International Civil Aviation Organization

The Third Meeting of Automatic Dependent Surveillance – Broadcast (ADS-B) Study and Implementation Task Force (ADS-B TF/3)

Bangkok, 23-25 March 2005

Agenda Item 4: Review States' activities on trials and demonstration of ADS-B

AUSTRALIAN UPPER AIRSPACE PROJECT UPDATE

(Prepared by Greg Dunstone, Airservices Australia)
(Presented by Greg Dunstone, Airservices Australia)

SUMMARY

This paper provides a brief UAP Progress Report

1 Background

1.1 The Australian Upper Airspace Project (UAP) has been described at previous ADS-B Task Force Meetings. Progress has continued at some pace during the last 6 months.

2 ADS-B Ground station deployment

2.1 Upper Airspace project ADS-B Ground stations have been installed at

- Melbourne airport – as the Airservices Australia Test & Evaluation unit
- Bundaberg – to replace the Bundaberg system in due course

2.2 Integration of a high performance GPS engine in the ground station has been completed. This unit uses HPL to generate the site monitor NUC (integrity) value.

2.3 Formal site acceptance testing has been completed and the manufacturing process has commenced for the other 28 duplicated sites. This equipment will be delivered in May/June 2005 and will be installed at remote sites progressively through the second half of 2005

3 RAIM prediction system

3.1 A system has been purchased to provide predictions of when aircraft may report integrity values corresponding to HPL > 0.5Nm. This system is a modification of Australia's existing "RAIM prediction system". The existing RAIM prediction system provides predictions to the pilot community that will be conduction Non Precision Approaches at specified locations.

3.2 Initial factory testing of the RAIM prediction system commenced in Boston USA. Delivery of an “interface” test unit is being used by Thales to check the interface between the RAIM system and Eurocat.

3.3 Discussions have taken place between Volpe (Manufacturer of RAIM system) and Airservices regarding verifying the RAIM prediction algorithm and comparing that to real navigators.

3.4 There are great difficulties in modelling the population of GPS engines because individual manufacturers build their avionics with different functionality/performance (whilst complying with minimum standards).

3.5 Australia will have to make a judgement on what type of avionics we intend to model – and we will then enter this as a site parameter into the RAIM (for ADS-B) system. We are likely to choose to model as close as possible to the GPS engines used by Airbus and Boeing.

It can be noted that indicated that :

- Many TSO129 GPS receivers assume that GPS selective availability (SA) is on. This factor is a major determinant of HPL output for these TSO129 receivers and hence ADS-B – although this is not true for TSO145/6 receivers

- The use of HPL=0.5Nm (as proposed for ADS-B) will mean that there are less RAIM outage predictions compared to NPA predictions (NPA uses 0.3Nm)

- Mask angle of 5 degrees is a major determinant of HPL and hence “RAIM holes”. TSO129 receivers are supposed to use 5 degrees, but most manufacturers have “better” than TSO129 by using lower mask angles WHEN there is inadequate geometry. This means that most engines will be better than the prediction. We can tailor the RAIM prediction system to use any mask angle.

4 Eurocat enhancements

4.1 Eurocat enhancements to support 1000 ADS-B aircraft, revised rules for matching ADS-B data to flight plans and an number of other changes are being provided. Formal Testing of the Eurocat enhancements has commenced. An Airservices Australia team is located at two test platforms, one at Melbourne airport and another at the Thales factory.

5 Bypass system

5.1 An ADS-B bypass system has been developed which takes ADS-B data from the ADS-B ground stations and presents it to the controller workstation directly without centralised processing.

5.2 Factory test for the ADS-B bypass system was successfully completed. The bypass system has now been installed at Thales factory and at Melbourne airport. Testing and debug is continuing.

6 Ultimate fallback system

6.1 Airservices Australia provides controllers with a “secondary” controller workstation processor which can be used in the event of common mode workstation failure. This “secondary system” receives radar, ADS-B and flight plan data independent from the main ATC system.

6.2 Development of the modifications to the “Ultimate fallback” system to support ADS-B has commenced.

7 ATC procedure & ATC training development

7.1 ATC procedure development and ATC training development has commenced.

8 Safety Case development

8.1 The Design safety case for the Upper Airspace Project has been completed and forwarded to the regulator. Preparation of the Implementation Safety case has commenced.

9 Site works and Data links

9.1 Some minor delays associated with site activities (including the VHF program) and datalink (ground station to TAAATS) have occurred. The installation dates for the sites are now as follows. Commissioning is expected to follow within two months after installation.

Bundaberg	DSGK	QLD	Jul 2005
Balgo Hill	BGO	WA	Aug 2005
Caiguna	CAG	WA	Aug 2005
Doongan	DGN	WA	Aug 2005
Esperance	ESP	WA	Aug 2005
Jackson	JAK	QLD	Aug 2005
Thursday Island	TUD	QLD	Aug 2005
Ayers Rock AP	AYE	NT	Sep 2005
Birdsville	BDV	QLD	Sep 2005
Broken Hill	BHI	SA	Sep 2005
Mornington Island	MTI	QLD	Sep 2005
West Gap (Alice Springs)	WGP	NT	Sep 2005
Warburton	WBR	WA	Oct 2005
Broome	BRM	WA	Oct 2005
Leonora	LEO	WA	Oct 2005
Longreach	LRE	QLD	Oct 2005
Telfer	TEF	WA	Nov 2005
Meekatharra	MEK	WA	Nov 2005
Mt Barrow	BOW	TAS	Nov 2005
Mt Isa (DCA Hill)	MA	QLD	Nov 2005
Newman	NWN	WA	Nov 2005
Oodnadatta	OOD	SA	Nov 2005
Tennant Creek	TNK	NT	Nov 2005
Karratha	KA	WA	Dec 2005
Mt Oxley	MXL	NSW	Dec 2005
Nullabor	NUB	SA	Dec 2005
Woomera	WR	SA	Dec 2005
Billabong	BLB	WA	Jan 2006

10 Transition planning

10.1 Transition planning has commenced. It is envisaged that Bundaberg will be commissioned first as a one-for-one replacement of the existing commissioned system.

10.2 Then as other sites come on line, and ATC training is completed, the new sites will provide a situational awareness service.

10.3 Some time later, following CASA approval, Airservices Australia anticipate authorisation of a 5NM separation standard to be used for the Upper Airspace Project.

11 Communication to staff

11. ADS-B newsletters and an intranet site have been used to communicate with staff, particularly field controllers. The latest newsletters are attached.

12 Conclusion

12.1 The meeting is invited to note the progress of the Upper Airspace project.

IMPROVEMENTS IN ICING AND TURBULENCE FORECASTS

ICAO JOURNAL

VOLUME 60 NUMBER 1, 2005

ADS-BROADCAST

Australia's continent-wide ATC surveillance system leading the way forward

Continent-wide ATC surveillance system soon to become reality in Australia

In recent years Australia has been preparing to implement a network of ADS-B ground stations that will lead to improved air traffic management throughout its continental airspace. By the end of 2005, a large percentage of the Australian jet fleet is expected to be fully equipped for the upgraded service.

GREG DUNSTONE
AIRSERVICES AUSTRALIA

Airservices Australia has been active in the field of automatic dependent surveillance-broadcast (ADS-B) for some years because the technology offers the possibility of continent-wide air traffic control (ATC) surveillance for the first time. That dream is about to become reality this year when Airservices Australia commissions a network of ADS-B ground stations in late 2005.

Bundaberg Operational Trial. In 2002 Airservices Australia installed a single ADS-B ground station at Bundaberg, Queensland, equipped a number of aircraft with ADS-B avionics, and modified Australia's operational air traffic management (ATM) system to process and display ADS-B tracks. The technology used is Mode S extended squitter on 1090 megahertz (MHz), which is recommended by ICAO as the initial worldwide interoperable ADS-B link.

The Australian ATC system and the ATC training simulator were enhanced to support ADS-B and operational procedures were developed to use the technology at active ATC positions. Training of controllers was completed in 2004, and a safety case for operational ATC use of the Bundaberg system was completed and approved.

Initial operations were limited to ATC situational awareness and then to the provision of air traffic information. The Bundaberg area is served by radar above 12,000 feet, and the major focus of ADS-B at this site was to improve lower level surveillance coverage to allow earlier issuance of clearances as aircraft climbed into controlled airspace. Bundaberg proved to be a good site to conduct initial comparative tests since radar and ADS-B were both available at higher flight levels.

Approval to provide five nautical mile (NM) separation services based on ADS-B surveillance data was granted by the Civil Aviation Safety Authority (CASA) of Australia in December 2004.

Many lessons were learned during the deployment and, like all new technologies, some teething problems were experienced. However, the system performance exceeded expectations since detection coverage, position accuracy, velocity vector accuracy and update rate were found to be better than Australia's fast rotation monopulse secondary surveillance radars (MSSRs).

Support for the new technology from airline operators and air traffic controllers has been strong. The industry views ADS-B as a key safety and efficiency initiative, and clearly sees the potential benefits of extensive deployment across the continent. Airlines gave significant support to the operational trial, in part by allowing the installation of additional avionics in their aircraft and by conducting the required pilot training.

Upper Airspace Project (UAP). Encouraged by the results of the Bundaberg operational trial, a plan was formulated to deploy ADS-B across the continent in all areas not covered by radar. Currently, procedural ATC is used to separate aircraft in these areas using voice position reports received on very high frequency (VHF) air-ground frequencies. The objective was to increase safety through provision of automated safety alerts, and to increase operational flexibility and efficiency through use of 5 NM separation standards, primarily to aircraft operating above flight

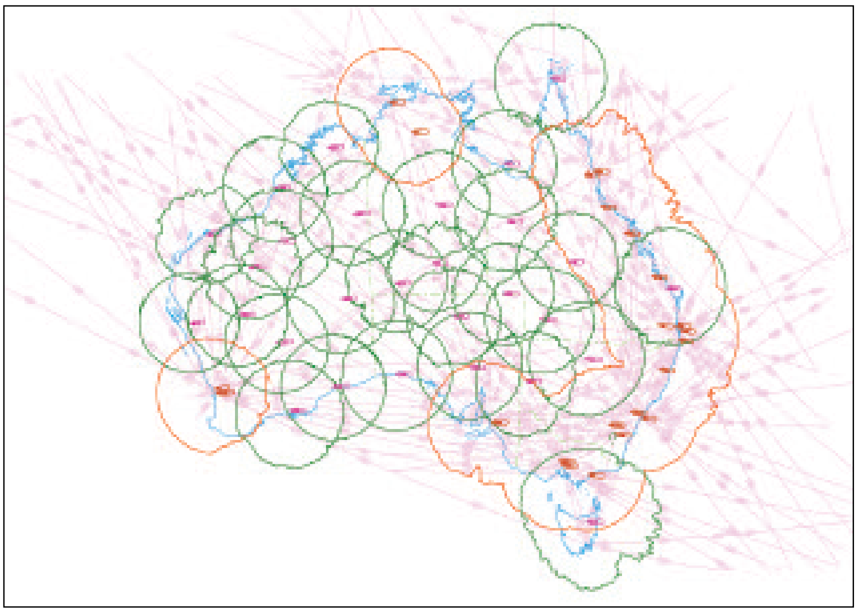


Figure 1. The Upper Airspace Project implemented by Australia combines radar (orange) and ADS-B (green) coverage to provide ATC surveillance across the continent.

level (FL) 300. The initiative, approved in 2003, is known as the ADS-B Upper Airspace Project (UAP). A diagram of the planned resulting radar and ADS-B coverage is shown in *Figure 1.*

The UAP does not require mandatory equipage by airlines but rather the delivery of benefits to those that choose to do so. Airlines that do equip will be afforded operational priority, and capable aircraft will not be required to provide voice position reports. Pilots of such aircraft can also expect to receive their preferred flight level requests more often.

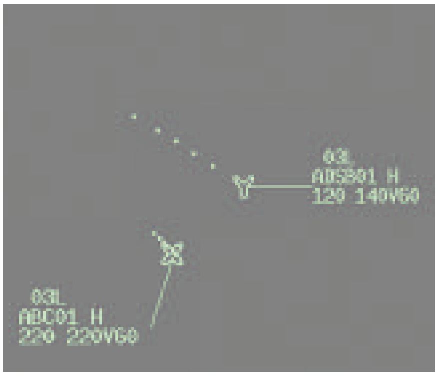
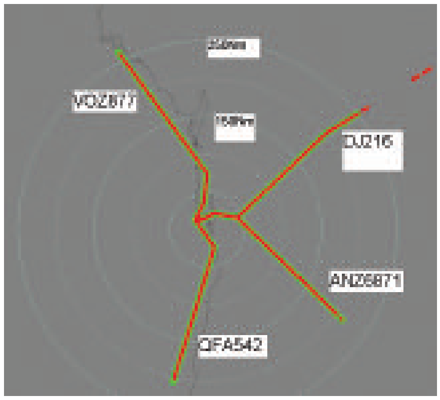


Figure 2 (above). Different ADS-B track symbols are used to convey the level of accuracy and reliability of data. Figure 3 (top right) compares red ADS-B tracks and green radar tracks for four flights. In Figure 4 (right) the ADS-B antenna can be seen mounted on one side of the Brisbane Airport radar tower.

Most importantly, ADS-B equipped aircraft will be provided with an additional safety net because of the ability to detect mismatches between controller expectation and reality. Both route conformance monitoring and cleared level adherence monitoring will be provided using ADS-B reports received every second. Today, in procedural airspace, reliance is placed on voice reports and, for some aircraft with FANS-1/A equipment, on ADS contract (ADS-C). Automated surveillance and detection using ADS-B will remove the reliance on voice reports and is expected to add significantly to en-route safety.

It is necessary that controllers be able to operate in a mixed equipage environment. While ADS-B separation will be applied in cases where both aircraft are equipped for this service, procedural ATC will be used otherwise. This is achievable in Australian airspace because of the capabilities of the Australian advanced air traffic system (TAAATS). Based on the Eurocat-X ATC system, TAAATS displays different position symbols for flight plan tracks, radar tracks, ADS-C and unique ADS-B position symbols. The display is based on a priority system: if the aircraft is detected by radar, the radar symbol is always displayed; where there is no radar detection, ADS-B symbols may be shown. Finally, when no surveillance data are available, a flight plan track is shown. If a radar track is also detected by ADS-B, a special indicator is depicted in the label.



In fact, two possible ADS-B symbols will be displayed under the UAP. These are illustrated in *Figure 2.* A Class 1 ADS-B symbol will be displayed when the data are received through ADS-B ground stations with a position accuracy and integrity adequate for the provision of a 5 NM separation standard. The track symbol shown at the left in Figure 2 is an example of a Class 1 track; this is the existing ADS-B track symbol being used in the Bundaberg ADS-B trial in Eastern Queensland.

The second track symbol will also be used any time data is received only from an ADS-B ground station, but in this case the data may have a theoretically lower reliability, for example, an ADS-B position report without the necessary integrity and accuracy to support the provision of the 5 NM separation standard. Such a report could result from an examination of the ADS-B downlinked integrity data or could apply to particular ground stations that were not designed to the same reliability standard. However, the positional data could be suitable for the application of another standard, provision of traffic information, situational awareness and automated safety alerting functions.

Policies, standards and procedures for the use of ADS-B surveillance using these track symbols in Australian airspace are currently under development. In the meantime, all contracts necessary for the purchase and deployment of the nationwide programme have been placed, including one with Thales ATM of France, for 28 duplicated ADS-B ground stations.

Contracts have been awarded for further enhancements to the ATC system, such as the ability to support 1,000 ADS-B reports per second, and graphical ATC displays of global positioning system (GPS) receiver autonomous integrity monitoring (RAIM) capability.

A separate back-up system has also been developed to deliver ADS-B tracks to controllers' displays in the event that the central TAAATS processing nodes fail, similar to a radar direct access or bypass channel. The processing is simple and uses the downlinked flight identity that is included in ADS-B messages. The bypass system has been built "in house" by a separate software team than that involved with the contractor's system, and has been subjected to the same system engineering and testing processes as the primary ATC system.

An ADS-B ground station software test bed has been established and will be used to manage the software configuration and testing of future software upgrades.

Factory testing of the ground stations has commenced and prototype stations established at Melbourne and Bundaberg. One such ground station was temporarily installed on the Brisbane Terminal area radar tower to provide a direct comparison of ADS-B and radar performance at a single location. This experiment showed that ADS-B detection capability and accuracy are equal to or better than radar. It has also demonstrated that ADS-B can coexist with existing primary and secondary surveillance radars.

Figure 3 illustrates MSSR tracks in green and ADS-B tracks in red. As shown in *Figure 4,* the ADS-B antenna mounted on the Brisbane radar tower is situated below the SSR antenna, accounting for the slightly lower range in most cases. Still, in some cases high integrity ADS-B messages from commercial in-service airliners were received from distances of more than 340 NM from the sensor.

These trials and initial deployments also showed a remarkably high "take-up rate" of the technology in commercial airliners. A significant percentage of Airbus A320 and A330s operating in Australia are equipped as well as numerous Boeing B737-800 and long-haul B777 aircraft. New aircraft from Boeing and Airbus typically include ADS-B capabilities. It is expected that by the end of 2005 a large percentage of high flying jets based in Australia will be fully equipped.

Many international aircraft have already been observed transmitting Mode S ADS-B messages in accordance with ICAO Annex 10* including Singapore Airlines, British Airways, Vietnam Airlines, Asiana, EVA Air, Cargolux and others (*Figure 5*). This is occurring largely because of the synergy created by the European requirements for elementary and enhanced surveillance and the fact that Boeing and Airbus have made this capability available on new aircraft. Typically, the major avionics manufacturers have included ADS-B functionality in the same transponder software upgrade as the enhanced surveillance upgrade. The same cannot be said for the manufacturers of regional aircraft, which have not yet included ADS-B avionics in new aircraft deliveries, although this is expected to change during the next year or two.

The installation strategy for UAP is to proceed simultaneously with a project to replace all existing VHF radios in Australia. As installation teams visit remote sites to replace old radios with new ones, they will also install the ADS-B receivers and antennas, and will connect these to the digital communications infrastructure. The ADS-B radio is DC-powered and consumes less than 100 watts. Some sites that are very remote and are powered by solar cells communicate with ATC centres via satellite. Remote monitoring and control is critical to successful deployment and considerable focus has been placed on this aspect during specification and testing. It will be possible, for example, to perform remote delivery of software upgrades.

The ease of installation has been demonstrated a number of times as Australia has deployed ground stations. At a recent ICAO ADS-B Task Force meeting in Singapore, three separate ADS-B ground station vendors set up live ADS-B demonstrations within a few hours of their ADS-B ground stations and antennas being released from customs.

A separate contract was awarded to the Volpe National Transportation Systems Center, part of the U.S. Department of Transportation, to develop enhancements to Australia's existing GPS RAIM prediction system. As Australia allows non-precision approaches to be flown using GPS receivers, the current system makes and electronically distributes predictions regarding the expected periods when non-precision approaches may not be available using Technical Standard Order (TSO) 129 GPS navigators. This system makes predictions for numerous airports in the region based on the satellite almanac and GPS notices to airmen (NOTAMs) on the assumption that the aircraft is using a TSO 129 navigator. The situation with ADS-B is different, since the predictions are required for geographical areas instead of defined airports with GPS approaches.

The RAIM system enhancements will initially deliver predictions for 1 degree latitude by 1 degree longitude blocks of airspace. The objective is to warn controllers of possible ADS-B outages that may arise from GPS satellite faults, maintenance or geometry. This is achieved by displaying a colour outline overlay on controllers' screens for areas that may be subject to an outage in the next tens of minutes (*Figure 6*).

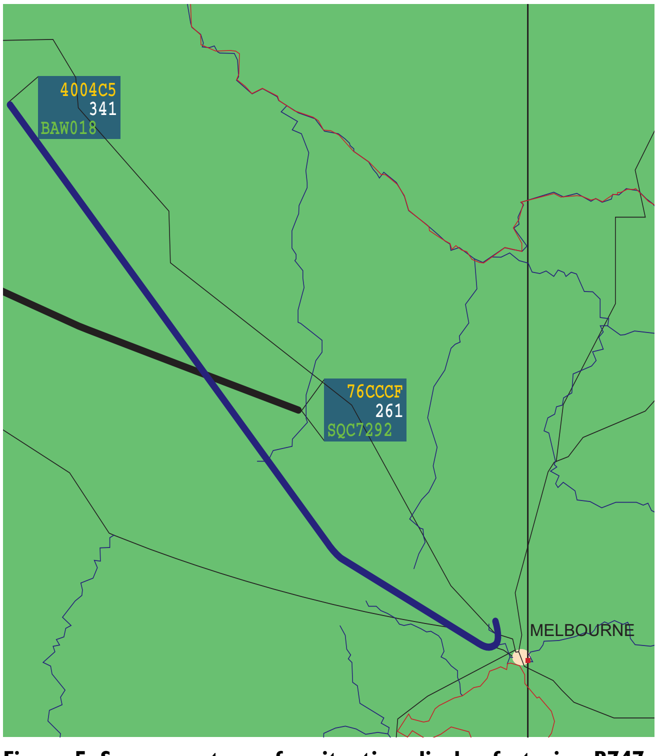


Figure 5. Screen capture of a situation display featuring B747s operated by British Airways and Singapore Airlines using an ADS-B receiver located at Melbourne Airport.

The UAP project is expected to start coming online in late 2005. Installation, training updates, certification and related activities are scheduled to occur in 2005.

Lower Airspace Project (LAP). The next envisaged step in Australia is to extend ADS-B benefits to those operating below FL300, and to strengthen the benefit package above that level. A project called the ADS-B Lower Airspace Project (LAP) is being developed for consideration by the

Australian aviation industry. LAP is being discussed extensively, and agreement has been reached on the scope of the project, which is now being subjected to a cross-industry business case that includes consideration of the overall costs and benefits to the industry and identifies which industry segments are net winners.

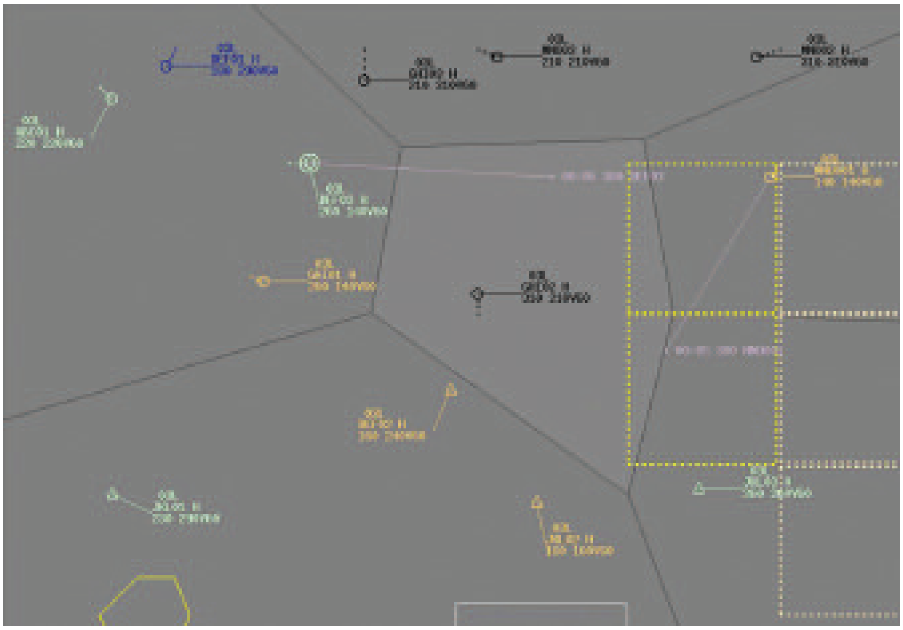


Figure 6. Colour outline overlay is used to warn controllers of areas that may be subject to GPS outage in a matter of minutes.

The project development phase has identified a synergistic benefit related to general aviation (GA) aircraft. Specifically, if a GA aircraft is fitted with ADS-B, it is almost essential to also equip that aircraft with a high-quality GPS system; for LAP, this has prompted inclusion of a plan to decommission some navaids as a result of the availability of high-performance GPS receivers installed as part of the ADS-B deployment.

The proposed scope of the LAP includes four elements, as described below.

The first element is the replacement of ageing en-route SSR-only radars in Australia with ADS-B ground stations. Existing terminal area radars will be replaced with new Mode S and short-range primary radars. For this to occur, and for the same level of service to be provided, it will be necessary for all aircraft using the controlled airspace currently served by en-route SSRs to be equipped with 1090 MHz extended squitter ADS-B capable avionics.

Second, there is a need to outfit a large portion of the Australian aircraft fleet with “ADS-B out” avionics. The Australian regulator has published two TSOs (C10005 and C10004) that outline a minimum avionics package for the low-end general aviation fleet. To ensure operators install the upgrade, the Australian industry is considering mandatory ADS-B equipage in certain airspace such as that served by existing en-route radars. A mandate will also significantly improve the benefits of ADS-B to those operating above FL300. Without such a mandate, ADS-B will only be advantageous in cases where two equipped aircraft are being separated, whereas with a mandate imposed equipped aircraft will derive the benefit when in proximity to any other aircraft.

Industry is also considering how mandatory equipage can best be funded, particularly for GA operators. Since airspace users effectively fund the deployment of navaids and radars in Australia, the financial advantage of not replacing these facilities can offset the cost of general aviation equipage allowing a transition to an ADS-B environment.

CASA, the Australian regulator, has published a discussion paper which considers these issues in general. These documents are available on the CASA website (http://rrp.casa.gov.au/dp/dp0410as.pdf).

A third element is the possible deployment of additional ADS-B ground stations to provide increased surveillance in regional Australia and at flight levels not served by the UAP. At this stage, a further 16 ADS-B ground stations could be included in the initial phase.

Finally, the project plans to decommission and not replace a significant number of VHF omnidirectional radio range (VOR) stations and non-directional beacons (NDBs) while maintaining a back-up network of navaids. In their place, TSO 145/6 GPS navigators would be approved for “only means” navigation. This is included in LAP because navigator avionics and ADS-B avionics share common elements and hence could be purchased and installed in the same subsidized avionics package.

To support LAP, Airservices Australia is working with GA avionics manufacturers to develop low-cost avionics. It is envisaged that an “ADS-B out” avionics unit will necessarily output a current aircraft position that visual flight rules (VFR) pilots will be able to view on simple cockpit displays such as a pocket PC or personal digital assistant (PDA). Such displays may include terrain maps. Airservices Australia has also purchased a 1090 extended squitter low-cost receiver allowing general aviation to display proximate traffic on multi-function or PDA displays. This unit is expected to be demonstrated in an aircraft in the first quarter of 2005.

The future. Once the fleet is transmitting ADS-B information, Australia expects to derive further downstream benefits in

continued on page 28

* Annex 10 to the *Convention on International Civil Aviation,* also known as the Chicago Convention, contains standards and recommended practices for aeronautical telecommunications. In all, 18 annexes to the Chicago Convention contain provisions for the safe, orderly and efficient development of international civil aviation.

Greg Dunstone is Manager of the ADS-B Programme at Airservices Australia. Based in Canberra, he also chairs the ICAO ADS-B Task Force established by the regional group responsible for air navigation planning and implementation in Asia/Pacific. Further details about the Australian programme are available at Airservices Australia’s website (www.airservicesaustralia.com).

ICAO Council appointment

H. A. Wilson (Saint Lucia)

Herald Alexander Wilson has been appointed Representative of Saint Lucia on the Council of ICAO. The tenure of Mr. Wilson commenced on 15 November 2004.

Mr. Wilson has acquired 36 years of experience in the field of civil aviation following his successful completion of an air traffic controller's course in Trinidad and Tobago in 1968. He holds a bachelor of science degree in aviation management from Embry-Riddle Aeronautical University in Florida, and a post-graduate diploma in professional aviation business management from McGill University of Montreal. His aviation training has taken him to the United Kingdom, Lebanon, the United States, Canada and Singapore, and has covered a wide range of subjects, among them aviation security, aircraft accident investigation, airport management, airworthiness administration, air transport and aviation safety oversight.

In 1984, Mr. Wilson was appointed Deputy General Manager of the Saint Lucia Air and Sea Ports Authority, where he was responsible for the operations and development of the two international airports on the island.

Mr. Wilson currently holds the position of Director General of Civil Aviation in the newly established Eastern Caribbean Civil Aviation Authority of the Organization of Eastern Caribbean States (OECS), which is a grouping of several small island States.

Mr. Wilson, the holder of a private pilot's licence, has represented Saint Lucia at many regional and international meetings, including bilateral and multilateral air services negotiations. □

ADS-B implementation

continued from page 8

the support of air traffic management. These may include:

- improved airport surface surveillance using ADS-B and multilateration;
- improved operational control and fleet management for all aviation sectors once surveillance data can be more easily shared;
- improved safety through surveillance data sharing between States, particularly at flight information region (FIR) boundaries;
- possible use of ADS-B for precision runway monitoring at Sydney;
- progression of airspace reform, giving greater freedom to recreational and glider communities;
- improved flow management; and
- the deployment of more advanced applications, such as the air-air applications being examined by Eurocontrol and the U.S. Federal Aviation Administration. □

ATC simulation

continued from page 12

valuable for training, but can also be used in other applications, thereby maximizing the purchaser's investment. For example, airport authorities can use the simulator to assess the traffic flow effects of new runway, taxiway and holding area configurations, and can even employ its "eye point" technique to optimally position a proposed new control tower or other visual or radar surveillance facilities. The eye-point feature is a unique tool which allows the controller to display the view seen from literally any location, including the flight deck of a selected aircraft, either in the air or on the ground, or from the cab of an airport surface vehicle or even a nearby mountain top.

Conversely, the eye-point feature can be used to assess whether a planned new terminal or other building — the location, shape and size of which can be simply, yet accurately, programmed into the tower's visual scene — will create unacceptable blind spots from the tower. In one such application, a European customer has already used Raytheon Canada's FIRST*plus* to help determine the optimum location of a soon to be constructed new tower and other airfield buildings. In a tower location study, of course, the eye-point feature allows controllers on the planning team to put themselves in the virtual tower at the appropriate height above the ground, where they can then assess the visual coverage of the airport from that location: an extremely helpful and potentially cost-saving planning capability. And perhaps even more valuable, air traffic specialists can use the simulator's radar displays to evaluate changes in airspace design, and assess the advantages and disadvantages of proposed reconfigurations and associated new procedures prior to their introduction.

Yet the simulator's training benefits are not limited to air traffic control applications. The airport visual scene, with its runways, taxiways and service buildings, coupled with the system's ability to simulate aircraft accidents and other airport emergencies, allow crash, fire and rescue personnel, airport security managers and others to create a wide range of adverse situations in order to assess current response strategies and, if necessary, develop new procedures.

When initially installed, the simulator's computers are normally configured to cover the user's airspace and airports as well as the current radar and tower control configurations although, as indicated above, any of these data can be readily modified by user personnel. The options available are too numerous to list but, to mention just two examples, paper or electronic flight strips in user-definable formats can be selected and military features, from arrester barriers to overhead formation breaks and even to the inclusion of unmanned aircraft, can be incorporated.

Advanced simulators also store virtually all recent civil and military aircraft types, together with their performance characteristics in various operating conditions and configurations. In the case of civil airliners, careful attention to an individual air carrier's distinctive paint scheme is also important, for it allows quick recognition by tower personnel of aircraft both on the aerodrome surface and in the air. In the case of a distant aircraft, a simulated binocular feature can be pointed at the target, allowing its type and colour scheme to easily reveal its identity.

The future. Clearly, air traffic controller training today is a far cry from those early days when a student's classroom instruction was simply a precursor to an extended apprenticeship within an operational organization.

Modern, realistic simulation training can now produce highly qualified individuals who not only understand the requirements and protocols of the various control positions at an ATC facility,