International Civil Aviation Organization

ICAO/FAA Workshop on ADS-B and Multilateration Implementation

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ICAO concepts and references regarding ADS-B, Multilateration and other Surveillance techniques

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North American, Central American and Caribbean Office

Outline

- Introduction
- Multilateration (MLAT)
- Automatic Dependant Surveillance- Contract (ADS-C)
- Automatic Dependant Surveillance- Broadcast (ADS-B)
- ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

INTRODUCTION

Air traffic is growing at a significant rate.

increasing demand for more operating flexibility

improve aircraft efficiency

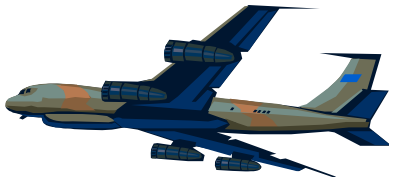
reduce the impact of air travel on the environment

Improved tools are required to safely manage increasing levels and complexity of air traffic

Aeronautical surveillance

Aeronautical surveillance systems are designed to be used by ATS to improve capacity and to enhance safety.

INTRODUCTION



Surveillance

ability to accurately determine, track and update the position of aircraft

separation standards

how efficiently a given airspace may be utilized

electronic surveillance systems

- aircraft positions are updated frequently
- safely accommodating a higher density of aircraft through reduced separation minima
- an indication of any unexpected aircraft movements
- important safety function

Requirements for ATS surveillance systems are contained in the *Procedures for Air Navigation Services — ATM (PANS-ATM, Doc 4444), Chapters 6 and 8.*

INTRODUCTION

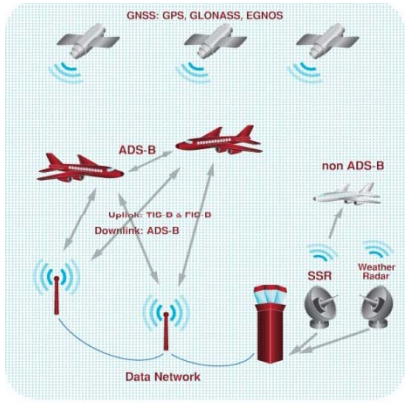
SURVEILLANCE CATEGORIES

✓ **Independent non-cooperative surveillance**

PSR

✓ **Independent cooperative surveillance**

SSR, Multilateration, etc.



✓ **Dependent cooperative surveillance**

ADS-B, ADS-C, etc

✓ **Specific surveillance schemes** **Mode S EL, Mode S EH**

INTRODUCTION

APPLICATIONS OF AIR TRAFFIC SURVEILLANCE

Area control service

ADS-C (oceanic and remote areas), SSR, WAM, ADS-B and long-range primary radars collocated with SSR.

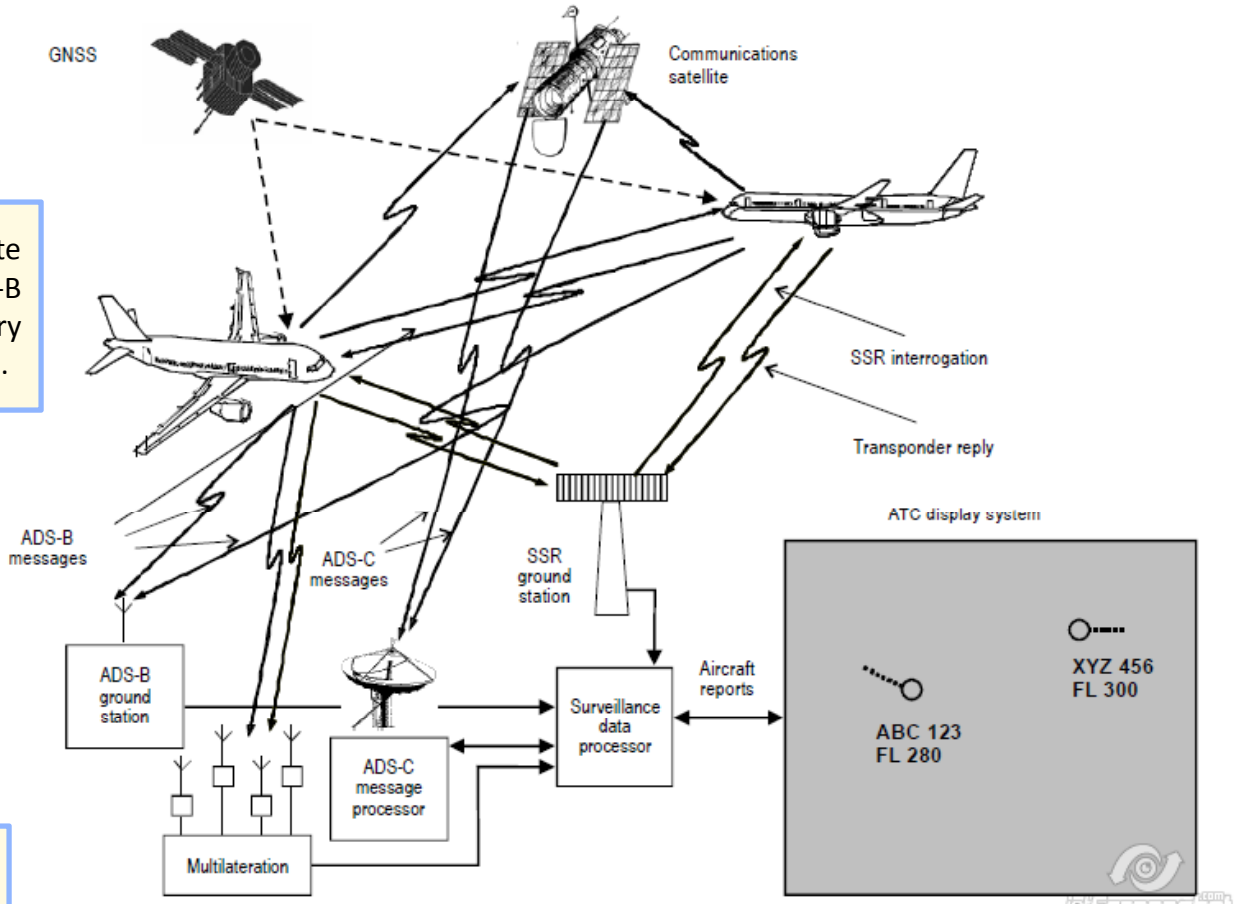
Approach control service

primary radar, SSR, multilateration (WAM) and ADS-B.

Aerodrome control service

primary radar, multilateration and ADS-B.

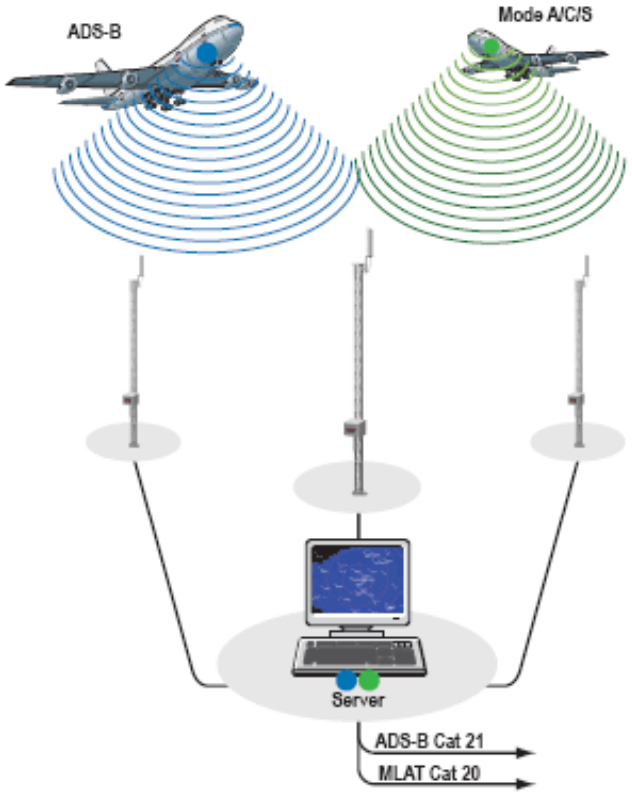
A-SMGCS | PRM | FIS | PRECISION APP



Mode S radar, MLAT and ADS-B: -> aircraft ID -> improve shortage and constraints of Mode A codes.

MULTILATERATION

cooperative and independent surveillance system that makes use of signals transmitted by an aircraft (normally the 1090 MHz SSR transponder replies or squitters) to calculate the aircraft's position.



can make use of currently existing aircraft transmissions, they can be deployed without any changes to the airborne infrastructure

Multilateration techniques have been successfully deployed for airport surveillance and for larger areas such as en-route or approach areas are called WAM systems.

MULTILATERATION

- relies on signals from an aircraft's transponder being detected at a number of receiving stations.
- uses a technique known as TDOA to establish surfaces that represent constant differences in distance between the target and pairs of receiving stations. The aircraft position is determined by the intersection of these surfaces.
- can theoretically be performed using any signals transmitted periodically from an aircraft.

MULTILATERATION

- consists of a number of antennas and a central processing unit calculating the aircraft's position from the TDOA of the signal at the different antennas.
- requires a minimum of four receiving stations to calculate an aircraft's position. If the aircraft's pressure altitude is known then the position may be resolved using three receiving stations.
- operational MLATs have many more receiving stations to ensure adequate coverage and performance.

More details on its operation on Doc 9924 Appendix L

MULTILATERATION

MLATs can be active and passive

- A passive system consists only of receivers
- An active system has one or more transmitting antennas in order to interrogate the aircraft's SSR transponder.
  - The main advantage: it is not dependent on other sources to trigger a transmission from an aircraft.
  - The main disadvantage: it generates additional interference on the 1 030 MHz and1 090 MHz channels.

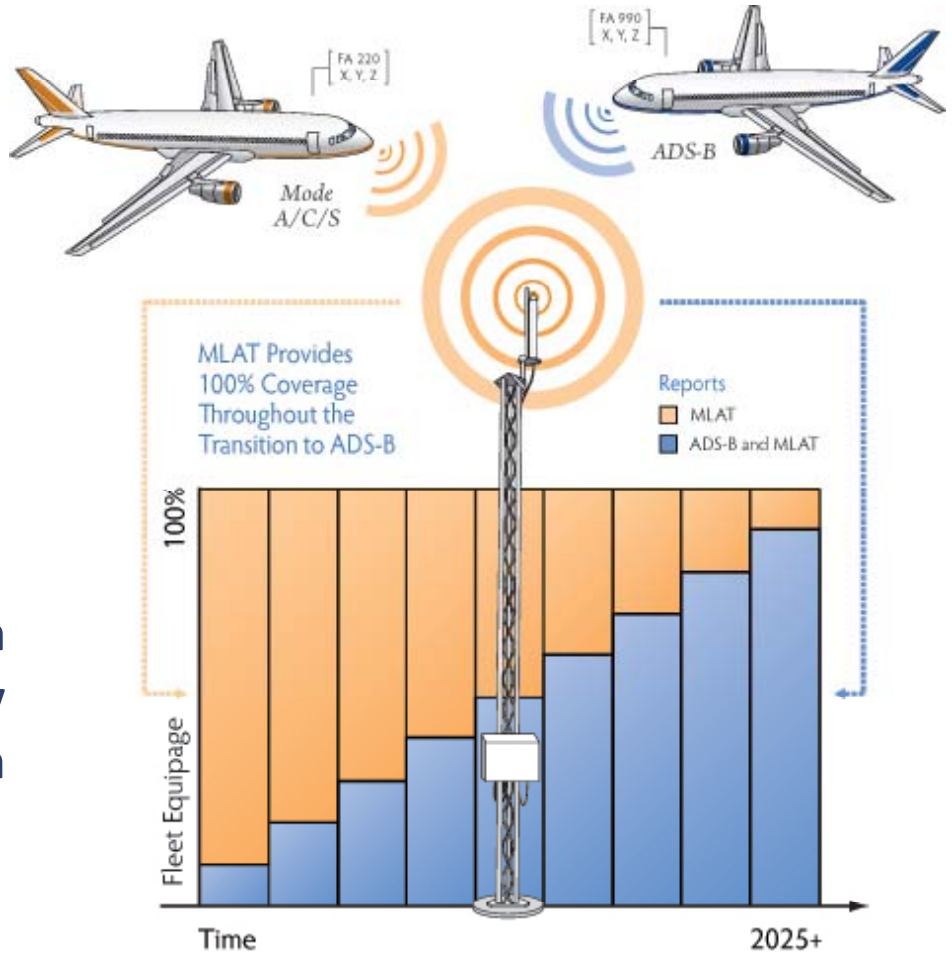
MULTILATERATION

- The accuracy of an MLAT is non-linear within the coverage volume, dependent on :
  - the geometry of the target in relation to the receiving stations
  - the accuracy to which the relative time of receipt of the signal at each station can be determined.
- needs a common time reference to determine the relative TOA of the signal at the receiving stations (time-stamped by a common clock or synchronism by a common reference such as GNSS)
- may include transmitting stations capable of interrogating aircraft transponders.
- Some systems also use the interrogations and subsequent replies to measure the range of the aircraft from the transmitting station in a similar manner to radar. This range measurement supplements the multilateration TDOA

MULTILATERATION

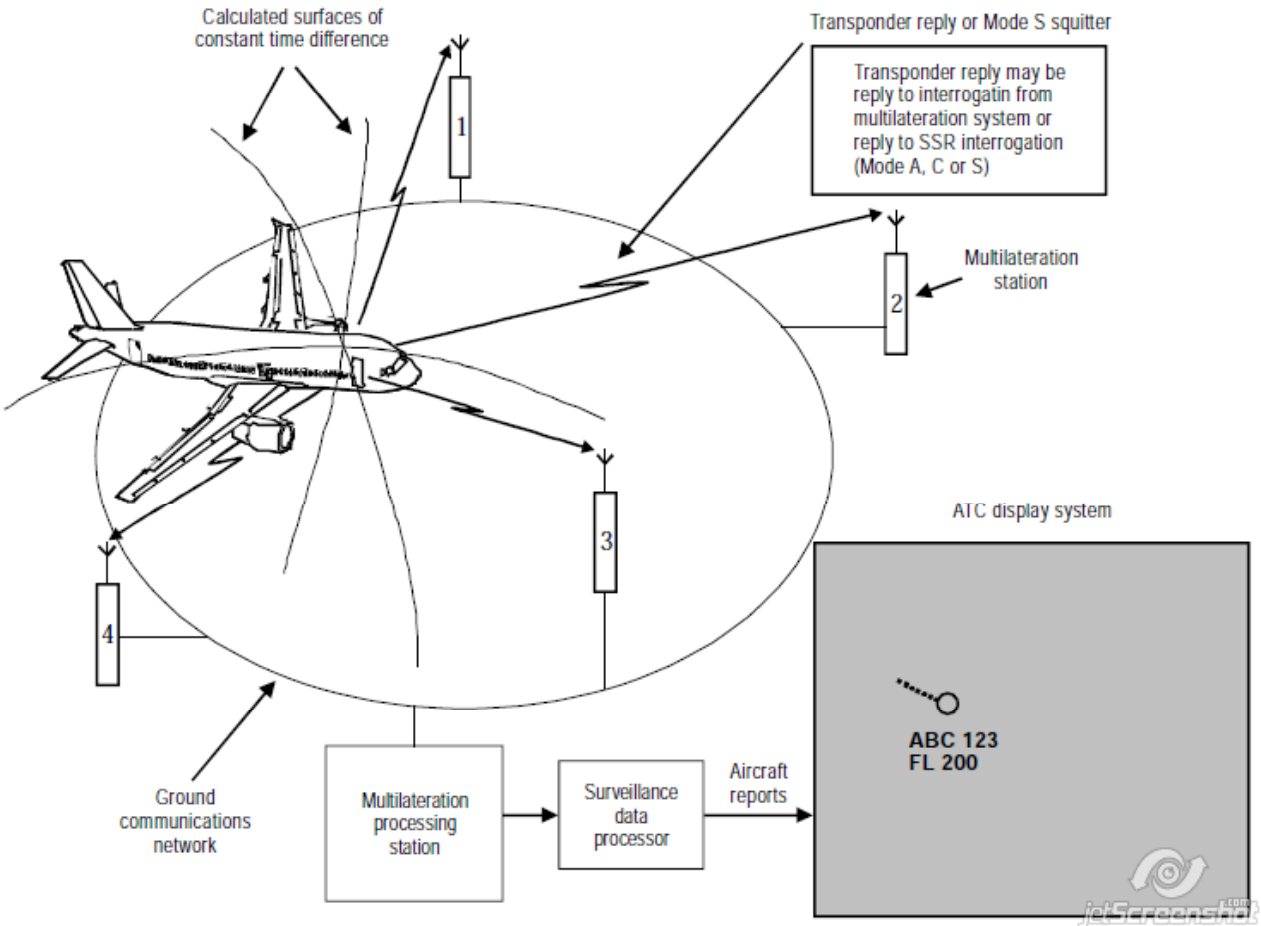
- can process ES signals in two ways:
  - a) by using TDOA, as with all other transponder signals; and
  - b) by decoding the message content to determine the aircraft's position (latitude and longitude), pressure altitude and velocity.

✓**provides a transition to an environment where the majority of aircraft will be equipped with ADS-B.**



MULTILATERATION

Multilateration may be used for airport surface, terminal area and en-route surveillance.



MULTILATERATION

CAPABILITIES OF MULTILATERATION

a) the use of any signals (Mode A/C, Mode S replies and squitters) transmitted by existing transponders without requiring additional aircraft equipage to locate aircraft;

b) Mode A/C, Mode S and ADS-B capabilities;

c) provision of coverage in difficult terrain. It is a modular system in that the coverage area may be extended by the addition of more stations, provided that the total number of stations remains within the processing capability of the system; and

d) provisions of high accuracy and high update rates. The system accuracy may also be controlled to some extent by the placement of the receiving stations.

MULTILATERATION

VALIDATION OF ADS-B PERFORMANCE

- WAM may be used to monitor the performance of ADS-B systems. There are a number of roles that multilateration could play, as follows:
  - a) *Verification of navigation accuracy. The ADS-B data can be checked against the multilateration data to* verify the track-keeping performance of the avionics;
  - b) *ADS-B integrity monitoring. WAM can be used to monitor the integrity of ADS-B as a surveillance* technique. This could be done to gather data for a safety case and to monitor the integrity of in-service systems. For example, a bias in one aircraft's position is a serious safety issue for ADS-B only surveillance, but a WAM system could identify this immediately;
  - c) *Anti-spoofing. ADS-B is vulnerable to spoofing. WAM systems can be used to identify genuine aircraft* and the source of spoof transmissions; and
  - d) *Migration path to ADS-B. WAM can provide ground-based surveillance similar to existing MSSR type* surveillance. In addition, each receiver can operate as a 1 090 ADS-B receiver providing surveillance for both ADS-B and non-ADS-B traffic.

MULTILATERATION

LIMITATIONS OF MULTILATERATION

a) aircraft have to be equipped with a functioning transponder;

b) Susceptible to multipath;

c) the transmitted signal has to be correctly detected at multiple receiving stations; and

d) communication links are needed between remote a receiver/transmitter sites and the master processing Station.

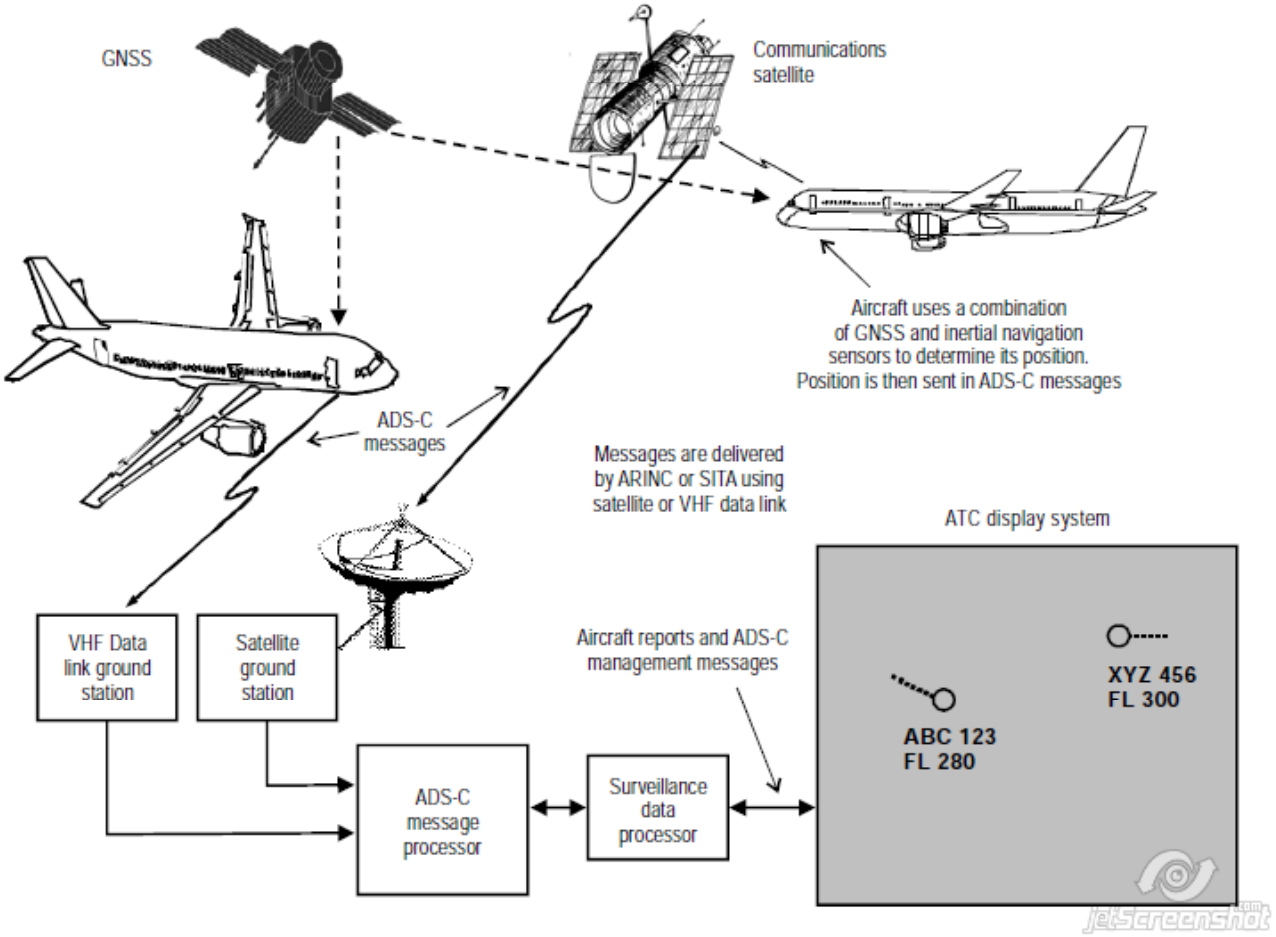
ADS-C

- the aircraft uses on-board navigation systems to determine its position, velocity and other data.
- A ground ATM system establishes a “contract” with the aircraft to report this information at regular intervals or when defined events occur. This information is transmitted on point-to-point data links.
- Information that may be transmitted in ADS-C reports includes:
  a. present position (latitude, longitude and altitude) plus time stamp and FOM;
  b. predicted route in terms of next and (next +1) waypoints;
  c. velocity (ground or air referenced); and
  d. meteorological data (wind speed, wind direction and temperature).

ADS-C

CAPABILITIES OF ADS-C

a) provision of surveillance in areas where the installation of radar or MLATs is not practical;
b) allows practical reporting of aircraft intent data (e.g. future waypoints); and
c) provision of a data link between the aircraft and ground



ADS-C

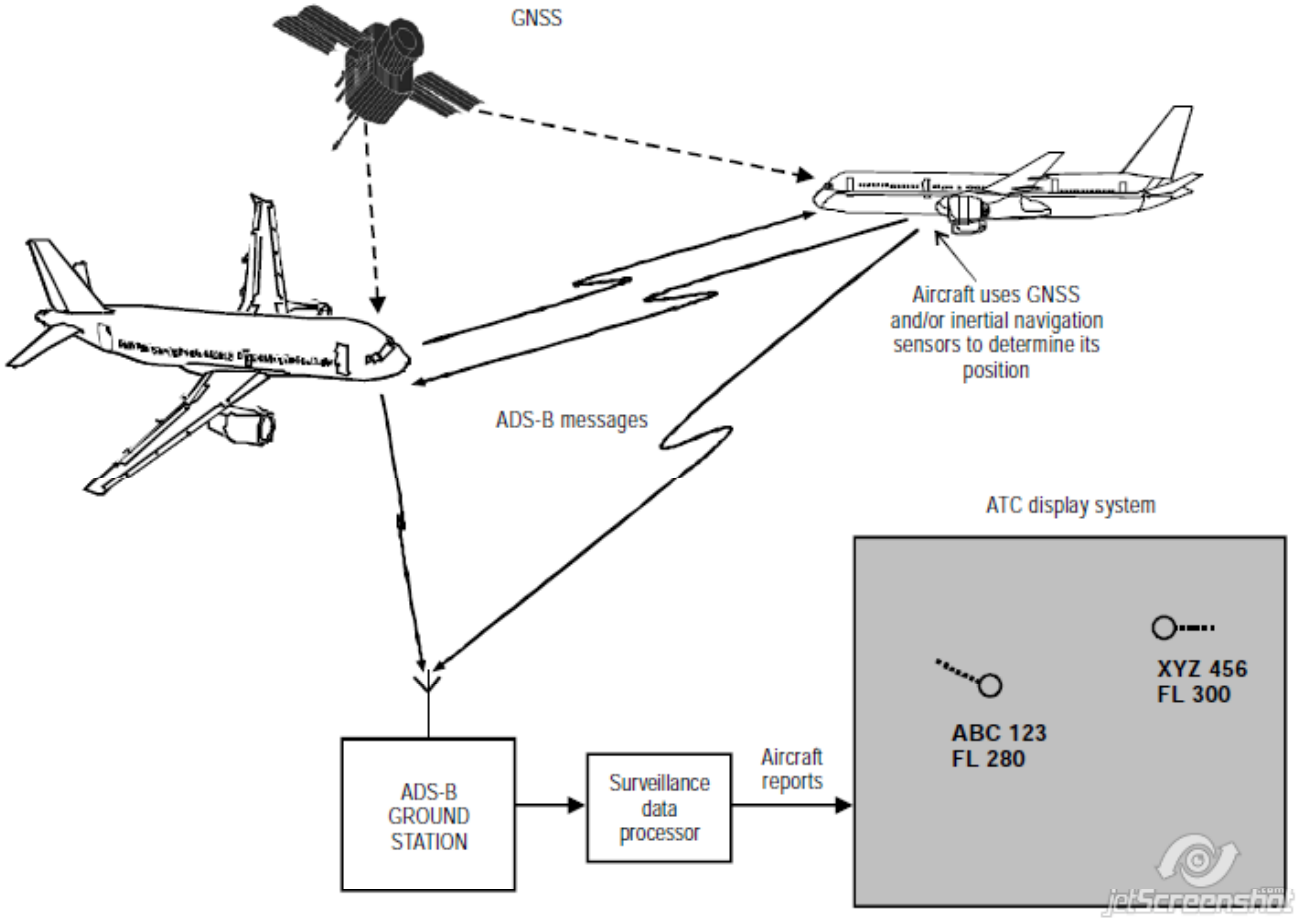
LIMITATIONS OF ADS-C:

- it is a dependent surveillance system, i.e. it relies on the aircraft being suitably equipped to correctly transmit the data;
- it requires the installation of additional avionics (for data communications): FANS 1/A or ATN;
- performance may be determined by the limitations of the communications media;
- a cost may be associated with the transmission of each report since the data is carried by a data link service provider; and
- it does not support ASA because the messages are not directly available to other aircraft.

ADS-B

ADS-B is the broadcast by an aircraft of its position (latitude and longitude), altitude, velocity, aircraft ID and other information obtained from on-board systems.

Every ADS-B position message includes an indication of the quality of the data which allows users to determine whether the data is good enough to support the intended function.



ADS-B

- Since ADS-B messages are broadcast, they can be received and processed by any suitable receiver.
- ADS-B supports both ground-based and airborne surveillance applications.
  - For aeronautical surveillance, ground stations are deployed to receive and process the ADS-B messages.
  - In airborne applications, aircraft equipped with ADSB receivers can process the messages from other aircraft to determine the location of surrounding traffic in support of applications such as the CDTI.

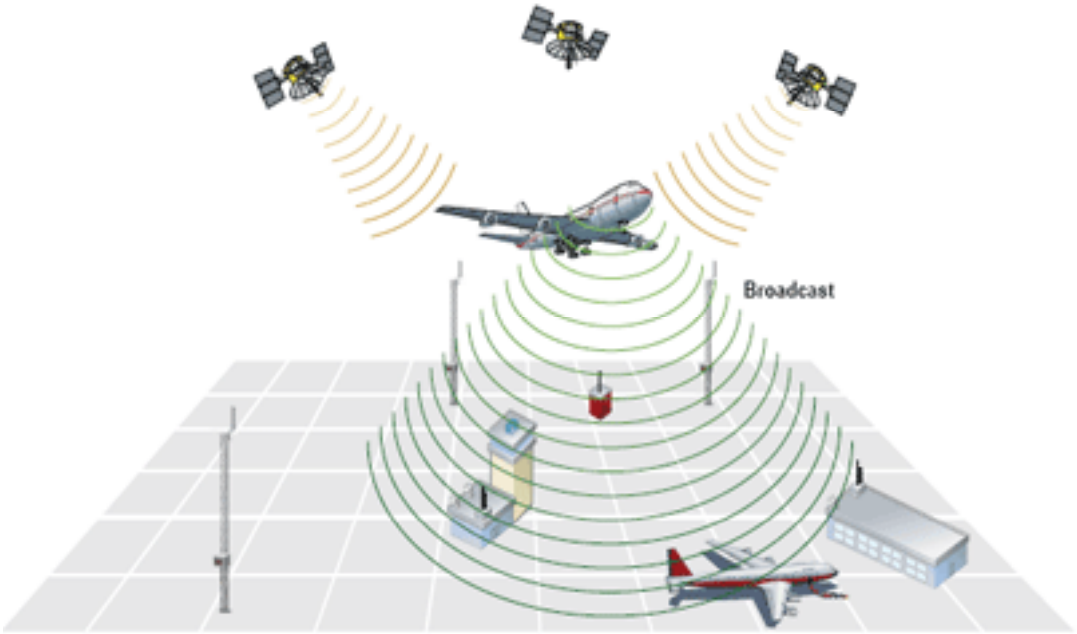
ADS-B

ADS-B OUT: A function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

ADS-B IN. A function that receives surveillance data from ADS-B OUT data sources.

Three ADS-B data links (or signal transmission systems) are available:

- Mode S 1090 ES
- UAT
- VDL Mode 4



ADS-B

CAPABILITIES OF ADS-B

a) the ground station is simpler than the stations of primary radar, secondary radar and multilateration.

- For a single ADS-B site, acquisition and installation costs are significantly lower. In many instances, the installation can be accommodated at navigation aid sites or sites such as VHF radios with existing infrastructure;

b) Immune to multipath;

c) each position report is transmitted with an indication of the integrity associated with the data, allowing users to determine which applications the data can support; and

d) supports both ground-based and airborne surveillance applications.

AIRBORNE SURVEILLANCE

- The evolution of the technology now allows the provision of surveillance capability and display of traffic on board aircraft, known as airborne surveillance.
- The capability to establish a complete air situation picture on board aircraft allows the development of new applications that are presently under development, for example:
  - a) merging and sequencing, which enables controllers to instruct flight crew to use their flight deck surveillance systems to follow another specified aircraft; and
  - b) the in-trail procedure, which enables an aircraft on oceanic routes to climb (or descend) through a flight level that would otherwise be blocked by the procedural separation minima and the proximity of other aircraft.

ADS-B

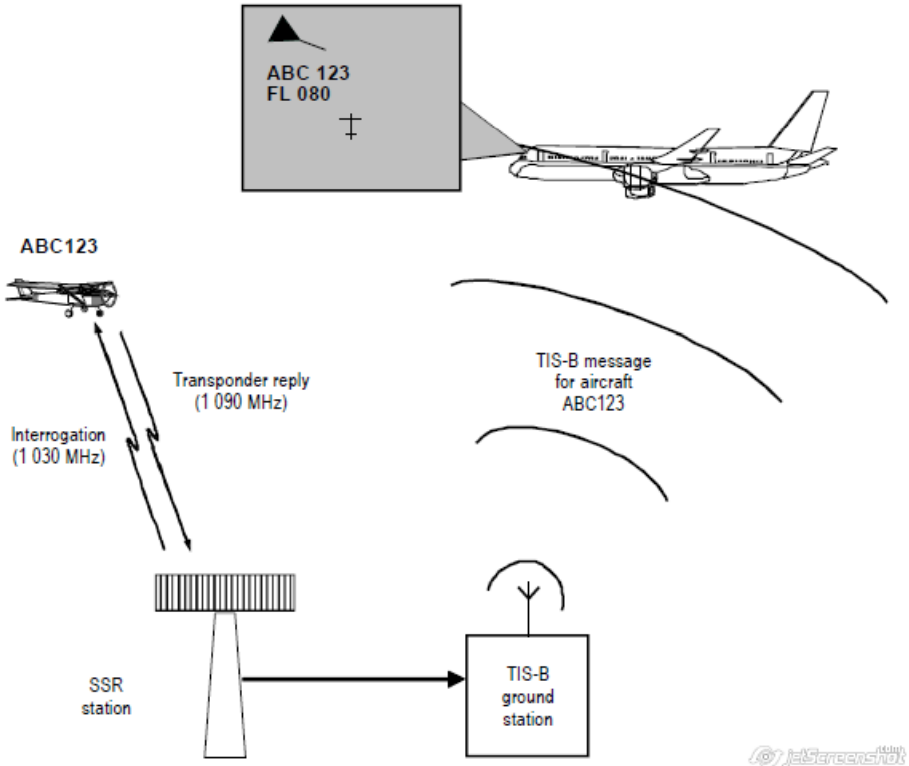
AIRBORNE SURVEILLANCE

- From the ADS-B IN function, the aircraft receives surveillance data transmitted by ADS-B OUT functions installed on other aircraft
- From the ground, the aircraft could also receive additional data from other aircraft not transmitting ADS-B OUT (TIS-B) or because their ADS-B OUT is transmitted using a different ADS-B technology (ADS-B rebroadcast: ADS-R).

ADS-B

AIRBORNE SURVEILLANCE

- TIS-B is the broadcast of aircraft surveillance data by ground stations using an ADS-B data link. -> improved situational awareness and support for ASA.
- TIS-B ground stations obtain aircraft surveillance data (SSR, MLATs).
- TIS-B provides service in an environment where not all aircraft are equipped with ADS-B. It provides visibility of non-ADS-B equipped aircraft to any aircraft capable of receiving the TIS-B message.



TIS-B messages are similar in format to ADS-B messages transmitted directly by aircraft.

ADS-B

AIRBORNE SURVEILLANCE

- ADS-R allows interoperability between ADS-B equipped aircraft operating on different data links.
- ADS-R ground station receives ADS-B messages from one link (e.g. UAT), processes the messages and rebroadcasts them on a different data link (e.g. 1 090 MHz ES).
- ICAO Docs 9861 and 9871 contain details of TIS-B and ADS-R.

AIRBORNE SURVEILLANCE

- ACAS interrogates Mode A/C and Mode S transponders on aircraft in its vicinity and listens for their replies. By processing these replies, ACAS determines which aircraft represent potential collision threats and provides appropriate indications (or advisories) to the flight crew to avoid collisions.
- Hybrid surveillance: allows ACAS to take advantage of information passively available from ADS-B OUT transmissions of suitably equipped extended aircraft:
  - At acquisition and periodically thereafter, ACAS validates the position and altitude contained in the ES with information received from its own active surveillance.
  - Aircraft whose position and altitude are validated can be maintained on passive surveillance, resulting in reduced ACAS interrogations.
  - Passive surveillance is only used on aircraft that are not considered to be a threat.
  - When an intruder approaches the conditions for a threat, ACAS switches to full active surveillance.
- *The Airborne Collision Avoidance System (ACAS) Manual (Doc 9863) contains a complete set of guidance material on ACAS.*

LIMITATIONS OF ADS-B

- a) it depends on proper equipage of all aircraft.
  - SIGNIFICANT ISSUE because a navigation source capable of supplying position/velocity information along with the necessary indication of accuracy/integrity of that information needs to be installed and certified;
- b) current implementations rely solely on GNSS for position and velocity.
  - SIGNIFICANT: Outages may be experienced when the performance or geometry of the satellite constellation is inadequate to support a given application.
  - Future systems that integrate GNSS information with data from other navigation sensors should overcome this limitation.
  - Also the advent of new constellations as GALILEO should improve GNSS performance
- c) provisions should be in place to validate the reported position.

ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

- ADS-B:
  - VDL Mode 4 : SARPs in Annex 10 Vol III
  - UAT: SARPs in Annex 10 Vol III
  - 1090 ES: Annex 10 Vol. IV Surveillance and Collision Avoidance Systems, Chapter 5.
    - version 0 and version 1 extended squitter ADS-B message formats are included in Doc 9871
    - Version 2 (being developed for 2012)
- MLAT: SARPs in Annex 10 Vol IV, Chapter 6. (Amendment 85, Nov. 2010)
- ADS-C:
  - SARPs in Annex 10 Vol III,
  - ATN SARPs and
  - related data link applications
  - FANS-1/A not done by ICAO

ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

- ✓ Manual on the SSR Systems (Doc 9684)
- ✓ Manual on Testing of Radio Navaids (Doc 8071), Vol III (Testing of Surveillance Radar Systems)
- ✓ Manual on Mode S Specific Services (Doc 9688)
- ✓ ACAS Manual (Doc 9863)
- ✓ Technical Provisions for Mode S Services and Extended Squitter (Doc 9871)

ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

- ✓ Manual on UAT (Doc 9861)
- ✓ Manual on VHF Digital Link (VDL) Mode 4. (Doc 9816)
- ✓ Manual of Air Traffic Services Data Link Applications (Doc 9694)
- ✓ Aeronautical Surveillance Manual (Doc 9924)

ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

- ✓ Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM) Chapters 6 and 8 (Doc 4444)
- ✓ Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) (Doc 8168)
- ✓ Manual of Surface Movement Guidance and Control Systems (SMGCS) (Doc 9476)
- ✓ Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual (Doc 9830)

ICAO References on ADS-B , MLAT, ADS-C and other surveillance techniques

European Organization for Civil Aviation Equipment (EUROCAE)

- EUROCAE ED-73C, *MOPS for Secondary Surveillance Radar Mode S Transponders.*
- EUROCAE ED-117, *MOPS for Mode S Multilateration Systems for Use in A-SMGCS.*
- EUROCAE ED-142, *Technical Specifications for Wide Area Multilateration System (WAM).*

RTCA

- RTCA/DO-181D, *Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*
- RTCA/DO-260, *Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance — Broadcast (ADS-B)*
- RTCA/DO-260A, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance — Broadcast (ADS-B) and Traffic Information Services — Broadcast (TIS-B)*

Thank you

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