

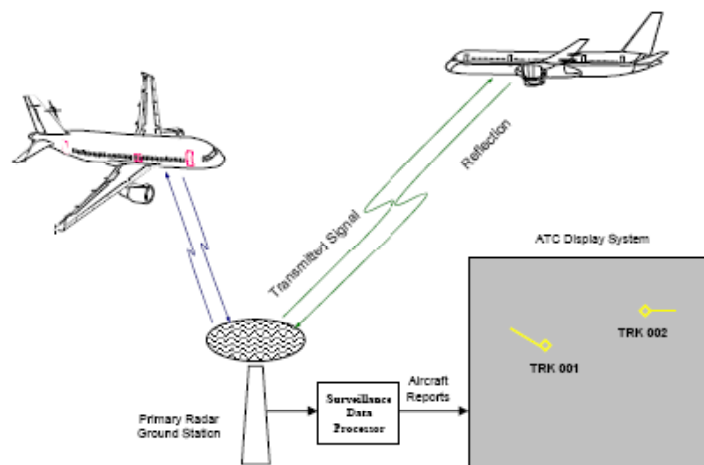
# COMPARISON OF SURVEILLANCE TECHNOLOGIES

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ICAO

ICAO Seminar on the Implementation of  
Aeronautical Surveillance and Automation Systems  
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## Primary Surveillance Radar (PSR)



## Main PSR Types

**L-Band (1-2 GHz)**  
**(En-route - up to 200 NM)**



**S-Band (2-4 GHz)**  
**(Terminal - up to 80 NM)**

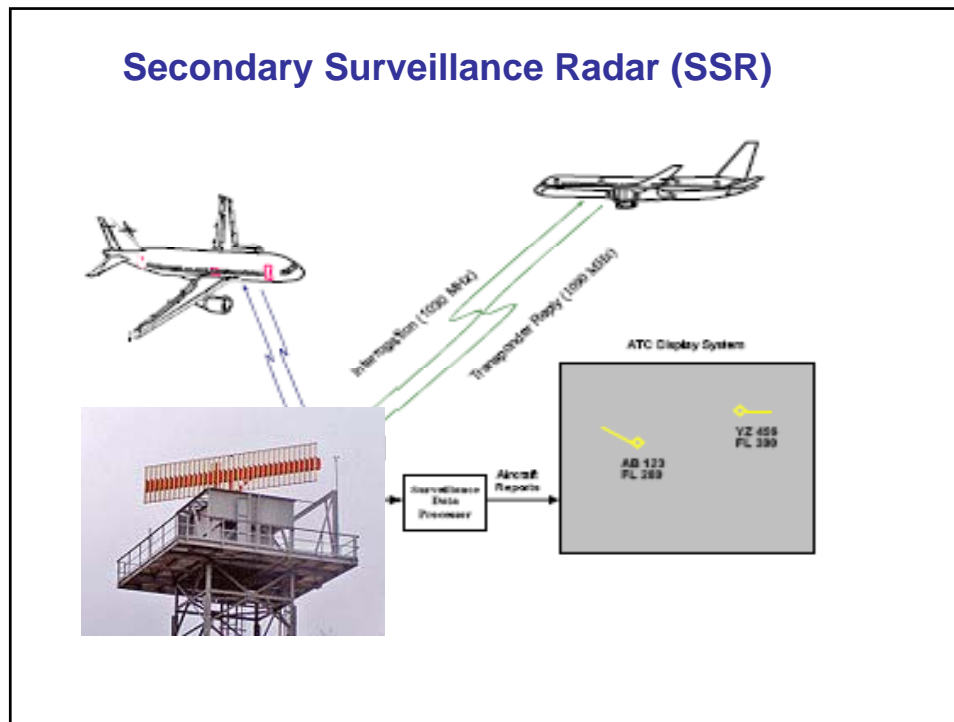


### Strengths

- PSR does not require a transponder to be installed or operating on aircraft thus allowing the detection and management of non equipped/faulty aircraft or non co-operative aircraft<sup>1</sup>
- Can provide a weather channel output if display of weather is required.
- Well suited for aerodrome surface surveillance

### Weaknesses

- PSR does not provide identity
- Does not provide altitude<sup>2</sup>
- Position is based on slant range measurement rather than true range (which presents some difficulties for multi-radar tracking systems)
- Can often report false targets (ground vehicles, weather, birds etc)
- Poor detection performance in the presence of ground and weather clutter especially for flight tangential to the radar
- Expensive compared to Secondary Surveillance Radar (SSR)
- A update rate between 4 and 12 seconds (longer than typical multilateration or ADS-B)
- High transmitter power required for long range performance – brings interference and environmental concerns
- Systems are very expensive to install and maintain
- Systems require optimum site with unobstructed view to aircraft, and with the minimum of ground clutter visible to the radar
- Cannot resolve two aircraft at a similar location at the same range, due to poor azimuth resolution performance.



### Strengths

- SSR allows communication of identity (4 digit octal codes) when matched with flight plan data held by the ground system
- Allows communication of altitude and emergency states to ground system
- Provides good detection capability independent of clutter and weather.
- Provides moderately high update rate.
- Provision of altitude allows correction for slant range error

### Weakness

- Poor azimuth accuracy and resolution (particularly for classical SSR)
- Can sometimes report false targets or position (reflections, multipath)
- Can sometimes confuse Mode A replies as Mode C and vice versa
- Can sometimes report false altitude or 4 digit code
- No error detection provided in downlinked 4 digit code and altitude from Mode C transponders
- Systems are expensive to install and maintain
- Systems require optimum site with unobstructed view to aircraft
- Cannot resolve two aircraft at the same location (garbling/ resolution performance)
- Dependent on aircraft avionics
- Not accurate enough for aerodrome surface applications due to transponder delay uncertainty

### SSR Mode S (with a LVA antenna)



Mode S radars typically use monopulse techniques to measure the azimuth position of an aircraft and have large vertical aperture antennas and hence are less subject to multipath effects. In addition, they are able to discretely interrogate single aircraft transponders and hence can discriminate between two aircraft at the same geographical position.

Mode S has additional capabilities which provide:

- improved ability to distinguish between Mode S equipped aircraft (resolution performance)
- error detection and correction of downlinked data
- improved tracking relying on Mode S 24 bit address (reduced tracking ambiguity)
- improved altitude quantisation

### Combined/Collocated PSR & MSSR Improved overall surveillance performance (e.g. redundancy and better tracking)



## ADS-B Using 1090 ES



A/C in flight

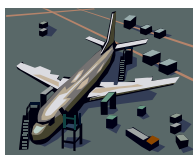
ES rate is slightly randomized and varies from 2/s (for position/velocity) 0.2/s (for identification)



Obstacle



TIS-B Station



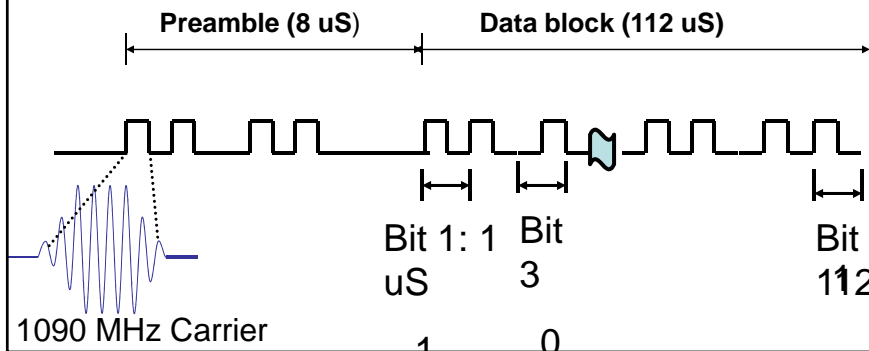
A/C on ground



Surface vehicle

## 1090 ES Signal In Space

Same as for Mode S reply to ground interrogation



## **ES Versions**

**Version 0 (RTCA DO-260) - In Annex 10 since 2002**

**Version 1 (RTCA DO-260 A)- In Annex 10 Since 2007**

**Version 2 (RTCA DO-260B/EUROCAE ED-102 A) –  
Being finalized by ASP**

**Version number only affects the message contents**

**Version 1 has more elaborate indication of accuracy and integrity. Version 2 have even more.**

**All versions described in Doc 9871.**

**Edition 2 of the document will contain Version 2**

**Major ADS-B plans in U.S. 7 Europe will use Version 2**

## **More on Integrity, Accuracy, etc**

**The aircraft should indicate in its ADS-B messages how much trust can be placed on the information it broadcasts.**

**Version 0: Navigation Uncertainty Category (NUC) that shows accuracy and/or integrity.**

**NUC<sub>P</sub> (for position) from 0 to 9**

**NUC<sub>R</sub>: (for velocity) from 0 to 4**

**Higher NUC = Higher report quality**

**Version 1:****Navigation Accuracy Category (NAC) (0 to 11)****Navigation Integrity Category (NIC) (0 to 11)****Surveillance Integrity Level (SIL) (0 to 3)****Both Versions 0 and 1 have been operationally implemented in a number of places**

## Strengths of ADS-B

**Strengths**

- Simple ground station design without transmitter
- Can be installed at sites shared with other users
- Very low ground station cost (but highly variable ADS-B avionics fitment cost)
- Very high update rate
- Almost perfect resolution
- High accuracy and integrity (airborne measurements)
- Higher performance velocity vector measured by avionics and then broadcast, rather than determined from positional data received on the ground
- Accuracy not dependent on range from ground station
- Facilitates exchange of surveillance data across FIR boundaries
- Can be easily deployed for temporary use (emergency, special events etc)
- Can support the display of callsigns on simple display systems without interfaces to flight planning systems since callsign is provided directly from the aircraft
- Facilitates future provision of innovative ATM services based on air-to-air ADS B.

## Changes Between DO-260A & DO-260B (1090ES ADS-B Version 1 and Version 2)

Capability	DO-260	DO-260A	DO-260B	Comments
NUC (Navigation Uncertainty Code)	✓			Baseline
Mode A Code		✓	✓	Support legacy ATC infrastructure
NACp (Navigation Accuracy Code for Position)		✓	✓	Replaced NUC
SIL (Surveillance Integrity Level)		✓		Replaced NUC
NIC (Navigation Integrity Code)		✓	✓	Replaced NUC
Revise SIL to become Source Integrity Level & add: SDA (System Design Assurance)			✓	Clearly separates the reporting to reflect equipment certification levels and navigation source fault detection capability
Revise NIC/NAC/SIL and add GVA (Geometric Vertical Accuracy)			✓	To improve vertical accuracy, decouple vertical from NIC/NAC/SIL and add GVA
Add ADS-B IN bits			✓	Enhancement to show both UAT IN and 1090ES IN receiver equipage
Changes to the Target State Report			✓	To better align with available aircraft data
Offer non-diversity antenna options for small aircraft			✓	Lower cost of equipage for General Aviation
Revise latency requirement (limit extrapolation)			✓	Enhancement
New guidance on how to determine NACv			✓	Fix
New guidance on how to select the best position/state vector sources			✓	Fix
Changes to the Mode A Code transmission rates			✓	Improvements and squitter efficiencies
Redefine TCAS status bits			✓	Fix
Fixes and improvement to NIC reporting and modified surface movement field for airport surface			✓	Improvements for Surface applications

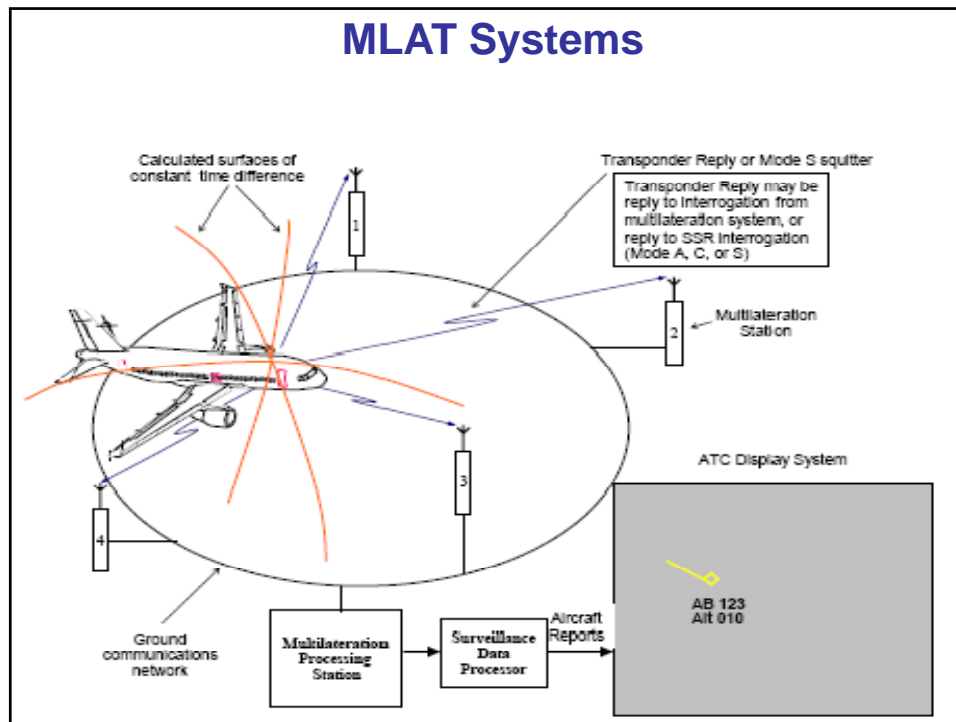
## Weakness of ADS-B

### Weakness

- Dependent on aircraft avionics. This can be a major issue in some environments.
- Equipage rates are relatively low at this stage
- Systems require optimum site with unobstructed view to aircraft
- Some outages expected due to poor GPS geometry when satellites out of service, although exposure expected to reduce in the future with use of GNSS augmentation & internal support<sup>3</sup>
- ADS-B has the capacity to evolve towards the broadcast and use of other data, such as Trajectory Change Point (TCP) or others, already defined in the standard

### ADS-B Critical issue

The critical issue for ADS-B is that it requires ADS-B avionics including GPS or similar in participating aircraft. Whilst many airliner manufacturers produce aircraft with ADS-B out avionics a large legacy fleet remains to be equipped.



### MLAT : Relatively simpler and lighter equipment

*Antennas*

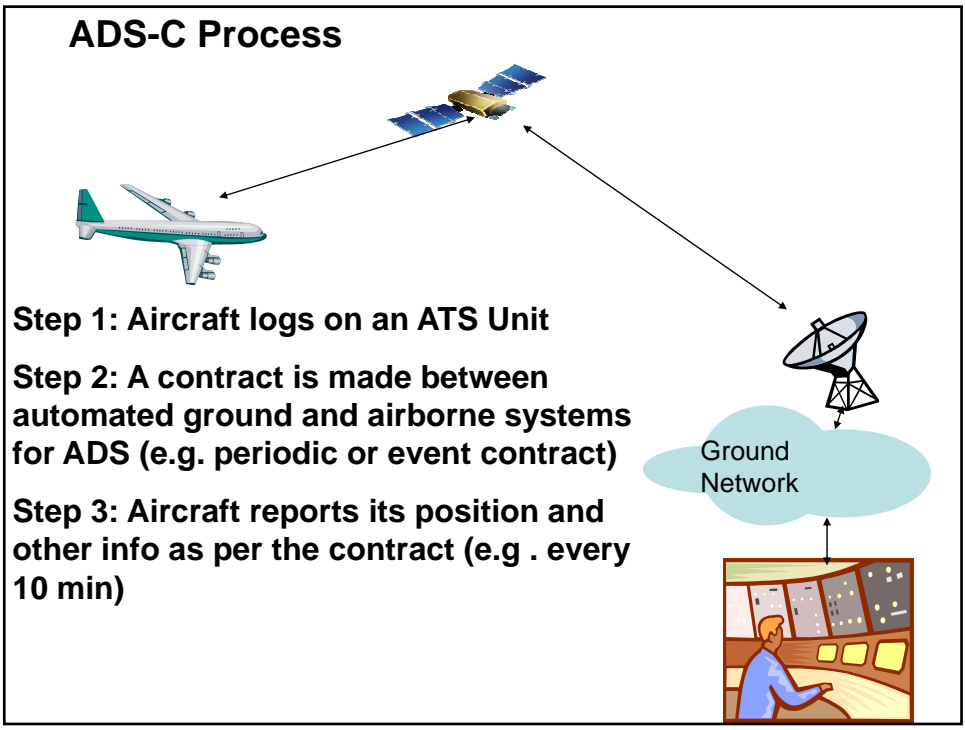
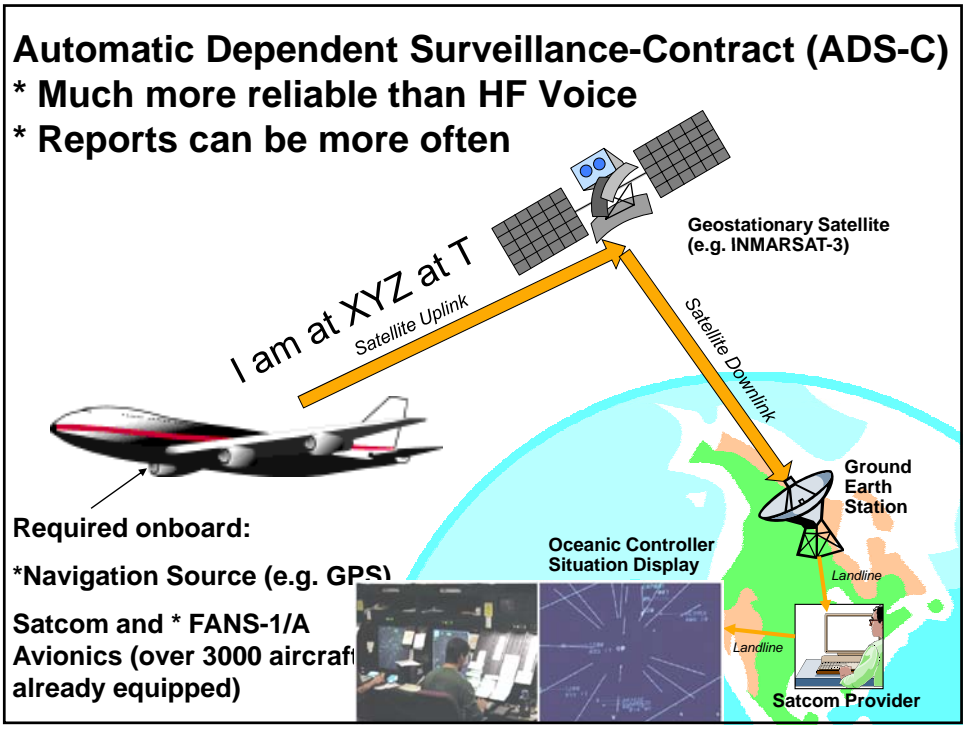


## Strengths of MLAT

- Provides aircraft identification using 4 digit octal codes, 24 bit Mode S codes or Flight Identity (ADS-B or Mode S based) to ground system
- Allows communication of identity, altitude and emergency states downlinked from aircraft
- Provides good detection capability independent of clutter and weather
- Is able to provide a high update rate
- Can resolve two aircraft at the same location (garbling / resolution performance) if aircraft are Mode S capable using selective address interrogation
- Can operate as a set of multiple ADS-B ground stations
- Can be installed at sites shared with other users
- Is an attractive transition path before widescale ADS-B equipage occurs in some States
- Lower cost than radar<sup>9</sup>
- Data feed can be made to resemble radar data (and hence can be used in some ATC automation systems that are not adapted to support native multilateration data)<sup>10</sup>
- In some locations, when existing infrastructure is available, the systems can be inexpensive to install and maintain compared to alternative systems.

## Weakness of MLAT

- Requires multiple sites
- Requires multiple communication links
- Sometimes reports false targets (reflections, multipath)
- No error detection provided in downlinked 4 digit code and altitude from Mode C transponders
- Systems can be moderately expensive to install and maintain because of the costs associated with the provision and maintenance of multiple sites especially if existing infrastructure is not available
- Systems require multiple sites with unobstructed view to aircraft. This can be a significant problem in some environments
- Requires a transmitter to trigger aircraft to transmit the data required for ATC applications
- Not yet endorsed by ICAO
- Requires multiple transmitter sites for large coverage, due to the poor uplink antenna gain when omni-antenna used (compared to high gain radar antenna).



**There are over 3000 A/C equipped with FANS-1/A (about 40% in NAT and similar figures in other regions)**

**There is however no global mandate for carriage of data link avionics**

**Moreover, not every oceanic area control centre is equipped with the data link work station.**

**The decision on the operational use of ADS-C (and other applications such as controller-pilot data link communications (CPDLC)) is made at a regional level.**

**Aircraft equipage and operational use of ADS-C has financial implications for air navigation service providers and aircraft operating agencies.**

## **Strength and Weakness of ADS-C**

### **Strengths**

- Provides surveillance coverage over very remote regions and oceans except in the polar regions
- Supports a subset of the safety net applications (Cleared Level Adherence Monitoring : CLAM, Route adherence monitoring : RAM , and ADS Route conformance warning : ARCW<sup>11</sup>) but unable to support more tactical alerts like STCA
- Low capital cost for ANSP
- Minimal maintenance costs

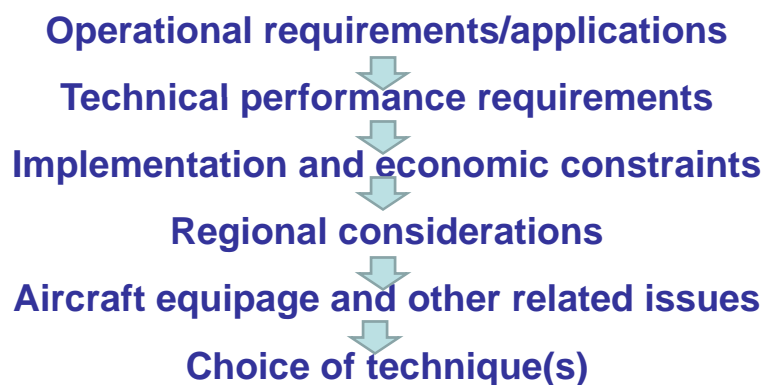
### **Weakness**

- High costs per report (service provider)
- Low reporting rates
- No ability to offer radar like separation services (vectoring etc)
- Expensive avionics fitment
- FANS-1/A is not ICAO-compliant, but has been accepted as a transition step
- ATN variant is not mature but will support higher reporting rates<sup>12</sup>
- Long latency when satellite communication link is used
- Availability not as high as other systems (not all elements are duplicated)
- Susceptibility to failure/overload at satellite earth stations
- Relatively low message delivery reliability

**Technical Performance Figures  
(to be used for comparing various techniques)**

- \* Data supplied to the ATM (e.g. position, identity and pressure altitude, as in a Mode S SSR)
- \* Range (e.g. up to 80 NM for an S-Band PSR)
- \* Position accuracy (e.g. 10-150 m for MLAT)
- \* Update period (e.g. 1 to 5 Sec. in MLAT)
- \* Track capacity : (e.g. up to 400 aircraft)
- \* Other related aspects like latency, RCMS, message format, MTBF, MTTR and so on.

**Decision Process**



***Note: There are no global (ICAO) mandate for any specific technique or systems.***

**Thank you for your attention**