INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

GUIDANCE MATERIAL ON
PROCESSING AND DISPLAY OF ADS-B DATA
AT AIR TRAFFIC CONTROLLER POSITIONS

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PROCESSING AND DISPLAY OF ADS-B DATA

1 Introduction

A wide variety of ATC systems will process and display ADS-B data. The displays can be simple PC based standalone systems or sophisticated automation systems. The displays could support enroute, terminal, tower ATC.

This document considers the ATC display component of the ATC system only – and will ignore the sensor capabilities.

2 The need for ATC Surveillance

Surveillance plays an important role in Air Traffic Control (ATC). The ability to accurately and reliably determine the location of aircraft has a direct influence on the separation distances required between aircraft (i.e. separation standards), and therefore on how efficiently a given airspace may be utilised.

In areas without electronic surveillance, where ATC is reliant on pilots to report their position (either by voice or CPDLC),, aircraft have to be separated by relatively large distances to account for the uncertainty in the estimated position of aircraft and the timeliness of the information.

Conversely in terminal areas where accurate and reliable surveillance systems are used and aircraft positions are updated more frequently, the airspace or airport surface can be used more efficiently to safely accommodate a higher density of aircraft. It also allows aircraft vectoring for efficiency, capacity and safety reasons.

ATC surveillance serves to close the gap between ATC expectations of aircraft movements based on clearances or instructions issued to pilots, and the actual trajectories of these aircraft. In this way it indicates to ATC when expectations are not matched, providing an important safety function. Surveillance provides “blunder” detection.

The demand for increased flexibility to airspace users by reducing restrictions associated with flying along fixed routes requires improved navigation capability on board the aircraft. Equally, accurate surveillance is required to assist in the detection and resolution of any potential conflicts associated with the flexible use of the airspace which is likely to result in a more dynamic environment.

Accurate surveillance can be used as the basis of automated alerting systems. The ability to actively track aircraft enables ATC to be alerted when an aircraft is detected to deviate from its assigned altitude or route, or when the predicted future positions of two or more aircraft conflict. It also supports minimum safe altitude warnings, danger area warnings and other similar alerts.

Surveillance is used to update flight plans, improving estimates at future waypoints and also removing the workload for pilots in providing voice reports on reaching waypoints.

3 General Requirements of an Air - Ground Surveillance System

The most basic function of a surveillance system is to periodically provide an accurate estimate of the position, altitude and identity of aircraft. PANS ATM Section 8.2 SITUATION DISPLAY provides further details.

Depending on the ATC application that a surveillance system is intended to support, there will be other requirements of the system.

A surveillance system may be characterised in terms of the parameters listed below:

1. Coverage volume – the volume of airspace in which the system operates to specification.
2. Accuracy – a measure of the difference between the estimated and true position of an aircraft.
3. Integrity – an indication that the aircraft's estimated position is within a stated containment volume of its true position. Integrity includes the concept of an alarm being generated if this ceases to be the case, within a defined time to alarm. Integrity can be used to indicate whether the system is operating normally.
4. Update rate – the rate at which the aircraft's position on the ATC display is updated.
5. Reliability – the probability that the system will continue operating to specification within a defined period. Sometimes this is called continuity.
6. Availability – the percentage of the total operating time during which the system is performing to specification.

Other issues which need to be considered when designing a surveillance system for ATC are:

1. The ability to uniquely identify targets.
2. The impact of the loss of surveillance of individual aircraft both in the short (few seconds) and long term
3. The impact of the loss of surveillance over an extended area.
4. Backup or emergency procedures to be applied in the event of aircraft or ground system failure.
5. The ability to operate to specification with the expected traffic density.
6. The ability to operate in harmony with other systems such as the Airborne Collision Avoidance Systems (ACAS) and Airborne Separation Assistance Systems (ASAS).
7. The ability to obtain Aircraft Derived Data (ADD).
8. The interaction between communication, navigation, and surveillance functions.

4 The ADS-B display is One Part of a Surveillance System

Whilst this paper concentrates on ADS-B display, this is just one part of an overall system that provides data for use in ATC. A complete system includes:

- Position and altitude sensors. Some of these sensors may be ground based (e.g. radars) or may be airborne (e.g. altitude sensors). Datalinks are used to transmit data from airborne sensors to the ground,
    - The Fundamental Data provided to the air traffic controller is aircraft position, aircraft identity and altitude. Further information such as aircraft direction, speed, the rate of climb may also be provided.
- A system to transmit the data from the reception point on the ground to the ATC centre,
- A display system or ATC automation system
    - Data from a sensor system may be presented on a standalone display or combined with data from other sensor(s) and/or other data in an automation system and then presented on a plan view situation display.
    - The situation display provides Air Traffic Controllers with plan view of the position of aircraft relative to each other and to routes, waypoints and geographic features. Suitable maps are required on ATC displays. Such displays support controllers in providing Separation and other services to aircraft.
    - Automation systems may use surveillance data to implement automated safety net functions such as Route Adherence Monitoring, Cleared Level Alarm, Conflict Alert, Lowest Safe Altitude and Danger Area Infringement Warning. These facilities increase overall safety.
    - Appropriate Surveillance system monitoring /alerting – eg parrots & site monitors
- Suitably trained air traffic controllers, aircrew and
- Suitable standards and procedures to use the system including separation minima
    - ICAO PANS-ATM (Doc.4444, Chapter 8) details radar separation minima of five 5 NM and 3 NM. These minima allow for a considerable increase in airspace utilisation compared to procedural control. Changes to ICAO documents were published in 2007 recognising ADS-B use to support 5 NM separation standards. ICAO's Separation & Airspace Safety Panel (SASP) is working on proposals to allow 3 NM separation standards using ADS-B.
    - Due to the low update rate, ACARS based ADS-C surveillance is unlikely to ever support 3 NM and 5 NM separation standards. However it is used to support 30/30 and 50/50 NM procedures used in some regions. ATN and VDL2 based ADS-C may reduce the achievable separation standards in some regions.

5 Essential Display System Requirements

The following display system processing is considered the minimum necessary for any display to ATC :

5.1 Filtering data which has inadequate positional quality.

It is essential that data which does not meet the required quality standards be filtered so that misleading data is not displayed to ATC. Typically this will involve testing the Figure of Merit (FOM) in Asterix Cat 21 [1]messages.

5.2 Filtering data from aircraft known to have poor avionics.

ADS-B data transmitted from some avionics is not suitable for operational use[2]. Usually there are State regulations that prohibit ADS-B data transmissions not complying with the standards. However, sometimes such aircraft are still detected. The overall system needs to have a mechanism to protect ATC from misleading data from such aircraft. A database and/or ATC supervisor function could also be used to temporarily or permanently disable ADS-B data from particular aircraft with defined 24 bit codes.

5.3 Process multiple reports from same aircraft

ADS-B data is derived in the aircraft. Therefore messages received at separate ground stations will (assuming no signal loss) be identical. No fusion, merging or weighting of positional data is needed because the most recent data is the most valuable. As a result it is necessary to ignore ADS-B positional data which is received with a time stamp earlier than other positional data from the same aircraft. A single position symbol should be presented to the controller. Other data associated with report from ground station may or may not be useful.

5.4 Display of positional data

Positional data provided by ADS-B is expressed in latitude and longitude, referenced to WGS84. This data must be accurately mapped onto the display system so that it registers correctly with maps and other sensor data.

5.5 Adjustment of positional data based on time of applicability

The processing of positional data must also correct the positional data to allow for aircraft movement between the time of applicability of the data and the display time. The system should ignore data

[1] Asterix Category 21 messages are the internationally accepted means of transmission of data from ADS-B systems to ATC automation systems. The FOM data in the Asterix messages is usually derived from ADS-B quality parameters including NUC or NIC,NAC,SIL.

[2] Eg: Some transponder models can transmit intermittent or incorrect data, some transmit integrity data based on HFOM, some avionics have faults.

when the time of applicability is too far in the past[3]. Typically the ADS-B velocity vector is used, however the velocity vector can be calculated by the ATC system. Additionally, the system must allow for 'coasting' of the track in the event of missed reports to minimise occurrences of 'dropped' or 'jumping' tracks.

5.6 Positional data reasonableness checking

Reasonableness checking of ADS-B position data to detect and reject invalid position jumps is also required. Some avionics occasionally transmit incorrect (~300 NM in error) positional data for one or two reports. These misleading reports should be discarded.

5.7 Display of altitude data

Barometric altitude data must be processed in the same way as SSR mode C data. It can be displayed as a flight level or, when below the transition level/altitude, it should be QNH corrected.

5.8 Display of Flight ID

Flight ID should be unambiguously displayed to ATC. This may be based upon the received Flight ID or may be based upon Flight Plan data that has been appropriately correlated with the ADS-B data.. FlightID is received less frequently by the ground station and the ATC system may need to implement a timeout system to "coast" FlightID for a parameter time.

5.9 Emergency alerts

The display system should appropriately alert ATC when emergency situations are flagged in ADS-B messages.

5.10 ADS-B failure indication

The display system should appropriately alert ATC when ADS-B data is not available.

5.11 Velocity vector

It is highly desirable that the display system is able to use and display ADS-B velocity vectors graphically. These can be derived from the ADS-B messages (preferred) or calculated by the display system itself.

6 Display of ADS-B and radar/multilat.

When ADS-B is to be displayed with radar or multilateration[4], a number of issues need to be considered as follows : An example of one State's display of ADS-B data is shown in Appendix B.

A	Is ATC to be made aware that a particular position report is ADS-B	It is useful for ATC to know that data is based on ADS-B. This allows ATC to be aware of susceptibility to failure modes

[3] This can protect against ADS-B ground stations incorrectly time tagging data : eg : using GPS time instead of UTC time at GPS engine startup.

[4] Multilateration can be considered to be "radar like" because the positional data is not dependent on aircraft position determination.

	based?	relevant to the technology (such as RAIM outage) or airborne avionics failure. Eg: The aircraft crew can be asked to switch to an alternate GPS if the failure is due to GPS avionics failure.
B	Is ATC to be made aware that ADS-B data is being received from an aircraft under radar/multilat surveillance?	It is useful for ATC to know that ADS-B data is being received from an individual aircraft before it leaves radar coverage. Unexpected loss of surveillance data at edge of radar coverage could result in a separation breakdown. Confirmation of continued surveillance allows the use of more efficient separation standards.
C	When ADS-B and radar/multilat data is received from the one aircraft, is the positional data from radar and ADS-B to be "fused" (eg: using a Kalman filter) or does radar/multilat or ADS-B have priority?	Some states have used a priority system whereby ADS-B is only displayed to controllers when there is no radar detection. This has been useful for a gradual transition to ADS-B. A "fusion" system takes value from high quality ADS-B position, velocity data and update rate. Fusion allows the positional and other "aircraft state" data to be presented to controllers as truly merged/ fused data taking into account the relative strengths and weaknesses of the various surveillance technologies. "Fusion" needs to use a number of criteria to ensure that the items being fused relate to the same aircraft. These criteria could include position, velocity, 24 bit ICAO code, FlightID (transmitted callsign), altitude, Mode A code if available, whether the tracks are coupled to the same flight plan.
D	If displayed separately, is the radar/multilat data and ADS-B time synchronized for display	ADS-B data can be extrapolated to the time of display of nearby aircraft detected by radar or multilateration. Equally radar/multilat data can be extrapolated to the time of display of nearby aircraft supported by ADS-B data, or both can be extrapolated till time of display (asynchronous from either radar/multilat or ADS-B reports)
E	Do the safety alerts work appropriately for ADS-B only, radar/multilat only and targets with both radar/multilat and ADS-B?	It is desirable that safety nets work in all situations.
F	Is a Flight Plan indicator for ADS-B equipage used.	It is desirable for ATC to know whether the aircraft is ADS-B capable before the aircraft enters ADS-B coverage. This assists with strategic planning performed by the controller.

7 Other Display System Requirements

A large number of optional ADS-B processing capabilities/functions can be deployed. These are listed in Appendix A. States should consider whether the listed functionality is required in their environment.

8 Processing ADS-B like radar data

ADS-B has several characteristics that make it desirable for it to be treated differently from radar:

However, in some cases, States may wish to minimize ATC system modification and prefer to feed ADS-B to the display system as if it were a radar. This is possible but has some disadvantages shown below that need to be considered and managed. In most cases performance can be expected to be no worse than existing radars. Rather, such a system will simply fail to take full advantage of all the ADS-B performance benefits available.

A	ADS-B accuracy and update rate may be degraded if treated as a radar	Existing ATC systems may quantize the data in relatively coarse steps degrading the data. Extrapolation of ADS-B so that it is reported in a radar azimuth order may also degrade performance. Existing ATC systems may not support high update rate "radar feeds" containing ADS-B data.
B	ADS-B has very different error characteristics compared to radar.	This may have an impact on tracking, but probably no worse than existing radar.
C	ADS-B has different failure modes and the controller needs to be aware that the data is ADS-B derived – and hence susceptible to GPS outage effects. Existing ATC system may display ADS-B using same symbology as a radar.	If there is a predicted GPS RAIM[5] outage, the controller will need to know which targets may be affected. Equally, ADS-B is likely to be available during a period of radar down-time.
D	ADS-B data transmission usually begins whilst the aircraft is on the airport surface, whereas radar transmission usually start after takeoff.	Processing may be required to remove aircraft on airport surface. This can be done in the ground station or the ATC system.
E	Different emergency alert flags are	If radar message formats are used, it may not be

[5] Receiver Autonomous Integrity Monitoring (RAIM) confirms the ongoing integrity of ADS-B data derived from GPS. In some circumstances the integrity may not be able to be confirmed to the desired level. RAIM prediction systems can predict when such loss of integrity may occur, based on GPS geometry and GPS maintenance notifications (NANUs).

	possible compared to radar	possible to convey all desired emergency alerts to the controller
F	Flight ID and 24 bit code are available for matching report-to-report and report-to-flight plan. These fields are available from ADS-B and Mode S radars for Mode S transponders, but are otherwise not available.	Some radar processing systems are unable to manage the processing and display of FlightID or 24 bit code received from the “radar”.
G	4 digit SSR octal code may not be available from ADS-B transmissions. In this case, consideration is required of how the ATC system will match ADS-B data to the flight plan	Some radar processing systems rely on Mode A code for tracking or for matching the target to a flight plan. Mode A code may not be available from DO260 ADS-B avionics.

APPENDIX A

POSSIBLE ATC AUTOMATION ADS-B FEATURES

	Feature	Description	Comment
DISPLAY	Allow “coasting” so that low quality ADS-B data is useable for a limited time.	Technique to allow “coasting” through short GPS geometry ADS-B outages	Increased reliability/continuity
	Display different position symbol when ADS-B comes from a source without adequate communications reliability for 5 NM separation.	Indicate to controller that ATC separation is not possible with this lower quality ADS-B data	Optional use of lower quality symbol
	RAIM display	Consider if a RAIM prediction system is required to indicate to controllers or supervisor possible GPS outages in particular airspace	Optional warning to ATC regarding GPS constellation status
	Indicate failure of ADS-B receiver to technical or operational staff		Typically this will involve site monitor processing
	Delete reports for aircraft “on ground”	If ATC does not desire to “see” traffic still on airport surface	
	Option to display 24 bit code	Eg: if no flight ID is available or to resolve matching problems. Possibly display mode A code if available.	
	Update ATC simulator to support ADS-B	ADS-B training must include ability to manage ADS-B events such as loss of GPS	
	Indicate to a controller that an aircraft is being detected by ADS-B whilst inside radar coverage	Advise controller that if the displayed aircraft leaves radar coverage, surveillance will continue with ADS-B (whereas non equipped aircraft will leave surveillance coverage)	Aircraft could be non ADS-B because it is not equipped, or because it is not within the ADS-B coverage area. This processing could be considered unnecessary by some states especially if an ADS-B mandate exists.

	Feature	Description	Comment
	Decide if and how to use geometric altitude	Possible use of geometric altitude if baro is not available. Possible use for checking QNH value is correct?	
	Decide if and how to use barometric altitude in geographic areas without QNH sensors	Possible altitude filtering in these areas to prevent display of misleading altitude	
PROCESS	Ability to process all appropriate fields of ADS-B Asterix Cat 21 V0.23	Process appropriately position, velocity, Flight ID, 24 bit code, geo and baro altitude, SPI, emergency indicators, FOM etc	
	Protect or warn against Duplicate 24 bit codes within airspace. Eg: From different ground stations		Possibility exists of 2 aircraft on same 24 bit code
	Protect and manage against invalid 24 bit codes		Possibility exists of receiving invalid 24 bit codes
	Black list processing :Remove selected aircraft (24 bit codes) if these airframes are known to transmit inadequate ADS-B data.		Can be used in environments where the regulatory process required all transmitters to be compliant to the standards
	White list processing :Remove all aircraft except selected aircraft (24 bit codes) which are known to transmit adequate ADS-B data.		Useful when there is uncertainty about the ADS-B avionics in the fleet.
	Allow manual uncoupling of ADS-B report and flight plan	In case of erroneous coupling allow controller to detach so that ADS-B data does not update flight plan	
	Allow manual coupling if ADS-B report and flight plan	In cases where for various reasons automatic coupling does not occur.	
	Allow for QNH correction of ADS-B data below transition level/altitude	Normal QNH processing but applied to ADS-B	

	Feature	Description	Comment
	Vertical rate smoothing	Vertical rate data from ADS-B can be “noisy” and may need smoothing for some applications, especially for vertical velocity prediction for safety alerts. Need to consider geo and baro vertical rates.	
	ADS-B data to update flight plan		
	ADS-B data to match to flight plan using Flight ID in ADS-B message to Flight ID of flight plan. May also use 24 bit code if the 24 bit code is in the flight plan.	Direct matching to FlightID, perhaps using other criteria to reduce risk of false matching.	
	Support appropriate safety nets	STCA, RAM, CLAM, DAIW,….	
	Support flight plan indicators that advise of ADS-B equipage	Advises equipage but does not confirm that it is working!	
	Ensure playing area accounts for new coverage	New coverage may be provided by ADS-B	
	ADS-B bypass processing	Provide for ADS-B bypass channel if required	Consider flight plan matching, QNH correction, extrapolation, FOM filtering etc
	Recording and replay of ADS-B data	Same as for radar but processing required for ADS-B	
	Allow for visibility of ADS-B ground transmissions	Matching to flight plan may occur before departure because ADS-B data may be received whilst taxiing	Aircraft transmit ADS-B messages whilst taxiing. These messages can be received and processed.
	Site monitor processing	An integrity monitoring tool and fault detection tool	Monitor position, signal strength, HPL, GPS satellite ranging errors….

OTHER POSSIBLE ADS-B FEATURES

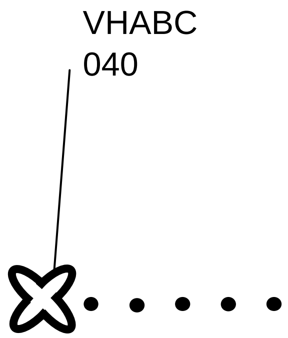
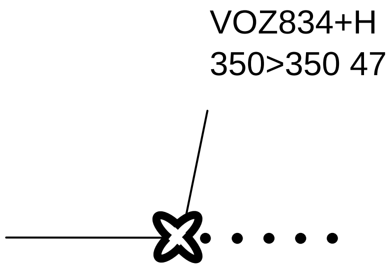
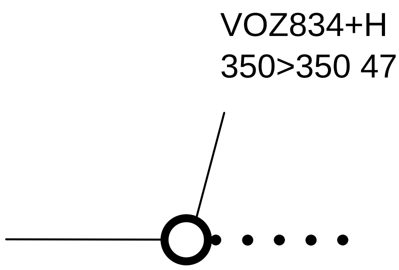
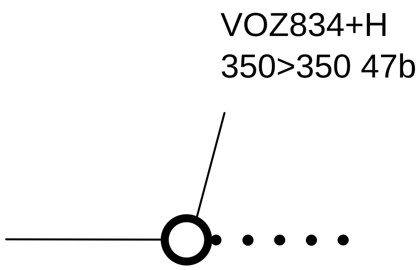
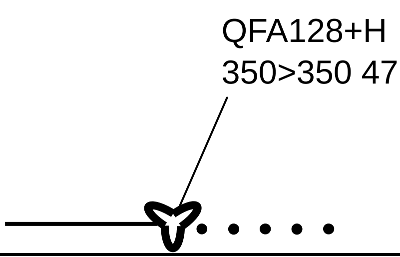
Feature	Description	Comment
Capability to manually disable display of ADS-B returns from a	Allow data to be discarded from a designated aircraft.	Could be useful in the unlikely event of erroneous data from an

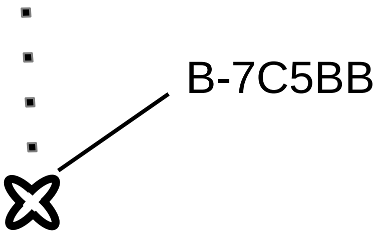
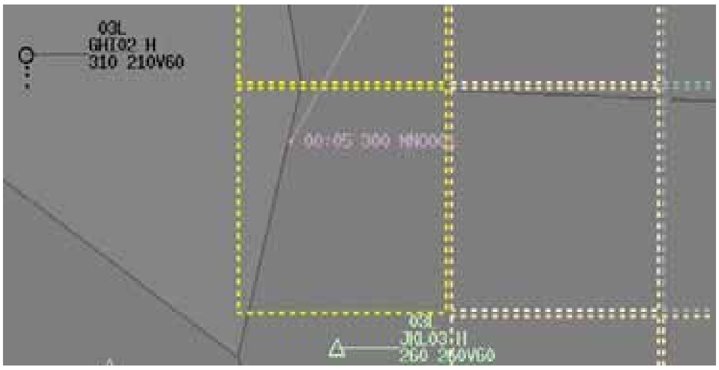
Feature	Description	Comment
particular target		aircraft
Display of new alerts (if used)	Lifeguard / medical and Minimum fuel. Also future “selected altitude” mismatch with Cleared flight level alert.	
Display of ACAS RA events		A downlink message has been defined in ICAO Doc 9871
Alert controllers to significant difference between ADS-B and other surveillance source		
RVSM Monitoring	Provide RVSM validation based on comparison of Geometric (GPS) altitude data and Barometric ADS-B data.	The capability to perform RVSM monitoring using ADS-B is not yet confirmed – however confirmation is currently expected by 2012.

APPENDIX B

ADS-B Display employed by one state

The following shows the ADS-B symbology used by Australia in 2010.

ADS-B track NOT matched to Flight Plan. Includes FlightID (from ADS-B transmission) and Altitude	
ADS-B track matched to Flight Plan	
Radar track – no ADS-B from this aircraft)	
Radar track – ADS-B being detected from this aircraft ("b" included in label – this is only displayed when the ADS-B data is of sufficient quality to allow its use for separation)	
ADS-B track – data from low reliability site – not suitable for 5 NM separation	

ADS-B track optional 24 bit code display "B-" indicates that 24 bit code expressed in hex follows	
ADS-B site monitor display on technical & supervisor display only.	
RAIM Prediction Display Dashed lines indicate areas of predicted RAIM outage in next 10 and 30 minutes. Radar and ADS-C tracks shown	

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