travelling Wave Tube
Tx	Transmitter
UAT	Universal Access Transceiver
VDL	VHF Data Link
VHF	Very High Frequency
WAM	Wide Area Multilateration

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GLOBAL SURVEILLANCE

While widely deployed Primary and Secondary Radars are considered as highly proven equipment, more recent technologies such as Automatic Dependent Surveillance – Broadcast (ADS-B) and Wide Area Multilateration (WAM) offer mature alternatives to secondary radar.

Choosing a surveillance solution adapted to your current and future operational needs, your ATM environment and your budget is not easy.

The objective of the booklet is to present the available surveillance sensors, the interface to automation systems, some application cases and the concept of Global Surveillance proposed by Thales so as to meet tomorrow's traffic flows whilst meeting your quests for higher safety, enhanced efficiency and lower costs.