ADS-B Introduction / Tutorial

APANPIRG ADS-B TASK FORCE SEMINAR
Nadi, Fiji

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Introduction & Overview

• Dependent Surveillance concepts
• Some benefits
• HOW ADS-B works
• ADS-B Links & ICAO
• Details of ModeS & ADS-B
• ADS-B fitment
• Synergy with multilateration
• Regional ADS-B plans
• Discussion
Procedural ATC
(Dependent “Surveillance”)

• Pilots report their position
  – Using a voice channel (HF, VHF)
  – Slow, cumbersome
  – Exposed to human error
  – Broadcast: Everyone “on frequency” hears it

• Procedures and standards maintain safety

• A form of dependant surveillance
  – We rely on the pilot/aircraft navigation capability
Primary Radar Surveillance
(Independent)

- Radar measures position of aircraft
  - in range & azimuth

- Moderate update, accurate
  - Allows smaller separation stds

- Detects **non co-operative** targets

- Typically used in busy terminal areas
Secondary Radar Surveillance (Co-operative)

• Radar measures position of aircraft
  – in range & azimuth
  – but relies on cooperation of aircraft to reply

• High update, more accurate

• Allows addition of Safety alerts

• Depends on transponder to downlink altitude
  – Altitude data is “dependent” surveillance
  – datalink has no error check

• “SSR only” typically used enroute
Automatic Dependent Surveillance

The aircraft measures its own position

- **Automatic**
  - no pilot input required
  - No interrogation from ground

- **Dependent**
  - extremely accurate position and velocity vector from aircraft (e.g. GPS)

- **Surveillance**
  - aircraft position, altitude, velocity vector, + . . .
ADS-C (Contract)

- FANS1/A Equipment in “big” aircraft
  - Expensive avionics

- Uses satellite and VHF datalinks

- Provides automatic, accurate routine reports
  - Slow update rate ~ in minutes (eg: every 14 minutes)
  - Allows exception reporting & supports safety alerts
  - Reports are invisible to other aircraft

- ATC system defines update message rate
Typically broadcast 2/second

- Provides automatic, accurate routine reports
  - High update rate ~ (eg: every 0.5 seconds)
  - Reports are visible to other aircraft
- Rate determined by avionics
- Line of sight coverage
  - No satellite
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Benefits of Surveillance

• Safety
  – ATC situational awareness
  – ATC safety nets
  – SAR
  – FIR boundary safety

• Operational flexibility benefit
  – Higher air traffic throughput
  – Higher Probability of clearance requests
  – Optimum route/ level
  – Strategic enabler for User preferred route
  – Efficiency – smaller separation standards

• Operational control/ fleet management
ADS-B Benefits

Radar-like separation standards will apply

Procedural separation

Procedural separation

Procedural separation
ADS-B Benefits

Radar-like separation standards will apply

ADS-B equipped aircraft will be subject to reduced separation standards, allowing more aircraft to operate at optimum levels.
ADS-B Potential Benefits

- Oceanic Surveillance
- Replace radar
- ATC in non-radar environment
- Surface surveillance runway incursion avoidance
- Collaborative decision making
- Ramp Management
- Sustain Visual Runway capacities
- Enhances pilot situational awareness

Collision Avoidance

© Airservices Australia
At a low price compared to radar

ADS-B ground stations are simple and economical

**Cost Comparison**

**ADS-B**  
~ $100K-$400K USD

**RADAR**  
~ $1M - $4M USD

- Maintenance
- Power
- Site space
- Building
- Road
- Environmental
- Rotating machinery
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How ADS-B Works

An aircraft with ADS-B capability determines its position using GPS.
How ADS-B Works

An aircraft with ADS-B capability determines its position using GPS.

The Mode S transponder then broadcasts that position at rapid intervals, along with identity, altitude and velocity information.

Dedicated ADS-B ground stations can receive the broadcasts and relay the information to air traffic control for precise tracking of the aircraft.

Other proximate aircraft can also receive the broadcasts.
Typically two broadcasts / second

ADS-B “OUT”

POSITION, ALTITUDE, IDENTITY(CALLSIGN), VELOCITY VECTOR, VERTICAL RATE

Air-Ground Surveillance

ADS-B Ground Station
ADS-B "IN"

Transmissions defined in ICAO standards

Enhanced “See & Avoid” Air-Air Surveillance

Traffic Displayed on MFD or PDA
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ADS-B Functions

APPLICATIONS supported by ADS-B

<table>
<thead>
<tr>
<th>ADS-B core applications</th>
<th>Optional/Ancillary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATC Surveillance</strong></td>
<td></td>
</tr>
<tr>
<td>- Separation</td>
<td>- TIS (Traffic Info Service)</td>
</tr>
<tr>
<td>- Safety nets</td>
<td>- FIS (Flight info service)</td>
</tr>
<tr>
<td>- Traffic info</td>
<td></td>
</tr>
<tr>
<td>Airborne surveillance</td>
<td></td>
</tr>
<tr>
<td>- Cockpit display (CDTI)</td>
<td></td>
</tr>
<tr>
<td>- In trail climb</td>
<td></td>
</tr>
<tr>
<td>- Delegated separation</td>
<td></td>
</tr>
</tbody>
</table>

International “standardised” DATALINKS

<table>
<thead>
<tr>
<th>VDL Mode 4</th>
<th>ModeS</th>
<th>UAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDL Mode 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1090 Mhz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended Squitter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ground systems
Worldwide Consensus to use 1090ES datalink as initial link

• Has allowed Industry and ATC providers to invest
  – At last!
  – End of prolonged link decision debate is extremely welcome to our customers because they can start to get benefits
  – Airlines ARE equipping
Anc11 Support Mode S for near term

AN-Conf/11-WP/202

7-12 Report on Agenda Item 7

7.4.5.5 On the basis of the above considerations with regard to potential near term ADS-B solutions, the meeting formulated the following Recommendation:

**Recommendation 7/1 — Strategy for the near-term introduction of ADS-B**

That States:

a) note that a common element in most of the approaches currently adopted for early implementation of ADS-B is the selection of the SSR Mode S extended squitter as the initial data link; and

b) take into account this common element to the extent possible in their national and regional implementation choices in order to facilitate global interoperability for the initial introduction of ADS-B.
Worldwide ADS-B link status

- FAA has chosen Mode S for Air Transport aircraft and UAT for “low end GA”

- Eurocontrol has supported Mode S as the interoperable link for the near term. Europe expects an additional link to be required.

- Eurocontrol and FAA are co-operating in Requirements Focus Group (RFG) developing application descriptions and other documentation.
  - Independent of link
  - Expectation is to deliver this to ICAO
ICAO PANELS

• OPLINK:
  – Has developed an ADS-B Conops - Endorsed by ANC11
  – Has developed PANS ATM changes

• SASP: Is developing 5Nm Separation standards

• SCRSP: Continues to refine ModeS standards

• ACP: Has defined VDL Mode4 and is developing UAT standards
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SSR background

AIRCRAFT

1030 Receiver

1030Mhz Interrogations 3 pulses (P1,P2,P3)

ModeA, C interrogations

1090 Transmitter

1090Mhz reply messages 12 pulses (no error detection)

ModeA, C replies
MODE S background

1030 Receiver

ModeA, C interrogations
1030Mhz register requests (phase encoded messages)

ModeA, C replies
1090Mhz reply messages (pulse position modulated with error detection)

1090 Transmitter

Readout: “Registers”
TCAS background

1030 Receiver

1030Mhz Interrogations 3 pulses

1030Mhz register requests (phase encoded messages)

1090Mhz reply pulses

1090Mhz reply messages (pulse position modulated with error detection)

1090 Transmitter

TCAS LOGIC & Display

Receive ModeC replies
Receive DF11
Receive DF0

Transmit DF11

1090 Receiver

1030 Transmitter

Mode C interrogate
Mode S interrogate (UF0)
Enhanced & Elementary Surveillance

DATA to FILL the REGISTERS

- Callsign panel
- GPS Receiver
- FMS
- Air Data Computer

1030 Receiver:
- 1030Mhz Interrogations 3 pulses
- 1030Mhz register requests (phase encoded messages)
- 1090Mhz reply pulses
- 1090Mhz reply messages (pulse position modulated with error detection)

Readout:
- Callsign
- Bank angle
- Selected level
- Airspeed
- Heading
ADS-B background

- 1030Mhz Interrogations 3 pulses
- 1030Mhz register requests (phase encoded messages)
- 1090Mhz reply pulses
- 1090Mhz reply messages (pulse position modulated with error detection)
- Mode C interrogate other aircraft & Mode S encounter

**Diagram:**

- GPS Receiver
- 1030 Receiver
- 1090 Transmitter
- 1090 Receiver
- TCAS LOGIC & Display
- 1030 Transmitter

**Transmit:** DF17/18 ADS-B

**Receive:** DF17, DF18 ADS-B & display
ADS-B simplified

- GPS Receiver
- ADS-B DF17/18
- 1090 Transmitter
- Receiver ADS-B
- 1090 Receiver
- Display

OPTIONAL
Mode S Transponder & ADS-B

TCAS

24 bit code DF11 acquisition squit
(TCAS : Here I am)

PARITY
CONTROL
24 bit AIRCRAFT ADDRESS
PARITY

ADS-B

POSITION, ALTITUDE, IDENTITY(CALLSIGN), VELOCITY VECTOR, VERTICAL RATE

CONTROL
24 bit AIRCRAFT ADDRESS
ADS-B MESSAGE 56 Bits
PARITY
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Airframes detected this year

IN AUSTRALIA

March | April | May | June | July | August
--- | --- | --- | --- | --- | ---
(no data) |  |  |  |  |  
Number of Airframes vs. Month
ADS-B Demonstration
Singapore Oct 2004

ADS-B antenna circled
Overnight Recording
13 October 2004
### ADS-B Aircraft in USA

Four US sites have been monitoring ADS-B since October 2004.

<table>
<thead>
<tr>
<th>Location</th>
<th>Days</th>
<th>Airframes</th>
<th>ADS-B</th>
<th>Mode-S</th>
<th>% ADSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whittier, CA</td>
<td>151</td>
<td>1906</td>
<td>34636</td>
<td>5.50%</td>
<td></td>
</tr>
<tr>
<td>Longmont, CO</td>
<td>188</td>
<td>2017</td>
<td>14133</td>
<td>14.27%</td>
<td></td>
</tr>
<tr>
<td>College Station, TX</td>
<td>189</td>
<td>1478</td>
<td>13876</td>
<td>10.65%</td>
<td></td>
</tr>
<tr>
<td>Alexandria, VA</td>
<td>177</td>
<td>2537</td>
<td>34752</td>
<td>7.30%</td>
<td></td>
</tr>
</tbody>
</table>

From October 2004 to the end of April 2005, a total of 3,154 different ADS-B equipped aircraft have been tracked by these four US ground stations.
Q: Why are aircraft equipping?
A: Mode S Transponder Mandate in Europe

European Elementary & Enhanced Surveillance Mandatory 3/2005
Extended 2007

Transponder vendors included ADS-B at the same time
• Although a GPS/ MMR is required for ADS-B
ADS-B Class B (ADS-B Out) Avionics Architecture

Baseline in Passenger configuration. May need to be upgraded to Change 7 to be compatible with upgraded Transponder

Replace if required for Flight ID

Existing Units
New Additions

Adapted from a FedEx presentation
Airliner Mod Kit for “ADS-B out”

Transponder Software

GPS data bus

Don’t need cockpit displays for ADS-B out

Adapted from a FedEx presentation
Smaller Aircraft Equipment are being developed

- Development of ADS-B capability in transponders
  - Low cost, size and weight

- eg Microair: Bundaberg Queensland
- eg Avionics AustralAsia: Brisbane Queensland
- eg Filser & Becker: Germany
- eg Honeywell & Garmin: USA

Airservices Australia Request for Proposal closes soon
Toulouse France Ground station
Airbus A380 with ADS-B
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Multilateration signals

- Principle: Triangulation from multiple sites

  - Use Mode A/C SSR on 1090 Mhz (A/c without mode S)
    - Need interrogation to trigger transponder
  
  - Use Mode S squitters on 1090 Mhz (A/c without ADS-B)
  
  - Use ADS-B squitters

DF11
DF17 or DF18

MULTILAT and ADS-B GROUND STATION(s)
Multi-lateration systems

- Airport surveillance multi-lateration systems use 1090Mhz receivers and decoders

- All commercial vendors offer ADS-B outputs from multi-lateration base stations
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ADS-B PLANS IN EUROPE
ECAC/EUROCONTROL ATM 2000+ and EATMP

Today’s Surveillance Infrastructure
- Procedural
- SSR
- PSR Major TMAs

Future Surveillance Infrastructure in 2010+
- ADS-B
- ADS-C
- SSR
- PSR Major TMAs
- SSR Mode S
- ASDE and/or Multilateration

- Dual-redundant SSR in all medium and high density airspace
- Single SSR coverage
- Multilateration at major airports
- ADS-B for all airspace
FAA ATO Executive (JRC) has decided!

• ADS-B is the preferred surveillance technology
  – Over radar and multilatation

• Initial Investment Decision (2A)
  – To setup up ADS-B organisation (in 30 days)
  – To prepare NPRM for ADS-B mandate (< 6 months)
    → Dependent on Airspace
    → Using ModeS 1090 ES for air transport (DO260A)
    → Forward fit in 2008, retrofit 2012/2014
  – No funding yet – next fiscal

• Envisage decommissioning
  – > 300 SSR radars
  – PRMs and
  – SMR primary radars
Many hurdles along the way!

- ADS-B cuts across traditional FAA organisational structure
  - Oceanic, enroute, terminal, surface
  - Internal opposition

- Radar manufacturers can be expected to fight in congress
ADS-B Policy Issues

• Do we stay a “Radar-Centric” NAS for the next 60 years?

• What constitutes an adequate back-up to ADS-B?

• As an avionics dependent program – what model of user equipage will be the most effective – enabling realization of benefits
ADS-B Airspace Mandates

Mode C Veil
**ADS-B Impact on Future Surveillance Cost**

**Surveillance W/ADS-B Cost ($M) (F&E)**

- Surveillance with ADS-B
- Legacy Surveillance

**Surveillance W/ADS-B Cost ($M) (O&M)**

- Surveillance with ADS-B
- Legacy Surveillance

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**Surveillance With ADS-B Investment**

$4.14B F&E/$4.43B O&M

**NAS Savings**

$2.8B F&E/$1.33B O&M
Regional plans

- Hong Kong: Surface movement application
- Australia: Non radar application over continent
- China: Western China possible surveillance
- Singapore: Surface movement application
- Indonesia: Radar alternative. Announced 15 site program
- Japan: Support radar performance
- India: Infill radar coverage holes
- New Zealand: Possible infill @ Queenstown. Maybe multilat instead
- Fiji: Considering ATC surveillance (no radars today)
- Mongolia: VDL4 trials already. 1090ES trial starting
- Pacific Island states: Potential for surveillance
Its time to deploy “ADS-B out”

Time for talking about ADS-B links is over

Its time to get the benefits for customers.
Discussion

More details on Airservices Website

Contact me:
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Issues with UAT

- US ADS-B link policy
  - 1090MHz for international operations & if operate above 18,000 feet
  - UAT for aircraft that only operate below 18,000 feet

- No aircraft to aircraft between UAT and 1090 aircraft unless an aircraft fits both systems

- US propose ground system receiving on one link and rebroadcasting on the other link
  - only emulates air to air while both are in coverage of ground stations
  - more expensive – 2 receivers, 2 transmitters & a server, vs 1 receiver
Traffic Information Service Broadcast (TIS-B)

A service provided by ground stations, broadcasting information relating to aircraft based on surveillance carried out by ground systems, using ADS-B signals, formats and protocols, compatible with ADS-B receiving equipment.
Standards for Mode S

- **ICAO → Signals in Space**
  - Annex 10 SARPS Amend 77

- **AVIONICS & TEST STANDARDS**
  - **RTCA**
    - ADS-B MASPDS DO242
    - ADS-B MOPS 1090 DO260 & DO260A
    - Mode S MOPS DO-181c include ADS-B

- **FORM/FIT STANDARDS**
  - **AEEC**
    - ARINC 718A

- **FAA (Regulator)**
  - TSO C112
  - TSO C116

- **CASA (Regulator)**
  - ATSO C1004 ModeAC + ADS_B
  - ATSO C1005 ADS-B alone

- **EUROCAE**
  - ED73 B Mode S MOPS
  - ED102 ADS-B for 1090Mhz

- **JAA (Regulator)**
  - JTSO 2C112
2.3 EXTENDED SQUITTER FORMATS

This section defines the formats and coding that shall be used for extended squitter ADS-B messages. When the extended squitter capability is implemented as an extended squitter/non-transponder device (ES/NT, Annex 10, Volume IV, 3.1.2.8.7), the convention for register numbering shall not apply. The data content and the transmit times shall be the same as specified for the transponder case.

2.3.1 FORMAT TYPE CODES

The format type code shall differentiate the Mode S extended squitter messages into several classes as specified in the following table:

<table>
<thead>
<tr>
<th>Type code</th>
<th>Format</th>
<th>Horizontal protection limit, (HPL)</th>
<th>95% Containment radius, ( \mu ) and ( \nu ), on horizontal and vertical position error</th>
<th>Altitude type (2.3.2.4)</th>
<th>NUC_P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No position information</td>
<td></td>
<td>Baro altitude or no altitude information</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Identification (Category Set D)</td>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identification (Category Set C)</td>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Identification (Category Set B)</td>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Identification (Category Set A)</td>
<td></td>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Surface position</td>
<td>HPL &lt; 7.5 m</td>
<td>( \mu &lt; 3 ) m</td>
<td>No altitude information</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Surface position</td>
<td>HPL &lt; 25 m</td>
<td>( 3 ) m &lt; ( \mu ) &lt; ( 10 ) m</td>
<td>No altitude information</td>
<td>8</td>
</tr>
</tbody>
</table>
Questions?

More details on Airservices Website

Contact me:
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