PART 1: ATC SURVEILLANCE

- Surveillance types including ADS-B
- Air to Ground ADS-B
- Air-Air ADS-B
- ICAO and ADS-B
Procedural “Surveillance” (Dependent)

- 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 standards
- 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-A (ADS-C Contract)

- FANS1/A Equipment in “big” aircraft
  - Expensive avionics
  - Not ICAO defined. Asia/Pacific didn’t wait for ICAO

- ATN & ICAO ADS-C
  - Expensive avionics
  - Limited availability

- Uses satellite and VHF datalinks

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

- ATC system defines update message rate
ADS-B (Broadcast)

- **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, + . . .

- **Broadcast**
  - any ground station or aircraft can monitor

Typically broadcast 2/second
ADS-B Functions

APPLICATIONS supported by ADS-B

**ADS-B core applications**

**ATC Surveillance**
- Separation
- Safety nets
- Traffic info

**Airborne surveillance**
- Cockpit display (CDTI)
- In trail climb
- Delegated separation

**Optional/Ancillary**
- Broadcast services
  - TIS (Traffic Info Service)
  - FIS (Flight info service)

---

International “standardised” DATALINKS

**VDL Mode 4**
**ModeS**
**UAT**

Ground systems
Automatic Dependent Surveillance Broadcast “Out”

“ADS-B OUT”

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

Typically broadcast 2 /second

ADS-B Ground station
ADS-B “IN”

- Display on TCAS or other display
- Longer range than TCAS
- Can include velocity vector & identity

Enhanced “see & avoid”
Air-Air Surveillance

- Display on MFD or PDA
- 1090Rx
PART 1 : ATC SURVEILLANCE

• Surveillance types including ADS-B
• Air to Ground ADS-B
• Air-Air ADS-B
• ICAO and ADS-B
European Joint Coordination Board

PACKAGE 1

• Five **Ground Surveillance** applications
  – ATC surveillance for en-route airspace (ADS-B-ACC);
  – ATC surveillance in terminal areas (ADS-B-TMA);
  – ATC surveillance in non-radar areas (ADS-B-NRA);
  – Airport surface surveillance (ADS-B-APT); and
  – Aircraft derived data for ground tools (ADS-B-ADD).
Automatic Dependent Surveillance Broadcast

Typically broadcast 2 / second

ADS-B Ground station

DOWNLINK MESSAGES

ASTERIX DATA FORMAT

ADS-B OUT
Asterix Cat 21 Messages

EUROCONTROL STANDARD DOCUMENT
FOR
SURVEILLANCE DATA EXCHANGE
Part 12 : Category 021
ADS-B Messages

Table 1 - Data Items of Category 021

<table>
<thead>
<tr>
<th>Reference Number</th>
<th>Description</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>021/010</td>
<td>Data Source Identification</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/020</td>
<td>Emitter Category</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/030</td>
<td>Time of Day</td>
<td>1/128 s</td>
</tr>
<tr>
<td>021/032</td>
<td>Time of Day Accuracy</td>
<td>1/256 s</td>
</tr>
<tr>
<td>021/040</td>
<td>Target Report Descriptor</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/080</td>
<td>Target Address</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/090</td>
<td>Figure of Merit</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/095</td>
<td>Velocity Accuracy</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/110</td>
<td>Trajectory Intent</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/130</td>
<td>Position in WGS-84 co-ordinates</td>
<td>180°/2.5°</td>
</tr>
<tr>
<td>021/140</td>
<td>Geometric Altitude</td>
<td>6.25 ft</td>
</tr>
<tr>
<td>021/145</td>
<td>Flight Level</td>
<td>1/4 FL</td>
</tr>
<tr>
<td>021/146</td>
<td>Intermediate State Selected Altitude</td>
<td>25 ft</td>
</tr>
<tr>
<td>021/148</td>
<td>Final State Selected Altitude</td>
<td>25 ft</td>
</tr>
<tr>
<td>021/150</td>
<td>Air Speed</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/151</td>
<td>True Air Speed</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/152</td>
<td>Magnetic Heading</td>
<td>360°/2°</td>
</tr>
<tr>
<td>021/155</td>
<td>Barometric Vertical Rate</td>
<td>6.25 ft / min</td>
</tr>
<tr>
<td>021/157</td>
<td>Geometric Vertical Rate</td>
<td>6.25 ft / min</td>
</tr>
<tr>
<td>021/160</td>
<td>Ground Vector</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/165</td>
<td>Rate of Turn</td>
<td>1/4 deg</td>
</tr>
<tr>
<td>021/170</td>
<td>Target Identification</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/200</td>
<td>Target Status</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/210</td>
<td>Link Technology Indicator</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/220</td>
<td>Met Report</td>
<td>N.A.</td>
</tr>
<tr>
<td>021/230</td>
<td>Roll Angle</td>
<td>0.01 deg</td>
</tr>
</tbody>
</table>
ATC System able to process ADS-B

- Two methods:
  - Integrated tracker
    - Meld ADS-B and Radar data
  - Priority tracks
    - Display ADS-B or Radar data
Automatic Dependent Surveillance Broadcast

ADS-B ground stations are simple and economical

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

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

Cost Comparison

- Maintenance
- Power
- Site space
- Building
- Road
- Environmental
- Rotating machinery

© Airservices Australia
ADS-B UAP

Airline benefits

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

• Operational flexibility benefit
  – Higher Probability of clearance request
  – Optimum route/ level
  – Strategic enabler for User preferred route

• Operational control/ fleet management
Incident review

Summary All Incidents

- Inadequate coordination at sector
  - CO-ORD TIME, 19
- AIRCRAFT at FIR without warning
  - AWARENESS, 24
- AIRCRAFT on wrong route
  - RAM-FLIPCY, 22
- AIRCRAFT with bad estimates
  - ETO, 27
- AIRCRAFT @ wrong flight level
  - CLAM, 62
- Not ADS-B, 262
  - ADS-B would not have assisted
ATM Discontinuities

• Every FIR boundary represents a
  – Discontinuity
  – Different database
  – Risk, errors, different views of “true” situation

• Surveillance provides
  – Feedback (closes the loop)
    ➔ Rather than 30 minute position & level reports
  – Detects errors/ blunders
    ➔ ATC, pilot, other ATC
    ➔ Minimises the IMPACT of errors

• ADS-B may provide inexpensive means to share data
Main downlink data

- Positional data downlink
- Integrity data downlink
- Barometric altitude data downlink
- ICAO airframe unique 24 bit code
- Flight identity downlink
- Velocity vector data
Other useful data

- Geometric altitude
- Indicated speed (wind)
- Status data (emergencies, aircraft type category)
- Trajectory Intent data
  - not yet well enough defined
  - Not available outside FMS
ADS-B & Radar Velocity vectors
(B200 Sharp turn)
HPL

GPS
Calculate HPL

POSITION
HPL / HIL ARINC130

 ADS-B TRANSMITTER

POSITION
NUC (derived from HPL)

 ADS-B GROUND STATION

POSITION
FOM (derived from HPL)

ATC SYSTEM
Data “quality”

- **HPL = 20 Nm**: Discard data.
- **HPL = 2 Nm**: Not as good as radar; Display “Situational awareness symbol”; Use for CLAM/RAM.
- **HPL = 0.5 Nm**: As good as radar; Display “Good position symbol”; Use for separation & safety nets.
- **HPL = 0 Nm**: As good as radar; Display “Good position symbol”; Use for separation & safety nets.
**Table 2-11: “TYPE” Subfield Code Definitions (DF - 17 or 18)**

<table>
<thead>
<tr>
<th>Type Code</th>
<th>Format</th>
<th>Horizontal Protection Limit, HPL</th>
<th>95% Containment Radii, ( \mu ) and ( \nu ), On Horizontal and Vertical Position Error</th>
<th>Altitude Type</th>
<th>NUC_P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Position Information</td>
<td></td>
<td>No Altitude Information</td>
<td>No Altitude Information</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Identification (Category Set C)</td>
<td></td>
<td>No Altitude Information</td>
<td>Not Applicable</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identification (Category Set C)</td>
<td></td>
<td>No Altitude Information</td>
<td>Not Applicable</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Identification (Category Set C)</td>
<td></td>
<td>No Altitude Information</td>
<td>Not Applicable</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Identification (Category Set C)</td>
<td></td>
<td>No Altitude Information</td>
<td>Not Applicable</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Surface Position</td>
<td>HPL &lt; 7.5 m m &lt; 2 m ( \mu &lt; 2 ) m No Altitude Information</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>Surface Position</td>
<td>HPL &lt; 7.5 m m &lt; 2 m ( \mu &lt; 2 ) m No Altitude Information</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Surface Position</td>
<td>HPL &lt; 185.2 m (0.1 NM) 3 m m &lt; 10 m ( \mu &lt; 10 ) m No Altitude Information</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Surface Position</td>
<td>HPL &lt; 185.2 m (0.1 NM) 3 m m &lt; 10 m ( \mu &lt; 10 ) m No Altitude Information</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Airborne Position</td>
<td>HPL &lt; 7.5 m m &lt; 2 m ( \mu &lt; 2 ) m Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>Airborne Position</td>
<td>7.5 m HPL &lt; 25 m 3 m m &lt; 10 m ( \mu &lt; 10 ) m Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>Airborne Position</td>
<td>25 m HPL &lt; 185.2 m (0.1 NM) 3 m m &lt; 10 m ( \mu &lt; 10 ) m Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>Airborne Position</td>
<td>185.2 m (0.1 NM) &lt; HPL &lt; 370.4 m (0.2 NM) 92.6 m (0.05 NM) m &lt; 185.2 m (0.1 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>Airborne Position</td>
<td>370.4 m (0.2 NM) &lt; HPL &lt; 926 m (0.5 NM) 185.2 m (0.1 NM) m &lt; 463 m (0.25 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>Airborne Position</td>
<td>926 m (0.5 NM) &lt; HPL &lt; 1852 m (1.0 NM) 463 m (0.25 NM) m &lt; 926 m (0.5 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>Airborne Position</td>
<td>1852 m (1.0 NM) &lt; HPL &lt; 3704 m (2.0 NM) 926 m (0.5 NM) m &lt; 1852 m (1.0 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Airborne Position</td>
<td>3704 m (2.0 NM) &lt; HPL &lt; 3752 km (10 NM) 1852 km (10 NM) m &lt; 926 km (5.0 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>Airborne Position</td>
<td>1852 km (10 NM) &lt; HPL &lt; 3704 km (20 NM) 9.26 km (0.5 NM) m &lt; 1852 km (10 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Airborne Position</td>
<td>3704 km (20 NM) &lt; HPL &lt; 1852 km (100 NM) 18.52 km (100 NM) m &lt; 9.26 km (50 NM) Baro Altitude</td>
<td>No Altitude Information</td>
<td>Baro Altitude or No Altitude Information</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>Airborne Velocity</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
<td>Difference between “Baro Altitude” and “GNSS Height (HAE)”</td>
<td>NA</td>
</tr>
<tr>
<td>20</td>
<td>Airborne Position</td>
<td>HPL &lt; 7.5 m ( \mu &lt; 3 ) m and ( \nu &lt; 4 ) m 9 14 1852 km (10 NM)</td>
<td>GNSS Height (HAE)</td>
<td>GNSS Height (HAE)</td>
<td>9</td>
</tr>
<tr>
<td>21</td>
<td>Airborne Position</td>
<td>HPL &lt; 25 m ( \mu &lt; 10 ) m and ( \nu &lt; 15 ) m 18.52 km (100 NM)</td>
<td>GNSS Height (HAE)</td>
<td>GNSS Height (HAE)</td>
<td>8</td>
</tr>
<tr>
<td>22</td>
<td>Airborne Position</td>
<td>HPL &gt; 25 m ( \mu &gt; 10 ) m or ( \nu &gt; 15 ) m 18.52 km (100 NM)</td>
<td>GNSS Height (HAE)</td>
<td>GNSS Height (HAE)</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Notes:**
- **NUC** = Navigational Uncertainty Category
- Sometimes message "TYPE" is used
HPL / HFOM

- **HFOM**: Accuracy measure assuming that all satellites are operating correctly
- **HPL**: Integrity measure. Positional data within this limit with high degree of certainty (10^-7/ flight hour)
  - Even if a satellite gives false range data
  - Based on GPS receiver ability to detect satellite false range data given
    - Satellite geometry
    - RAIM algorithm capability
    - Assumption SA on/off
    - WAAS signal received
    - Geo satellite received
Good HDOP / HFOM – Poor HPL

- Good accuracy
- Poor ability to detect error on Satellite A
- Poor HPL
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.
PART 1 : ATC SURVEILLANCE

- Surveillance types including ADS-B
- Air to Ground ADS-B
- Air-Air ADS-B
- ICAO and ADS-B
European Joint Coordination Board

PACKAGE 1

• Seven **Air-Air Surveillance** applications
  – Enhanced traffic situational awareness on the airport surface (ATSA-SURF);
  – Enhanced traffic situational awareness during flight operations (ATSA-AIRB);
  – Enhanced visual acquisition for see & avoid (ATSA-S&A);
  – Enhanced successive visual approaches (ATSA-SVA);
  – Enhanced sequencing and merging operations (ASPA-S&M);
  – In-trail procedure in oceanic airspace (ASPA-ITP); and
  – Enhanced crossing and passing operations (ASPA-C&P).
BAe Systems
Pass Behind application
UPS Fleet Status
Successive visual approaches

- 32 B-767—100%
- 73 B-757—97%
- 11 A300-600—1090 Squit Only
PART 1 : ATC SURVEILLANCE

- Surveillance types including ADS-B
- Air to Ground ADS-B
- Air-Air ADS-B
- ICAO and ADS-B
ANC11 Supports ADS-B

AN-Conf/11-WP/190

1-12 Report on Agenda Item 1

Recommendation 1/7 — Ground and airborne automatic dependent surveillance-broadcast (ADS-B) applications for global interoperability

That ICAO and States:

a) recognize ADS-B as an enabler of the global ATM operational concept bringing substantial safety and capacity benefits;

b) support the cost-effective early implementation of packages of ground and airborne ADS-B applications, noting the early achievable benefits from new ATM applications; and

c) ensure that implementation of ADS-B is harmonized, compatible and interoperable with respect to operational procedures, supporting data link and ATM applications.
ICAO PANELS

• OPLINK : Has developed an ADS-B Conops  
  – Endorsed by ANC11
• SASP : Is developing 5Nm Separation standards
• SCRSP : Continues to refine ModeS standards
• ACP : Has defined VDL Mode4 and is developing UAT standards
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
Its time to deploy “ADS-B out”

Time for talking about links is over

Its time to get the benefits.
PART 2 : 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
- Avionics standards
- Fitment
- Ground system
- Multilat synergy
- Performance
SSR background

AIRCRAFT

1030 Receiver

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

ModeA, C interrogations

1090 Transmitter

ModeA, C replies

1090Mhz reply messages 12 pulses (no error detection)
MODE S background

1030 Receiver

1030Mhz register requests (phase encoded messages)

ModeA, C interrogations

1090 Transmitter

ModeA, C replies

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

Readout:
“Registers”
TCAS background

Transmit DF11

Receive Mode C replies
Receive DF11
Receive DF0

1030 Receiver

1090 Transmitter

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

1090 Receiver

1090 Receiver

TCAS LOGIC & Display

1030 Transmitter

Mode C interrogate
Mode S interrogate (UF0)

© Airservices Australia
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)

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

Readout:
- Callsign
- Bank angle
- Selected level
- Airspeed
- Heading

© Airservices Australia
**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)**

**GPS Receiver**

**TRANSMIT DF17/18 ADS-B**

**1090 Transmitter**

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

**1090 Receiver**

**1030 Transmitter**

**TCAS LOGIC & Display**

**Mode C interrogate other aircraft & Mode S encounter**
ADS-B simplified

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

© Airservices Australia
PART 2: 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
  - Avionics standards
  - Fitment
  - Ground system
  - Multilat synergy
  - Performance
Mode S Transponder & ADS-B

TCAS

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

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

Example: Message Data Block Waveform Corresponding to Bit Sequence 0010...001

© Airservices Australia
SSR MODE S EXTENDED LENGTH MESSAGE

Example: Message Data Block Waveform Corresponding to Bit Sequence 0010...001

Figure 2-1: ADS-B Message Transmission Waveform
## Mode S Extended Squitter

### Short Squitter
- **Control** (8 bits)
- **Mode S Address** (24 bits)
- **Parity** (24 bits)
- **Total Bits:** 56

### Long Squitter
- **Control** (8 bits)
- **Mode S Address** (24 bits)
- **ADS-B Message** (56 bits)
- **Parity**
- **Total Bits:** 112

### Squitter Type

<table>
<thead>
<tr>
<th>Airborne Position</th>
<th>Broadcast Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (5)</td>
<td>0.5s</td>
</tr>
<tr>
<td>Status/Ant (2+1)</td>
<td></td>
</tr>
<tr>
<td>Altitude (12)</td>
<td></td>
</tr>
<tr>
<td>T (1)</td>
<td></td>
</tr>
<tr>
<td>CPR (1)</td>
<td></td>
</tr>
<tr>
<td>Lat Long (34)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Airborne Velocity</th>
<th>Broadcast Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (5)</td>
<td>0.5s</td>
</tr>
<tr>
<td>Sub-type (3)</td>
<td></td>
</tr>
<tr>
<td>Intent (1)</td>
<td></td>
</tr>
<tr>
<td>IFR (1)</td>
<td></td>
</tr>
<tr>
<td>NUC (3)</td>
<td></td>
</tr>
<tr>
<td>Horizontal Velocity (22)</td>
<td></td>
</tr>
<tr>
<td>Vertical Velocity (11)</td>
<td></td>
</tr>
<tr>
<td>Turn (2)</td>
<td></td>
</tr>
<tr>
<td>Diff Baro Alt(8)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Position</th>
<th>Broadcast Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (5)</td>
<td>0.5s or 5s*</td>
</tr>
<tr>
<td>Movement (7)</td>
<td></td>
</tr>
<tr>
<td>Status (1)</td>
<td></td>
</tr>
<tr>
<td>Heading (7)</td>
<td></td>
</tr>
<tr>
<td>T (1)</td>
<td></td>
</tr>
<tr>
<td>CPR (1)</td>
<td></td>
</tr>
<tr>
<td>Lat Long (34)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aircraft Identific’N</th>
<th>Broadcast Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (5)</td>
<td>5s or 10s*</td>
</tr>
<tr>
<td>A/C type (3)</td>
<td>(* if stationary)</td>
</tr>
<tr>
<td>8 Character Aircraft Callsign (48 bits)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event Driven</th>
<th>Broadcast Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (5)</td>
<td>As required</td>
</tr>
<tr>
<td>Sub-type (3)</td>
<td></td>
</tr>
<tr>
<td>Event Data (48 bits)</td>
<td></td>
</tr>
</tbody>
</table>
PART 2 : 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
- Avionics standards
- Fitment
- Ground system
- Multilat synergy
- Performance
Standards for Mode S

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

- AVIONICS & TEST STANDARDS
  - RTCA
    → ADS-B MOPS 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 DRAFT

- JAA (Regulator)
  → JTSO 2C112

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

- AVIONICS & TEST STANDARDS
  - EUROCAE
    → ED73A Mode S MOPS
    → ED102 ADS-B for 1090Mhz

- FORM/FIT STANDARDS
  - EUROCAE
    → ED86

- FAA (Regulator)
  → TSO C112
  → TSO C116 DRAFT

- JAA (Regulator)
  → JTSO 2C112

- CASA (Regulator)
  → ATSO C1004 ModeAC + ADS_B
  → ATSO C1005 ADS-B alone
Part I

2.3 EXTENDED SQUIRTER 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></td>
<td>Baro altitude or no altitude information</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Identification (Category Set D)</td>
<td></td>
<td></td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Identification (Category Set C)</td>
<td></td>
<td></td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Identification (Category Set B)</td>
<td></td>
<td></td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Identification (Category Set A)</td>
<td></td>
<td></td>
<td>Not applicable</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 ( \leq \mu &lt; 10 ) m</td>
<td>No altitude information</td>
<td>8</td>
</tr>
</tbody>
</table>
Anc11 Support Mode S for near term

AN-Conf/11-WP/202

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.
PART 2 : 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
- Avionics standards

- Fitment
  - Ground system
  - Multilat synergy
  - Performance
ADS-B Class B (ADS-B Out) Avionics Architecture

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

- Transponder/TCAS Control Panel & Cables
  - Replace if required for Flight ID

- Mode S Transponder
  - Call Sign
  - Position, Velocity, ...

- GNSS/GPS
  - INTEGRITY

- Air Data Computer
  - Altitude

- Control Panel

- Upgrade To Include ADS-B Functionality

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
Avionics – Available today

- **Honeywell**
  - Air Transport: TRA-67A

- **Rockwell Collins**
  - Air Transport: TPR-901
  - Business / GA: TDR-94/94D

- **ACSS**
  - Air Transport: XS-950
  - Business / GA: RCZ-852

- **UPS-AT**
Prices for Avionics

• Close to zero for new aircraft off the production line
  – Eg: Airbus, Boeing
  – BUT Bombardier, SAAB & Embrarer don’t support it yet

• Expensive for old aircraft without GPS (eg B767)

• Cost of Service Bulletin from Boeing/Airbus depends on relationship. Low cost to Very high cost
European mandate

SSR-Mode S Elementary Surveillance (ELS)

1. GENERAL

1.1 The purpose of this Circular is to present comprehensive information on the current planning of the EUROCONTROL Member States and other States in the ICAO EUR Region concerning the requirements for the airborne carriage and operation of SSR Mode S equipment and more specifically the detailed requirements for the Mode S Elementary Surveillance functionality. It shall be read in conjunction with earlier State regulations concerning Mode S and ICAO Regional Supplementary Procedures Doc 7030, EUR Part 1. Additional material can be found in the Joint Aviation Authorities (JAA) Administrative and Guidance Material, Leaflet No. 13, Certification of Mode S Transponder Systems for Elementary Surveillance.
Airlines in Australia are equipping

Thank you Europe: for EHS, ELS mandate

- Qantas has committed to fit aircraft with ADS-B “out”
  - A330, A320, A380, B737, B747 (say >50% of fleet)
  - Jetstar expected fully fit 23 A320s

- Virgin Blue: 737-800s
  - Already has 15 transmitting
  - All future deliveries equipped

- Some already being detected by existing ADS-B Ground station
  - Airbus A330
  - Boeing 767, 777 and 737’s
  - Boeing 747’s detected

Transponders that meet standard ARINC718A
Policy

• Qantas group of airlines has expressed its support for the deployment of ADS-B as an ATC surveillance tool

• New jet aircraft received by Qantas will have an ADS-B capability and European requirements for “elementary” and “enhanced” SSR operation offer a convenient opportunity to retrofit the long haul fleet
The U.S. Population of ADS-B Equipped Aircraft is Growing

Active ADS-B transmitters – All Sites

Graph courtesy of Dr. Wilson Felder, Director, Office of Technology Development FAA

© Airservices Australia
Navigation Strategy in Australia

• Transition to GNSS Primary Means
  – Large aircraft become FMS/ GPS/ IRS
  – Smaller aircraft use TSO146 navigators

• Decommission navaids but maintain a Backup network
  – About 50% of Navaids removed
  – Keep ILS

• Navaid Life Extension Project
  – That are part of backup network
New Generation GPS receivers
TSO 145/146

• New “WAAS” GPS engines
  – WAAS capability not required in many countries
  – No WAAS ground monitoring

• Australia expects CASA approval for only means because of”
  – SA off assumption :
    ➔ Greater availability for a required integrity/accuracy

  – Fault detection & Exclusion (FDE)
    ➔ Operation continues if faulty GPS ranging signal

  – HPL output to external systems (ADS-B)
Enormous Synergy between

• New Surveillance and New Nav

• If ADS-B exists in aircraft then high quality GPS will exist in aircraft

• If ADS-B is installed – install NAV at same time (& vice versa)
LOWER AIRSPACE Project (LAP)

• Industry considering “LAP project”
  – ASTRA, CASA, Airservices Australia
• Remove most NDB/VORs
• Remove enroute radars
• Cross Industry funding to equip GA
  – Access Economics Cross Industry Business case prepared by ASTRA
Air Traffic Management

IFR ADS-B Option 1

Existing SSR transponder

SSR

Existing SSR Antenna

ADS-B Transmission

New Antenna

Position & Integrity

Traffic Antenna

1090 Transmitter

1090 Receiver

GPS ANTENNA

SMALL BOX

TSO146 GPS NAV

Moving Map Display

TRAFFIC

© Airservices Australia
VFR ADS-B options

Existing SSR transponder

SSR

Existing SSR Antenna

ADS-B Transmission

New Antenna

GPS ANTENNA

Small Box (in tail etc)

GPS engine

1090 Transmitter

Traffic Antennas

1090 Receiver

Moving Map Display

Traffic

Moving Map Display

© Airservices Australia
TWO ADS-B TSOs

• C10004
  – SSR Mode A/C transponder with ADS-B out

• C10005
  – ADS-B out only
  – Mandates output of TSO145 positional data too

• Both available at www.casa.gov.au
GA “VFR” CDTI

Transponder antenna

CDTI Receiver

© Airservices Australia
PDA version
PART 2 : 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
- Avionics standards
- Fitment

- Ground system
- Multilat synergy
- Performance
Typical ADS-B Receive only system

DME
OMNI ANTENNA
12 dBi antenna

GROUND STATION

LOW NOISE AMPLIFIER
SIGNAL PROCESSOR
COMPUTER

RF

MDS= Better than 90 dB

MESSAGES TO ATC

Thales ATM Ground station

© Airservices Australia
PART 2 : 1090ES & Mode S Technology

• Radar, ModeS and ADS-B review
• ADS-B messages
• Avionics standards
• Fitment
• Ground system

• Multilat synergy
• Performance
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
PART 2: 1090ES & Mode S Technology

- Radar, ModeS and ADS-B review
- ADS-B messages
- Avionics standards
- Fitment
- Ground system
- Multilat synergy
- Performance
Burnett Basin Trial Experience

ADS-B performance is BETTER THAN RADAR
• Mode S ADS-B gives excellent performance in Australia

Sensis Ground station @ Bundaberg
ADS-B on every enroute ATC Console
ADS-B “Noise”

POSITION NOISE IN NM
Actual vs Curve Fit

STANDARD DEVIATION = 0.0067 NM
(Sample = 3000 ADS-B reports)
Radar & ADS-B Noise distribution

VH-QPC System Tracks: ADS-B Position Noise vs Radar Position Noise

Samples:
- 240 ADS-B system track reports
- 240 Multi radar system track reports
- Same aircraft
- Same 20 min time interval

Number of Reports

Dist in nautical miles from Smoothed Track

ADS-B Position Noise
Radar Position Noise

Error “tails”
Radar & ADS-B “speed”

ADS_B

RADAR
Heading noise

**ADS_B**

**Radar System Track Heading Variation from Mean**

**ADS-B System Track Heading - Variation from Mean**

**Radar System Track Update Number**

**ADS_B Update Number**

**Radar System Track Update Number**

© Airservices Australia
BRISBANE TERMINAL AREA RADAR TOWER

ADS-B ANTENNA
SURFACE MOVEMENT RADAR AT LOW COST
What is needed for ATC useful ADS-B?

- ADS-B out fitted to aircraft
  - GPS output including INTEGRITY
  - Transponder software (or hardware if old transponder)

- ADS-B Ground station

- ATC system to display ADS-B
  - Preferably integrated (Tower systems could be standalone)
  - Links to get data to ATC system

- ATC procedures & Training
Thank you

Questions?