GENERAL AND SPORT AVIATION
AND THE USE OF SATELLITE-BASED SYSTEMS

(Particularly in Air Traffic Management)

The General and Sport Aviation sector should monitor what is going on in world Air Traffic Management or it may find that expensive and unsuitable electronic devices for position reporting may be mandated for them as well as other aircraft. This paper suggests a way forward

by Peter Hearne and Ian Strachan, October 2007

1. In some countries and some areas of airspace, Air Traffic Management (ATM) and Regulatory Authorities require both tracking and "electronic identification" of all aircraft. This trend is increasing, particularly where there is a forecast growth in Air Traffic. The authors of this paper are concerned that it may be thought that a future GNSS-based collision avoidance and identification system designed for the General Aviation and Sport Aircraft (GA/S) sector will be expensive, requiring equipment and costs more appropriate to Commercial Air Traffic (CAT). This may have led some of the GA/S community to dismiss future GNSS-based systems (such as ADS-B) as an alternative to radar-based transponders.

ADS-B stands for "Automatic Dependent Surveillance - Broadcast". It uses Global Navigation Satellite System (GNSS) data and a relatively simple low-powered broadcast link to transmit position and other aircraft data. This can be received by ground stations for Air Traffic Management and also by other aircraft for anti-collision purposes.

GNSS stands for Global Navigation Satellite System and is a generic term for all such systems. It includes the US GPS, Russian GLONASS, European Galileo and future systems.

Why might this apply to me? You might think "but this does not apply to me". Others have thought that they would not be affected, only to find that their own Regulatory Authority has a plan for the electronic identification (ID) of everything that flies. You might think that this would only include Commercial Air Traffic, military and the higher end of General Aviation (GA) like corporate jets. However, in some countries it includes microlights, gliders, motor gliders, hang gliders, para gliders and balloons. Safety from collision outside Controlled Airspace used to be a function of pilot airmanship and lookout, under the "see and avoid" principle. However, some Air Traffic Management (ATM) and Regulatory Authorities are now talking of "identify and avoid" in all classes of airspace. That is, to enable Air Traffic Controllers to electronically "see" everything that is airborne including outside controlled airspace. In addition, that all aircraft should have electronic warning of all other traffic, to reduce the risk of collision. The International Civil Aviation Organisation (ICAO) has recommended that in the future, all aircraft should have an electronic ID system that reports position and pressure altitude (Reference - ICAO Annex 6 parts 2 and 3). Although the responsibility of ICAO is primarily to Commercial Air Traffic, this has been interpreted by ATM and Regulatory Authorities in different ways. Some do not require electronic ID for GA and Sport aircraft operating outside Controlled Airspace. In some countries, all airspace is said to be "controlled" and the Authorities have to be asked to grant dispensations from certain regulations, many of which were originally designed for Commercial Air Traffic. Some Authorities have proposed a universal fit of radar transponders (including to microlights, gliders, hang gliders and balloons). However, many Authorities are introducing the GPS-based ADS-B system that is potentially more user-friendly to GA and Sport Aircraft because many of us are already carrying GPS for navigation display, flight recording and anti-collision functions.

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1.1 ADS-B is acknowledged as the system of the future for worldwide Air Traffic Management and for aircraft-to-aircraft anti-collision protection. It has been in development for at least 10 years and is now becoming operational in some parts of the world. When ADS-B is in full service it will give greater accuracy than radar and will allow a major reduction in expenditure on the present civil air traffic radar systems, many of which will be able to be eventually phased out. Australia already has 10 ADS-B operational ground stations (Annex A), and is commissioning some 20 more. On 1 October 2007, the US Federal Aviation Administration (FAA) issued a Notice of Proposed Rulemaking (NPRM) (Annex B) on a future ADS-B system. This shows that the US plans to build a network of no less than 548 ADS-B ground stations for North America and the Gulf of Mexico, the first one to be operational in 2010, the network to be complete in 2013. In Europe, it has also been reported (Annex C) that ADS-B may be adopted from 2015.

1.2 Looking at the specification for aircraft equipment, Commercial Traffic (CAT) flying in congested Controlled Airspace at transit speeds up to 500 knots TAS rightly has demanding requirements for "Required Navigation Performance" (RNP). Where GNSS-based equipment is concerned, the same requirements are not appropriate to aircraft flying at slower speeds and operating mainly outside controlled airspace. The slower speed does not imply lower accuracy. It implies that features such as anti-collision algorithms must be optimised for the tighter turn radius that can be achieved. Some features appropriate to CAT in busy terminal areas are simply not required by Light GA and Sport aircraft operating well away from such airspace. Therefore, there is a separate and less expensive requirement for GPS-based equipment that can be used for identification and collision avoidance in low speed aircraft, where they are flying is airspace where electronic ID is required.

1.3 GPS receivers used by Commercial Air Traffic will need the internal integrity monitoring necessary to carry out Category 1 approaches in low visibilities (IMC). They may also include GPS augmentation systems such as local differential beacons and area enhancements. Area enhancement systems include WAAS in the USA, EGNOS (Europe), GAGAN (India), GBAS (Australia), MSAS (Japan), Beidou (China) and equivalent systems. In due course, developments of these such as Local Area Augmentation Systems (LAAS) will enable the use of GPS for Cat 2 approaches and eventually Cat 3 when used in compound systems with dissimilar sensors such as Kalman-filtered Inertial Navigation Systems (INS) and Head-Up Displays including Infra Red imagery (HUD/FLIR).

1.4 There is no scientific reason for Regulatory bodies to require slower-speed GA/Sport aircraft using GPS outside Controlled Airspace (currently "free" of many restrictions that apply in Controlled Airspace) to meet requirements which are in excess of those for radar transponder equipment designed for higher speed CAT in controlled airspace (such as the latest Mode S transponders). The minimum equipment standard for GNSS for GA/Sport aircraft should therefore have performance and integrity similar to a current Mode S transponder system.

1.5 When GPS requirements are considered for anti-collision and identification purposes for GA/S traffic below, say 200 kts TAS, a different GNSS specification should be used. Equipment should be similar to the GPS already used in existing GA/Sport aircraft and should provide a level of accuracy, reliability and integrity superior to existing radar transponder systems including Mode S.

2. Some Regulatory Authorities such as the UK CAA have already accepted the principle of different technical levels of equipment more suited to GA/Sport aircraft by encouraging the development of a Low Powered mode-S Transponder (LPST). A similar approach should be taken for the certification of GNSS-based systems for identification, collision avoidance and non-RNP operations. That is, to accept low-cost GNSS-based anti-collision systems similar to the Swiss-produced GPS-based FLARM (Flight Alarm) with the addition of a longer range ADS-B-compatible radio link.

2.1 Anti-collision calculations using radar transponders are not as accurate or consistent as even the low cost GPS systems used by GA/Sport aircraft today. GPS performance has been extensively recorded for many years by gliding and other sport aviation activities. For instance, records of GPS accuracy from the FAI International Gliding Commission (IGC) using thousands of data points, show an overall average position error of 11.43 metres, much better than radar. These are from tests from moving vehicles over a number of accurately-surveyed ground points using the low-cost GPS receiver units that are fitted to IGC-approved Flight Recorders. In contrast, reliability figures for the latest Mode S transponders (in terms of availability in flight) appear to be not as good as current results from low-cost GPS systems. Finally, recent tests in The Netherlands of a battery-powered transponder have shown a battery life of some three hours in a multi-target environment where many transponder "replies" are required, well under the flight time of many GA and Sport aircraft.

3. To provide for Light GA and Sport aircraft in the future it is suggested that:

3.1 Regulatory bodies should be asked to publish the standards of performance, reliability and integrity which are actually being achieved in day-to-day commercial aircraft operations by the present transponder system including the latest Mode S devices. This data should then be used in defining the performance standards against which future systems will be accepted, including the GNSS-based systems of the future.

3.2 Regulatory bodies should be asked to draw up a specification for GNSS-based systems for low-speed aircraft based on the anti-collision principles such as those already in operational use in the Swiss FLARM system. In terms of cost, a basic FLARM unit retails at about 600 Euros. It has been reported that some 9000 FLARM devices are in service worldwide, fitted to gliders and other light aircraft. Other GPS-based anti-collision systems are already being developed such as the Filser TM200 which is understood to be priced at about 1000 Euros. Other companies are also understood to be developing such equipment for the GA/Sport aircraft sector.

3.3 The specification for an enhanced FLARM-type of system should include the transmission of aircraft position to ground stations in the internationally-agreed ADS-B message protocol and at a range appropriate to future Air Traffic Management (ATM) systems. Such systems can then be manufactured by a number of companies and approved by the various aviation Regulatory Authorities for use in the Light GA and Sport aircraft sectors.

4. The present radar-transponder-based Traffic alert and Collision Avoidance System (TCAS) requires each aircraft to digitise its airspeed, altitude heading and position. TCAS is an application of the Airborne Collision Avoidance System (ACAS), an ICAO standard. This data is then formatted for transmission and reception in the form of a "squitter" link in the transponder message that forms part of the radar interrogation process *(Squitter messages are down-link transmissions from a Mode S system, allowing passive acquisition of the data by other aircraft)*. This process is not without a price and any Low Cost mode S Transponder, if one is developed, is likely only to provide range and height (derived from time and distance measurement) when installed in light sports aircraft and those with limited or no electrical generating power (other than batteries charged before flight). There are also large numbers of older light GA aircraft to be considered. Although recent developments in instruments (the "glass cockpit") enable such outputs to be available to a transponder, it may be some time before these are fitted to a significant proportion of Light GA aircraft.

4.1 For an aircraft to have Mode S anti collision information, it needs TCAS. This is unlikely for most GA/Sport aircraft because high cost, power consumption and weight is likely to restrict the use of TCAS to CAT and corporate aircraft such as high-end GA (business jets and the more expensive range of propeller twins). Indeed, most pilots of GA/Sport aircraft will have little or no benefit themselves from fitting a Mode S transponder.

5. In terms of collision avoidance, minimising "GA on GA" and "GA on Military" conflicts is as least as important as "light GA on CAT and corporate aircraft". CAT and high-end corporate GA will be virtually the only ones to benefit from a universal fit of Mode S transponders.

5.1 On the other hand, ADS-B will enable better anti-collision protection for ALL classes of aircraft because when it comes in, more aircraft will be fitted with it. For instance, there are advantages to Light GA and Sport aircraft in carrying ADS-B. One is the ability to use the GNSS data to feed cockpit moving-map displays, many of which are already in use in LCD-based cockpit instruments or in bracket-mounted PDAs. These moving-map displays are a powerful aid in reducing inadvertent airspace infringements. Such low-cost ADS-B systems will provide improved navigational accuracy and collision avoidance between Commercial, Military and GA/Sport aircraft compared to the systems of the radar transponder era. Experience suggests that future international agreements will require compatibility between ADS-B (GPS based) collision avoidance and the older radar-transponder-based systems.

5.2 It has been forecast that many Unmanned Air Vehicles (UAV) will be used in the future. These will vary from military applications to general surveillance for mapping and other purposes such as border patrol. Sizes will vary from large long-endurance military vehicles to those similar to model aircraft. For all but the largest UAVs, ADS-B is the technology most likely to meet the demanding weight, space and power constraints in many UAVs.

6. Within Europe, the EUROCAE organisation (see italics below) should be involved in a similar way to RTCA in the USA (also see italics below). Other than in the USA, a single-nation system is unlikely to generate a sufficiently large market to achieve viable production prices. The involvement of EUROCAE within Europe would help international compatibility through its liaison with equivalent US bodies such as ARINC and RTCA.

EUROCAE stands for the European Organisation for Civil Aviation Equipment, It is the agency for certifying aviation equipment in Europe. Sport aviators already attend EUROCAE meetings, for instance an FAI representative who also attends RTCA meetings.

ARINC stands for Aeronautical Radio Inc and is used by the US FAA to develop and publish numbered standards.

RTCA is concerned with aviation electronic systems and acts as a US Federal Advisory Committee. The initials used to stand for the Radio Technical Commission for Aeronautics.

Source: Glossary to the Flight Recorder Specification of the International Gliding Commission (IGC) of the Fédération Aéronautique Internationale (FAI).

7. **Conclusion**. Where Regulatory Authorities might require General Aviation and Sport Aircraft to be electronically identified, we should be looking beyond the radar transponder era.

7.1 Radar Transponders. Concentration on the Mode S radar transponder system without consideration of the inevitable transition to future satellite-based systems, hinders improvements in collision avoidance in the largest worldwide aircraft group, that is, General and Sport Aviation. It is unlikely that it will be possible, on grounds of cost alone, that many GA/sport aircraft will be able to install the current Traffic alert and Collision Avoidance System (TCAS) system that makes the same use of Mode S transponder signals as in the well-financed Commercial Air Traffic, Corporate and Military sectors of aviation.

7.2 GNSS-based Systems. In contrast, many GA/sport aircraft carry GPS now and some 9,000 are already fitted with the Swiss FLARM GPS-based anti-collision system. A longer-range FLARM-type system using the ADS-B "squitter protocol" (see para 4) is forecast to be possible at prices under 1500 Euros and could be made by a number of different companies. This protocol is compatible with both Commercial Air Traffic, Military and GA/Sport aircraft in the future. The Automatic Dependent Surveillance - Broadcast system (ADS-B) is planned for future worldwide adoption. Australia already has 10 operational ADS-B ground stations with more to come and a network of over 500 ground stations in the USA is planned to be operational between 2010 and 2013. Finally, ADS-B is also the technology most likely to meet the demanding weight, space and power constraints in UAV operations that are forecast to be widespread in the future.

Annexes:

A. Australian ADS-B progress

B. US FAA NPRM 7-15 dated 1 October 2007 on ADS-B - extracts

C. Article - Europe to fit ADS-B

Annex A

Australian ADS-B Programs

from the web 2007-10-16 - http://www.airservicesaustralia.com/

Airservices Australia is expanding its Automatic Dependent Surveillance Broadcast (ADS-B) activities in order to promote and exploit the safety and operational benefits made possible by the new data link technology. Four correlated ADS-B programs are currently in various stages of development. A brief synopsis of each program is outlined below. For more information, click on the associated links.

1. **Australian Transition to Satellite Technology (ATLAS)**

Recent advances in the use of Global Navigation Satellite Systems (GNSS) for "only means" navigation and the use of Automatic Dependent Surveillance Broadcast (ADS-B) for radar-like services has made these two technologies viable options to advance Australian navigation and surveillance infrastructure into the 21st century. Australian Government aviation agencies are seeking comment on the proposed wider application of ADS-B and GNSS technologies to replace some of the existing radar and navaid network. A Joint Consultation Paper has been prepared by Airservices Australia, the Australian Defence Force, the Civil Aviation Safety Authority and the Department of Transport and Regional Services. The paper sets out the proposal, including discussion of proposed funding arrangements and regulatory changes. The paper and supporting material is available from:

http://www.dotars.gov.au/aviation/airspace_reform/satellite_tech.aspx.
Status: Joint Consultation Paper published. Response period closes 31 October 2007

2. **Upper Airspace Program**

A program aimed at providing near-term safety and operational benefits in high level, non-radar airspace. Includes installation of approximately 28 ADS-B ground stations, strategically located across Australia to provide air traffic surveillance above 30,000 feet in continental airspace outside of radar coverage.

Status: In progress - **10 of 28 ground stations commissioned and in use**

3. **Research and Development Programs**

R & D activities to facilitate the Lower Airspace ADS-B Programs. Activities include development of low-cost ADS-B transmitters for general aviation aircraft, air to air ADS-B receivers and cockpit displays to provide airborne traffic information to pilots.

Status: In progress

4. **International Activities**

Airservices Australia on behalf of Australia is participating in a number of international forums and panels developing standards and procedures for the implementation of ADS-B technology for air traffic control. Airservices Australia also provides consultancy services in support of ADS-B programs in other States.

Status: In progress

Annex B - FAA NPRM 7-15 on ADS-B - issued in Washington DC on October 1, 2007

These are extracts by that could be useful to the GA and Sport Aircraft community. The complete NPRM is worth reading, because it gives a lot of detail on the various facilities of the future ADS-B system

Page 12: The FAA believes that ADS-B technology is a key component in achieving many of the goals ... a new approach to surveillance performance requirements that can lead to greater and more efficient use of airspace. ... **While radar technology has advanced, it is essentially a product of 1940s World War II technology.**

Page 14: The future of air traffic surveillance cannot be based solely on the use of radar**. Radar technology also lacks the capability to provide services on the flight deck**. ... Newer and more advanced onboard avionics ... provide more accurate and timely aircraft information. ADS-B has been identified as the technology.

Page 15: The Global Positioning System (GPS) ... makes this information **more timely and accurate** than the information provided by the conventional radar system which has a latency factor since it is based on interrogation and reply.

Page 17: The preliminary estimate approved by the FAA's Joint Resource Council calls for **548 ground stations** to provide coverage for the National Airspace System (NAS) and in the Gulf of Mexico.

Page 18: **All ground infrastructure, including the provision of broadcast services, to be in place and available where current surveillance exists by the end of fiscal year 2013**.

Page 20: Accuracy and integrity of radar information is a function of range and decreases with distance **... Unlike radar, both the accuracy and integrity of ADS-B Out is uniform and consistent** throughout the service area.

Page 21: **We expect a reduction in aircraft fuel burn ... better surveillance ... more efficient use of airspace ... optimal aircraft routing ... addresses limits currently experienced with radar**.

Page 24: **The International Civil Aviation Organization (ICAO) is in the process of updating** the 1090ES Standards and Recommended Practices (SARPs). These updated SARPs are expected to become effective in November 2007.

Page 34: **The proposed accuracy requirement could make it possible for future airspace separation to be reduced**.

Page 50: **A 10-year compliance window gives the aviation community ample time to manage costs** and minimize the impact of ADS-B installation on their normal operations.

Page 56: Conflict Detection. The application would alert pilots of developing conflicts. Also, the surveillance range afforded by ADS-B would enable alerts to be issued in time to resolve potential conflicts with **minimum flight path disruption**.

Page 58: The Capstone safety program reduced the aircraft fatal accident rates for Alaska part 135 operators equipped with Capstone avionics by 45%. While this accident reduction is not solely attributable to ADS-B, the **ADS-B information in the flight deck did provide increase pilot awareness of surrounding traffic and directly contributed to the accident rate reduction**. In addition, search and rescue efforts for individuals in equipped aircraft has been dramatically improved.

Page 61: **EUROCONTROL is considering a plan to install ADS-B** ground broadcast transceivers in European areas that do not have adequate radar coverage ... proposed guidance is to use ADS-B for surveillance in medium density airspace where there is currently no surveillance capability.

Page 62: **Airservices Australia is installing ADS-B ground stations ... NAV Canada anticipates having ADS-B in Canada. The FAA is working with EUROCONTROL, Airservices Australia and NAV CANADA to harmonize operational concepts and minimum safety and performance requirements for ADS-B**.

Page 63: Since ADS-B employs one type of receiving equipment, it does not have to accommodate transition between differing surveillance systems. The consistency of the signal and information could increase the productivity of air traffic controllers.

Page 89: ICAO is developing standards that are ... similar to U.S. RTCA standards. **The FAA is actively engaged with the international community to ensure that the international and US ADS-B standards are as compatible as possible**.

Annex C: Extract from Flight International, 10 July 2007 page 10

Europe targets ADS-B for all flights by 2015

Air traffic management consultation document next year

by David Learmount, London

Europe has agreed on the objectives of a programme to introduce Automatic Dependent Surveillance - Broadcast (ADS-B) across the EU member states and beyond. Stakeholders, including the European Commission, will publish a consultation document by the second quarter of 2008. Rules for implementing ADS-B air traffic management surveillance are due in the first half of 2009.

Europe wants full user compliance by 2015 with a progressive increase in voluntary participation before then. Eurocontrol is working with some 'pioneer' carriers equipped with ADS-B extended squitter transponders.

Agreement on an ADS-B timetable was a big step toward Europe's future ATM surveillance system. It was not a surprise because a Eurocontrol survey of all affected industry players had already found that 70% of air-lines favoured ADS-B, according to Eurocontrol's CASCADE programme manager Alex Wandels.

CASCADE is Eurocontrol's programme for developing and co-ordinating datalinking strategies. The agreed international standard, certain to be reflected in the European draft rule, is based on 1096MHz ADS-B extended squitter (1090ES) transponders linked to an onboard global navigation satellite system receiver so aircraft can automatically transmit their position, identification and other data.

Wandels says 80% of carriers using Paris airports - where one of many ADS-B ground stations is located - are equipped with 1090ES but the equipment has only trial status at present and is not certificated.

The International Air Transport Association has approved the 1090ES standard for 100% airborne equipage of "ADS-B out" - the category that allows ATM surveillance - by 2015. Many will also have "ADS-B in", enabling aircraft to exchange position data.
