INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

REPORT OF

ADS-B SEMINAR AND THE SIXTH MEETING OF
AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B)
STUDY AND IMPLEMENTATION TASK FORCE (ADS-B SITF/6)

Seoul, Republic of Korea, 23-27 April 2007

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SUMMARY OF DISCUSSIONS

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1. Introduction

1.1 The ADS-B Seminar and the Sixth Meeting of Automatic Dependent Surveillance – Broadcast (ADS-B) Study and Implementation Task Force (ADS-B SITF/6) were held in Seoul, Republic of Korea from 23 to 27 April 2007. The Seminar and the Meeting were hosted by the Korean Civil Aviation Safety Authority (KCASA) and the Incheon International Airport Corporation (IIAC).

1.2 Honorable Vice Minister, Ministry of Construction and Transportation Mr. Choon-Hee Lee attended the opening ceremony. The Seminar and the Meeting were opened by the Head of KCASA, Mr. Sang-Ho Chung who extended a warm welcome to all of the participants. He stated that global aviation has experienced a significant growth for both passengers and cargo in Asia and Pacific Region in particular has shown the world's highest growth rate. He highlighted the importance of implementation of CNS/ATM systems including ADS-B as adopted by ICAO. In order to cope with the growth of air traffic, Republic of Korea has plan to significantly expand research and development project for the implementation and will continue working together with ICAO member states in the Region. He further stated that the Meeting will address various issues and develop plans to introduce ADS-B on time in Region in accordance with global roadmap set by ICAO.

1.3 On behalf of the President of the ICAO Council, the Secretary General, and the Regional Director of the ICAO Asia and Pacific Office, Mr. Jim Nagle, Chief CNS Section from ICAO HQ Montreal, extended warm welcome to all of participants. He expressed gratitude and appreciation to the Ministry of Construction and Transportation of the Republic of Korea. He thanked the KCASA and the IIAC for hosting the event in Seoul and for the excellent arrangements made for the Seminar and the Meeting. He highlighted the challenges as result of the unprecedented growth of global civil aviation and the recent Performance Based Navigation (PBN) and ADS-B related developments. He also highlighted the tasks to be taken by the Task Force and emphasized the important role of the Task Force and Seminars in exchanging ADS-B related information. He encouraged that implementation of ADS-B shall be in harmonized. He thanked all contributors and experts for supporting the Seminar.

1.4 In his opening remarks, Mr. Greg Dunstone, Chairman of the Task Force, highlighted the importance to improve surveillance and ATC capabilities in meeting the needs rapid air traffic growth. He recalled history of ADS-B and recent developments by the ADS-B Task Force. He stated that ADS-B is no longer a question for its widespread; it is now just a question of when that it will arrive in each State. He also highlighted the work need to be continued by the Meeting.

1.5 Mr. Jaehee Lee, President and CEO of the Incheon International Airport Corporation, extended a warm welcome to the participants and emphasized the need for the timely implementation of ADS-B. As an awarded best airport in the past two years, he expressed thanks for all support and his pleasure in jointly hosting the ADS-B Seminar and the Sixth Meeting of ADS-B Study and Implementation Task Force.

2. Attendance

2.1 The Seminar was attended by 210 participants and the Meeting was attended by 70 participants from Australia, Cambodia, China, Hong Kong-China, Fiji, France, India, Indonesia, Japan, Malaysia, Maldives, Nepal, New Caledonia, Pakistan, the Philippines, Republic of Korea, Singapore, Sri Lanka, Thailand, USA, Viet Nam, Austro Control, IATA, SITA and representatives from 9 industries. List of participants is at **Attachment 1.**

3. ADS-B Seminar

3.1 The ADS-B Seminar was organized in conjunction with the ADS-B SITF/6. The objective of the Seminar was to provide information to the participants on ADS-B planning and implementation. The Seminar was presented with 25 presentations covering a comprehensive list of topics on the ADS-B as follows:

- Basic ADS-B Concept, applications
- Global Air Navigation Plan and development by ADS-B related panels
- APANPIRG and ADS-B SITF activities
- Introduction to Multilateration
- Ground stations and Service provider
- ATC Automation and ADS-B
- Avionics products review
- States and ANSP trials, projects and deployment plan
- View of air space users
- Regulatory Considerations

3.2 During the Seminar, a number of speakers from various States and Industries provided valuable information on the ADS-B. The ADS-B Seminar was well received by all participants.

3.3 A demonstration on ADS-B ground station using 1090 ES link was provided by Thales ATM during the Seminar.

4. Officers and Secretariat

4.1 Mr. Greg Dunstone, Surveillance Program Leader of Airservices Australia chaired the Seminar and the Meeting. Mr. Jim Nagle, Chief CNS Section, ICAO Headquarters and Mr. Li Peng, Regional Officer CNS, ICAO Asia and Pacific Office acted as Secretaries.

5. Organization, working arrangements and language

5.1 The Meeting met as a single body for the Seminar and the Meeting except for first day of the Meeting on which four ad hoc working groups were established to discuss proposals for sub-regional implementation plans. The working language was English inclusive of all documentation and this Report. List of Working Papers and Information Papers presented at the Seminar and the Meeting is at **Attachment 2.**

Agenda Item 1: Adoption of Agenda

1.1 The agenda adopted by the meeting was as follows:

Agenda Item 1: Adoption of Agenda

Agenda Item 2: Review the outcome of the APANPIRG/17

Agenda Item 3: Review the guidance of revised global air navigation plan and progress made by ADS-B related ICAO panels

Agenda Item 4: Review Subject/Tasks List and List of Action Items

Agenda Item 5: Review the revised Terms of Reference

Agenda Item 6: Consider proposals to develop document (s) which compare alternative surveillance technologies

Agenda Item 7: Development of Asia/Pacific Regional ADS-B implementation plan, Cost benefit study and sub-regional based ADS-B implementation plan

- Reports by city pair teams;
- Review recommendations of city pair teams; and
- Identify sub-regional area (FIR) where there is a positive cost/benefit for Near-term implementation of ADS-B OUT

Agenda Item 8: Study and development of documents regarding multilateration applications

Agenda Item 9: Review States' activities and interregional issues on trials and implementation of ADS-B

Agenda Item 10: Discuss issues observed during the trial and implementation of ADS-B including review items from ADS-B Problem report database

Agenda Item 11: Any other business

Agenda Item 2: Review the outcome of the APANPIRG/17

2.1 Under this agenda item, the meeting reviewed the outcome of the Seventeenth Meeting of APANPIRG (APANPIRG/17) on matters relating to ADS-B.

2.2 It was noted that the APANPIRG/17 held from 21 to 25 August 2006 in Bangkok reviewed the work accomplished by the Fifth Meeting of the ADS-B Study and Implementation Task Force. It was also noted that the report of the Fifth Meeting of the Task Force was reviewed by CNS/MET SG/10 meeting held in Bangkok from 17 to 21 July 2006 and ATM/AIS/SAR SG/16 meeting held from 26 to 30 June 2006.

2.3 The APANPIRG/17 in its Conclusion 17/25 adopted the first Amendment to the ADS-B Implementation and Operational Guidance Document (AIGD) which is posted on the ICAO APAC website: http://www.icao.int/apac/edocs/index.html

2.4 The APANPIRG/17 meeting adopted Conclusion 17/26 regarding the need to study and investigate an expeditious way of presentation of ADS-B Data using ACAS hardware. It was informed that the Air Navigation Commission while reviewing report of APANPIRG/17 noted that the subject had been under investigation by the industry (under the titles of "hybrid surveillance" and "airborne surveillance applications"). It was also noted that recommendation of the ANC on this issue was to follow-up on relevant developments.

2.5 The APANPIRG/17 meeting made a decision on the development of Strategy for the implementation of surveillance systems in the ASIA/PAC region and adopted a revised Terms of Reference (TOR) for the ADS-B Study and Implementation Task Force.

Agenda Item 3: Review the guidance of revised global air navigation plan and progress made by ADS-B related ICAO panels

3.1 Under this agenda item, the meeting reviewed a paper presented by the Secretariat on the development of the Global Air Navigation Plan and updates on ADS-B related Panels.

Global Air Navigation Plan

3.2 The meeting noted that in 1998, the Global Plan was issued and followed by the first amendment in 2001. In light of the outcome of the Eleventh Air Navigation Conference(AN-Conf/11) held in 2003 and the Sixth Meeting of the Air Navigation Commission and in consultation with Industry in May 2004, the second amendment to the Global Plan was prepared in January 2006. The fifth meeting of ALLPIRG reviewed the amendment and provided their comments in March 2006. Comments received from States were reviewed by the Air Navigation Commission on 19 October 2006. The Council accepted the second amendment on 30 November 2006. The approved plan has been renamed as Global Air Navigation Plan (Doc.9750) and has already been translated in different languages. The official version of the plan will be distributed shortly.

3.3 It was noted that the Global Plan focuses efforts on maintaining consistent global harmonization and improving implementation efficiencies by drawing on the existing capabilities of the air navigation infrastructure and successful regional implementation. The Planning and Implementation Regional Groups (PIRGs) are expected to follow up on matters as stated below:

a) note that the Global Plan is a significant component in the development of regional and national plans and that, together with the global ATM operational concept, it provides an effective architecture for achieving a harmonized and seamless Global ATM system;

b) identify Global Plan Initiatives (GPIs) that most closely align with the well established implementation plans of their respective regions;

c) choose GPIs that would be most effective in achieving the objectives of the region while ensuring continuation of the work already accomplished;

d) implement GPIs that take into account the initiatives across regions, to align work programmes and to develop national and regional plans that facilitate achieving a Global ATM system;

e) utilize the planning tools as the common planning and implementation mechanism, thereby ensuring proper coordination and global integration; and

f) review at each PIRG meeting, as a part of its regular agenda, the progress achieved and challenges identified in the implementation of GPIs using a common template.

Development by Panels

3.4 It was informed that the effective dates of amendments to PANS-ATM as proposed by first meeting of OPLINK Panel including ADS-B based separation, etc. will be on 22 November 2007. As to the work of SAS Panel on ADS-B, the work to support 5 NM separations with ADS-B has been completed and has been published as Circular 311. Work has started to simultaneously obtain 3 NM separation approval for ADS-B and Multilateration. The expected publication is in early 2009.

3.5 Aeronautical Surveillance Panel (ASP) developed SARPs and supporting technical specifications for a new version of extended squitter messages (name as Version 1) in support of ADS-B which has improved elaboration of navigation and surveillance accuracy. The new and amended SARPs will be a part of Amendment 82 to Annex 10. Associated technical specification will be published as Technical Provisions for Mode S and Extended Squitter (Doc 9871) later this year. The meeting also noted the current work programme of ASP.

Agenda Item 4: Review Subject/Tasks List and List of Action Items

4.1 Under this agenda item, the meeting discussed subject and tasks to be undertaken by the Task Force.

4.2 APANPIRG/17 meeting had noted that many tasks identified in the Subject/Tasks list for ADS-B SITF had been completed and adopted a new TOR for the Task Force. According to the revised TOR, a draft Subject/Tasks list was initially prepared by the Chairman of the Task Force and distributed to Task Force members in November 2006.

4.3 The meeting reviewed and discussed the draft Subject/Tasks list prepared in a format associated with ICAO strategic objectives and GPIs. As a result of discussion, the meeting agreed to add a new item on the study and development of guidance material for ATM processing capability for integration of output of ADS-B and other surveillance sources. The meeting also agreed to further work on methods of computing the probability of detection at an ADS-B ground station and recommendation of the minimum probability of the detection required from a ground station for the provision of ADS-B service. The use of ADS-B reports from aircraft with low percentage of good NUC values for ATS needs to be reviewed and considered. l. These action items should be reflected into the Subject/Tasks List.

4.4 The meeting considered the need to continue its efforts in developing the sub-regional ADS-B implementation plan and project. It was agreed that the issues emerged during the trial and implementation stages should also be appropriately addressed by the Task Force. The exchange of information and experiences gained during the trial and implementation of ADS-B should be further encouraged. Accordingly, the meeting formulated the following draft Decision for adoption of the subject/tasks list

Draft Decision 6/1 - Subject/Tasks List of ADS-B Study and Implementation Task Force

That, the subject/tasks list for ADS-B Study and Implementation Task Force provided in **Appendix A** to the Report be adopted.

Agenda Item 5: Review the revised Terms of Reference

5.1 Under this agenda item, the meeting reviewed and discussed the new TOR of ADS-B Study and Implementation Task Force adopted by the APANPIRG/17 meeting.

5.2 It was noted that the APANPIRG/17 had noted the challenges faced by the Task Force in completing the task of region wide ADS-B cost/benefits study as indicated in its report. It was also noted that many tasks in the Subject/Tasks list have been completed. The meeting considered the comments in this regard made by the ATM/AIS/SAR Sub-group, CNS/MET Sub-group and IATA. The meeting established an ad-hoc working group to develop revised TOR for ADS-B Study and Implementation Task Force. It was considered necessary for the ADS-B Study and Implementation Task Force to further develop implementation plans for the near term ADS-B applications and to make comparison of alternative technology/solutions for surveillance. The meeting supported to study multilateration with specific considerations. The meeting also encouraged member States of the ADS-B SITF to make necessary arrangements for more participants with ATM and operational background to attend the future Task Force meetings.

5.3 While reviewing its TOR adopted by the APANPIRG/17, meeting considered that the TOR 1 (Technology comparison) was effectively completed during the meeting through provision of the Guidance Material on Comparison of Surveillance Technologies. Further significant progress on TOR3 (multilateration) was achieved by the production of Concept of Use for Multilateration. As a result of discussions, the meeting proposed a revised TOR for consideration by APANPIRG and formulated the following draft decision:

Draft Decision 6/2 - Revision of the Terms of Reference

That, the revised Terms of Reference (TOR) of the ADS-B Study and implementation Task Force shown in **Appendix B** to the Report be adopted.

Agenda Item 6: Consider proposals to develop document(s) which compare alternative surveillance technologies

6.1 Under this agenda item, the meeting reviewed a draft guidance material on comparison of the various surveillance technologies and a proposal for an amendment to the AIGD presented by Australia.

The guidance material on comparison of the various surveillance technologies

6.2 In order to meet one of the objectives specified in the revised TOR of the ADS-B Task Force, action was initiated and an initial draft of the paper prepared was distributed to members of the Task Force during the end of 2006. Comments received were consolidated into a draft paper.

6.3 In the draft paper it was recommended that States should actively consider ADS-B and Multilateration as the choice of replacement and new surveillance technology within the scope of available options, with particular regard to performance, cost and harmonization with global ATM concept developed by ICAO. It was also recommended that reference should be made to available documents developed by ICAO Panels and the guidance material adopted by ICAO such as ADS-B concept of use and the comparison matrix as developed by the SAS Panel. It was noted that the comparative performance and costs are highly variable dependent on the environment. Considerable care is required to ensure that site costs and lifetime support costs are considered.

6.4 As a result of the review and the foregoing recommendations the meeting further edited and amended the paper. The material was considered as a very useful document for planning surveillance infrastructure by States. The meeting therefore agreed to submit it for adoption by APANPIRG as a regional guidance material. In light of foregoing, the meeting formulated the following draft Conclusion:

Draft Conclusion 6/3 - The guidance material on comparison of the various surveillance technologies

That, the guidance material on comparison of the various surveillance technologies (GMST) provided in the **Appendix C** to the Report be adopted.

Amendment of ADS-B Implementation and Operations Guidance Document (AIGD)

6.5 The meeting reviewed a proposal to added new sub-paragraph into the AIGD in a Request for Change Form.

6.6 In order for controllers and pilots to be aware of different airborne ADS-B installations, their operation/limitations, including handling in exceptional cases and the impact these different installations can have on air traffic services, it was considered necessary to provide training to controllers on such issues. The meeting agreed to add the examples of radio telephony and/or CPDLC phraseology as recommended in the proposed amendment.

6.7 It was reconfirmed by IATA that despite the desirability of such functionality, no separate ADS-B switch-off option exists in the transponder control panels of most aircraft. Therefore, if ADS-B is switched off, TCAS protection could be disabled. It was recognized that crews need to be educated to respond UNABLE when requested to switch off ADS-B whether such action disables the transponder.

6.8 The meeting also agreed to add additional text into the paragraph 5.9.2.1 of AIGD regarding the explanation of flight plan and flight planning requirements.

6.9 In light of foregoing, the meeting formulated following draft Conclusion for the amendment of the ADS-B Implementation and Operations Guidance Document (AIGD):

Draft Conclusion 6/4 - The Second Amendment to the AIGD

That, the ADS-B Implementation and Operations Guidance Document (AIGD) be amended as shown in the **Appendix D** to the Report.

Agenda Item 7: Development of Asia/Pacific Regional ADS-B implementation plan Cost benefit study and sub-regional based ADS-B implementation plan

7.1 Under this agenda item, the meeting reviewed and updated the ADS-B aspect of CNS/ATM Implementation Planning Matrix presented by the Secretariat. It was noted that the matrix was regularly updated by CNS/MET Sub-group of APANPIRG and the Task Force meetings with respective to specific elements of CNS/ATM systems. It was also reviewed by the AIDC Review Task Force in February 2007. The Matrix lists status of implementation of major CNS/ATM elements within the Region.. The Matrix is used as a planning tool for monitoring the progress of implementation. The Matrix updated by the meeting is provided in **Appendix E** to this report.

7.2 The meeting also noted the planning information contained in the Regional Plan for CNS/ATM systems on ADS-B. It was further noted that amendment of the Regional Air Navigation Plan FASID Table CNS 4 including ADS-B related planning information provided by States was processed. The proposal was approved in February 2006.

7.3 The Secretariat informed the meeting that a workshop on the development of business case for the implementation of Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) systems will be held in Bangkok from 23 to 27 July 2007 under an ICAO Special Implementation Project (SIP) approved by the ICAO Council. The objective of this Workshop is to provide participants with practical experience for the development of a business case through specially designed hands-on exercises using real data. The Workshop will also discuss associated issues such as different elements of CNS/ATM systems, implementation options, planning mechanisms; performance based planning and harmonization tools. In light of the above, it is expected that both economists and CNS/ATM systems specialists would be nominated by States to attend the Workshop. To facilitate such an attendance, the Workshop is scheduled immediately after the CNS/MET SG/11 Meeting convened from 16 to 20 July 2007.

7.4 SITA presented a paper on an ADS-B managed service model which could be considered for the Asia and Pacific Regions. The service model aims to provide the platform for States to accelerate cost effective ADS-B implementation and maximize ADS-B usage especially through sharing of ATS surveillance data across FIR boundaries. The concept of the service supports the strategy for implementing seamless surveillance systems in the region. It was proposed that States consider the managed service model as an alternate solution to deploy ADS-B service. It was recalled that the ADS-B managed service concept as developed by Airservices Australia and SITA Alliance was noted by APANPIRG/17. With a view to provide guidelines for consideration and reference by States, the meeting reviewed the performance parameters as contained in the **Appendix F** and formulated the following Draft Conclusion:

Draft Conclusion 6/5 - Guidelines of performance parameters for using ADS-B managed service

That, States may wish to consider the performance parameters as contained in **Appendix F** to the Report as service performance guidelines while finalizing acquisition of an ADS-B managed service agreement with a service provider

7.5 In order to progress the development of sub-regional implementation of ADS-B in the Region, four ad hoc working groups were established during the meeting to discuss proposals for sub-regional implementation plans for North Asia, South Asia, South East Asia and Pacific Regions. The outcome of the discussions was briefly recorded in the **Appendix G** to this report. It was noted that several States had identified opportunities to cost effectively improve surveillance and share surveillance data across FIR boundaries.

7.6 Each group reported the results of their discussions to the Task Force. Of significance was a proposal for States to consider the benefits of a mandate for aircraft to be equipped with ADS-B OUT. The proposal was strongly supported by IATA. Taking into accounts the following considerations, the meeting formulated a draft Conclusion for consideration by APANPIRG/18.

:

- Traffic is growing in Asia Pacific Regions at a rate higher than any other regions in the world and flight safety needs to be maintained during the traffic increasing;

- IATA supports an ADS-B mandate commencing in 2010 in Asia and Pacific Regions;

- There is a need for early clear indications to avionics vendors, airframer OEMs, ANSPs, airlines, operators and regulators regarding the future of ADS-B;

- ATC surveillance is not available in many parts of the Region;

- States would invest in ADS-B ground infrastructure and ATC automation system integration of ADS-B if there was high expectation of avionics fitment;

- The availability of technical standards for 1090ES ADS-B OUT including Annex 10, RTCA DO260, DO260A, DO303 and EUROCAE ED126;

- The progress made by European in developing the draft NPA, the Australian NPRM and AC and the soon to be released FAA NPRM;

- The safety benefits that are expected to flow from fitment of ADS-B OUT;

- That 30% of flights by international aircraft in a number of states are already equipped;

- Additional benefits accrue to those already fitted if fitment rates rise

Draft Conclusion 6/6 - Consideration of a regional ADS-B Out Mandate

That, States consider the fitment of ADS-B Out for ADS-B separation service in Class A and C airspace with effective date soon after 1 January 2010.

Note: This mandate would allow aircraft equipped with avionics compliant with either

a) Version 1 ES as specified in Chapter 3 of draft Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871) (Equivalent to* ***DO260A****)*

or

b) Version 0 ES as specified in Annex 10, Volume IV, Chapter 3, Paragraph 3.1.2.8.6 (up to and including Amendment 82 to Annex 10) and Chapter 2 of draft Technical Provisions for Mode S Services and Extended Squitter *(ICAO Doc 9871) (Equivalent to **DO260**) to be used till at least 2020.*

7.7 As part of the works undertaken by the Task Force, Singapore conducted a survey on the readiness of the ADS-B service for ATS providers during the meeting. The result of the survey as tabulated in the Appendix H to the report were reviewed and endorsed by the meeting.

Agenda Item 8: Study and development of documents regarding multilateration applications

Concept of Use for Multilateration

8.1 The APANPIRG/17 meeting decided that the TOR of ADS-B Study and Implementation Task Force should include study and identification of suitable multilateration applications in the Asia and Pacific Regions including concept of use/operation.

8.2 At the request of the Chairman of the Task Force, a draft concept of use was prepared by Mr. Howard Anderson and Mr. Nick King for consideration by the meeting. The draft follows a similar structure to the ADS-B Concept of Use developed by the Operational Data Link Panel (OPLINK Panel) and adopted by the Eleventh Air Navigation Conference (ANConf/11) in 2003.

8.3 The meeting reviewed the draft Concept of Use for Multilateration and appreciated the contribution made. The meeting endorsed the Concept of Use without any amendment and agreed to submit it to APANPIRG/18 for adoption as a regional guidance document. Accordingly, the meeting formulated the following draft Conclusion:

Draft Conclusion 6/7 - Concept of Use for Multilateration

That, the Concept of Use for Multilateration provided in the **Appendix I** to the report be adopted as Version 1 for use as regional guidance material.

8.4 Japan informed the meeting that the evaluation tests of Multilateration was conducted at Tokyo International Airport System. The purposes of introduction of multilateration were to improve reliability, enhance target ID display and to provide surveillance for ASDE (SMR) blind area. A test facility was installed to evaluate the Multilateration system. First evaluation test was conducted from January to March 2006. Although the evaluation system worked correctly, system performance was not sufficient to satisfy EUROCAE MOPS (ED-117). It was also confirmed in the first evaluation test that there were problems such as the use of inadequate number of Remote Units (RU) and antenna height restriction imposed by airport regulation. These problems typically lead to a large position error and low detection probability by multi-path. The meeting noted that evaluation test for a modified system configuration was conducted from November to December 2006. The test result of the modified system satisfied the EUROCAE MOPS for a part of evaluation area for the detection probability and position accuracy.

Agenda Item 9: Review States' activities and interregional issues on trials and implementation of ADS-B

9.1 Under this agenda item, several information papers were presented to the meeting.

9.2 Australia informed the meeting of progress on ADS-B in Australia including:

- conversion of the Bundaberg trial into a fully operational ADS-B service providing 5 Nautical mile separation services;

- the reasons for the delays to the Australian UAP project ; where 5 sites are operational and providing real safety benefits to user;

- The creation of the Australian neighborhood program which provides support to safety & efficiency initiatives by Australia's neighbors;

- Australia's purchase of 20 additional duplicated ADS-B ground stations mainly for installation at enroute radar sites to improve performance, reliability and potentially support transition if the radars are to be decommissioned;

- Details of how aircraft are approved for operational ADS-B services under the Upper Airspace project;

- Details of the ATLAS project, an unapproved project which envisages transition to GNSS based navigation and surveillance including a potential subsidy to equip general aviation

9.2 Australia re-iterated that it remained committed to ADS-B and that reports in the press about spoofing, security, choice of technology other than 1090ES were incorrect. In addition it was confirmed that Australia has always planned that Terminal Area radars were to be replaced. The meeting was invited to note the continued progress of ADS-B in Australia despite some temporary setbacks

9.3 The operational aspects of the Australian Upper Airspace project were provided to the meeting including the following:

- The planned deployment sequence for sites
- UAP Stage 2 Services and Benefits
- Approval processes to participate in UAP
- Progress with approvals, nothing that over 380 airframes are now approved and more than 30% of international flights are ADS-B approved by the Australian regulator

9.4 Australia pointed out that it was complying with Doc.4444 and the regional AIGD when it requested inclusion of ADS-B in ICAO flight plan field 18. The meeting noted the importance of flight crews correctly entering Flight ID.

9.5 China informed the meeting of the Trial & Evaluation project for ADS-B being conducted by the General Administration of Civil Aviation of China. The airborne equipage data collected from Chinese airlines indicated that all 987 commercial aircraft were equipped with Mode S transponder, 458 of which (46.4%) were capable of supporting ADS-B OUT service. 712 aircraft were equipped with GPS capability (72.1%). It was suggested to further investigate the capability of aircraft if NUC value could be generated based on HPL. A plan is in place to conduct the trial & evaluation project for the area between Chengdu and Jiuzhai city pairs in Sichuan province. The objective of the project is to gain knowledge and experience of ADS-B technology. Two ADS-B ground stations will be installed at Chengdu and Jiuzhai airports. It was informed that the project is expected to be completed by end of 2008.

9.6 Republic of Korea provided information paper on ADS-B related activities in Korea and a new flight inspection aircraft to be made available in 2008. It was informed that five ongoing projects for ADS-B were being conducted in Rep. of Korea. Hanseo University introduced the results of the operational test on benefits analysis of ADS-B in Tae-an airport. The tests have shown that the volume and the air-ground voice communication were significantly reduced as a result of introduction of the ADS-B. Korea Aerospace Research Institute presented the results of the performance evaluation of the ground-to-ground surveillance test-bed based on ADS-B concept. In the test, functions of TIS-B, runway incursion prevention, conflict warning, way-point assignment had been evaluated. A brief report of first ADS-B flight test in the Rep. of Korea was provided to the meeting. IIAC informed the meeting of the status of ADS-B implementation and the operation plan for Incheon International Airport. It was anticipated that ADS-B will contribute to the safe operation of IIA and the smooth handling of increasing air traffic demand.

9.7 Singapore and Indonesia jointly presented an information paper to share the results of the ADS-B trials of Natuna ADS-B station. The trials commenced during the end of 2006 as part of Indonesia ADS-B trials project. The result of the trials has shown that it is possible to implement ADS-B services in areas within the coverage of the Natuna Station. Following the trial, DGCA Indonesia will explore a better location for installing the ADS-B antenna. As a result of discussion on the observations derived from the trial, the meeting agreed to further work on methods of computing the probability of detection at an ADS-B ground station and recommendation of the minimum probability of the detection required from a ground station for the provision of ADS-B service. The use of ADS-B reports from aircraft with low percentage of good NUC values for ATS shall be looked into as well.

9.8 Indonesia informed the meeting that DGCA Indonesia in cooperation with Airservices Australia had already performed the ADS-B Trial at the three strategically selected sites, these being Bali covering route A576, Kupang covering route A464 and Natuna Island providing coverage in Jakarta and Singapore FIR. The Trials were conducted from September 2006 and will continue until May 2007. The outcome of the trial was highlighted as follows:

a) A large number of aircraft were detected with ADS-B capability:

- Natuna : 521 Aircraft
- Kupang : 144 Aircraft
- Bali : 374 Aircraft

b) In line with the trial, DGCA has a plan in place for:

- Upgrading the Makassar Advanced Air Traffic System (MAATS) with ADS-B Application Capabilities in 2007.
- Installation 2 ADS-B Ground Station in 2007.
- ADS-B Surveillance sharing with adjacent States.

9.9 Hong Kong, China made a presentation on the ADS-B trials conducted by its Civil Aviation Department. In May 2004, a mini-scale trial system using multilateration-based technology was installed at Hong Kong International Airport for Surface Movement Guidance & Control operational evaluation. The trial system, originally consisting of only 9 remote units, was expanded to a configuration of 19 remote units in February 2007. Since November 2004, Hong Kong Civil Aviation Department has made use of one of these remote units to collect statistics on ADS-B equipage of the aircraft flying close to Hong Kong International Airport. From these quarterly equipage surveys, it was noted that there was a steady increase in the percentage of aircraft equipage, i.e. from the original 4% of flights in November 2004 to the 41% in March 2007. To facilitate more comprehensive trials on ADS-B, another dedicated ADS-B evaluation system was recently installed with the receiver mounted at the Tai Mo Shan, which is the highest mountain in Hong Kong. Based on targets of opportunity, one-week data was collected from 5-11 April 2007. Data was subsequently analyzed to determine the coverage achieved, aircraft detected, flights detected, percentage of aircraft fitted with ADS-B and percentage of good position data transmitted. Initial observations included:

- About 39% of aircraft were equipped with ADS-B capability;
- Around 65% of these equipped aircraft were transmitting position data (FOM > 5);
- 18% of equipped aircraft were permanently transmitting FOM of “0”;
- Changing call signs transmitted by aircraft might potentially cause problems to ATC system coupling;
- In general, the ADS-B signal coverage at Tai Mo Shan could be up to 290NM at a certain altitude. Relocation of the ADS-B receiver to other site(s) would be considered to collect another set of data/observations;
- ADS-B data created a slightly more accurate track especially in approach maneuvering;
- Velocity vectors of ADS-B tracks were also more accurate;
- Improved rate of ADS-B detections created a smoother track on sharp turns.

9.10 During the ADS-B Seminar several states informed the participants of significant progress including:

- FAA’s plans for an ADS-B mandate to be published as a NPRM this year, with expected applicability of the 2018-2020 time frame
- France has commenced installation of an ADS-B system in La Reunion and is pursuing ADS-B data sharing with adjacent states. This is expected to be repeated in New Caledonia in the following years. Additional trials are also underway in Corsica.

9.11 Australia provided Information Paper on the outcome of industry consultations in Australia in which CASA proposed Australian standards for the carriage and use of ADS-B avionics equipment. The issues raised by industry relevant to ADS-B regulation were discussed. The meeting noted the form of the final rule that CASA will promulgate shortly. It was noted that the effect of the promulgation of the rule will be to establish operational and technical standards for aircraft fitment of ADS-B avionics in Australia. Fitment of avionics is voluntary; however those aircraft operators who decide to equip their aircraft with ADS-B will gain with safety enhancement and by the provision of improved ATM services. The standards together with the guidance material will enable aircraft operators to go-ahead with avionics purchase and aircraft fitment in the knowledge that installations that comply with the standards will ensure inter-operability with the ADS-B ground stations now being rolled out by the Australian ANSP.

9.12 Fiji informed the meeting that Fiji is currently still using procedural control in the Domestic Airspace. There is a great need to enhance safety by implementing an appropriate surveillance system for positive control and separation which would also result in improved efficiency and effectiveness in air transportation within the domestic airspace. It was informed that a project team consisting of members from the ANSP and regulator identified the minimum operational requirements and total requirements for positive control and reduced separation within the domestic airspace. The locations of Ground Stations (GS) were also identified to obtain estimates of coverage plots when using ADS-B or multilateration (MLAT). Comparing the two options ADS-B was preferred over multilateration because with 6 GS it was able provide the minimum requirements (with 8 for further redundancy at two major airports and 10 GS for full coverage). MLAT on the other hand could not meet the minimum requirements with even 15 GS. Radar as the third option was ruled out due to high cost. Some of the challenges to be addressed include:

- aircraft equipage of all locally registered aircrafts (to implement ADS-B in the Fiji environment 100% equipage is required)
- the availability; cost and implementation of reliable and redundant communications links;
- acquisition of new sites or collocation with other service providers;
- addressing teething problems and envisaged problems shared by other States performing trials and implementation of ADS-B;
- the requirement for peer review hence identifying scope of works and related costs;
- the approval by airlines for implementation of the ADS-B project taking into consideration associated investment costs with implementation of appropriate fees and charges.

9.13 The meeting noted and appreciated the information provided on ADS-B Implementation Policy for Europe as defined by the Eurocontrol CASCADE programme. The meeting also noted IATA's policy on ADS-B presented to the ADS-B Seminar.

Agenda Item 10: Discuss issues observed during the trial and implementation of ADS-B including review items from ADS-B Problem report database

10.1 Under this agenda item, the meeting reviewed a working paper that summarised the ADS-B problem reports in the Asia Pacific ADS-B database of problems which is maintained by Australia. The meeting recognised that as a new technology, issues will be discovered and software bugs in particular will be identified.

10.2 The meeting considered the individual issues discovered. None of the issues was considered as serious enough to block operational use of ADS-B provided the impact of the issues had been addressed during implementation.

10.3 The members of the Task Force were requested to provide their problems discovered or observed in their trial programme or implementation project to the established regional reporting database using the specified procedure outlined at previous meetings or alternatively to the Chairman of the Task Force through e-mails.

Agenda Item 11: Any other business

Note of appreciation

11.1 The meeting expressed its appreciation and gratitude to the Korean Civil Aviation Authority (KCASA) and the Incheon International Airport Corporation (IIAC) for hosting the ADS-B Seminar, the excellent arrangements made for the meeting and for all activities organized during the meeting.

Security

11.2 France highlighted the concerns of some elements of the French Press regarding perceived security issues with ADS-B. The meeting considered that it could prepare brief guidance to states regarding issues surrounding ADS-B and security. An item was added to the Tasks List to reflect this agreement.

Time and Venue of Next Meeting

11.3 The meeting discussed whether the next meeting should be in 6 or 12 months. It was expressed that the meetings motivated progress towards implementation and hence a gap of 12 months was too long at this critical phase for many States. The interchange of ideas, and experience during initial trials and implementation was considered invaluable. Therefore a working group meeting was considered necessary in 6 months. The meeting also considered a Seminar for technical information updates worthwhile and valuable.

11.4 The working group meeting was scheduled to be held in October or November 2007 and the timing for next meeting of ADS-B Study and Implementation Task Force is scheduled to be held in April or May 2008. Since no offer for hosting the next meeting was received during meeting the members of the Task Force will be informed well in advance of venue of the meetings after consultation with the concerned.

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UPDATED ADS-B SUBJECT/TASKS LIST

No.	Subject/Tasks List	Associated with Strategic Objective	Associated GPI	Deliverables	Target Date	Action to be taken and led by
1	Conduct study and present a paper on a study for the use of ADS-B technology in airspace in the North Asia.	D. Efficiency	GPI01/02/05/06/07/09/ 14/16/17/21/22	Report of study for the use of ADS-B in North Asia area	10/2007	IATA
2	Report Organizational Policy on ADS-B data sharing with neighbors.	A. Safety D. Efficiency	GPI01/02/05/06/07/09/ 10/11/14/16/17/21/22	Status report	10/2007	All Members
3	Each State report on the number of airframes fitted and transmitting with good NUC/NIC.	D. Efficiency	GPI01/05/06/09/14/16/ 17/21/22	Report on statistics conducted	10/2007	All Members with Ground Stations
4	Develop draft comparison of surveillance technologies document including required site and network architecture, expected surveillance coverage, cost of system.	D. Efficiency	GPI01/02/05/06/07/09/ 14/16/17/21/22	A regional guidance material for implemetation	Completed (4/2007)	Greg Dunstone
5	Develop draft update to AIGD to incorporate multilateration.	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	The second amendment to the AIGD	Completed (4/2007)	Nick King, Chainan Chaisompong & Howard Anderson Anderson)
6	Provide a paper with an update on available equipment standards: (ARINC, Eurocae, RTCA, ICAO, TSO)	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	An information document for implementation	10/2007	USA
7	Develop a table detailing readiness of Airspace users & ATS providers	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Report of a survey conducted	Completed (4/2007)	Singapore

No.	Subject/Tasks List	Associated with Strategic Objective	Associated GPI	Deliverables	Target Date	Action to be taken and led by
8	Provide details of potential areas (FIRs) that where there is a positive cost/benefit for near term implementation of ADS-B Out	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Report of result of studies	4/2007	All
9	Develop a paper on how Probability of detection should be reported for ADS-B so that it can be compared to radar probability of detection	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Guidance material for implementation	10/2007	Greg Dunstone
10	Develop guidelines on how ADS-B equipage should be reported in future, especially the definition of "equipped".	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Guidelines for implementation	07/2007	Greg Dunstone
11	Develope outline of the performance criteria and identify issues to be considered when introducing ADS-B into an Air Traffic Control multi-sensor fusion process	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Guidance material for implementation	07/2007	Rick Castaldo, Greg Dunstone Michel G. Procoudine
12	Deveop brief guidance paper on security issues associated with ADS-B	D. Efficiency	GPI01/05/06/09/ 14/16/17/21/22	Guidance material for implementation	10/2007	Patrick Souchu, Greg Dunstone, Mike Gahan

PROPOSEDTHE REVISED TERMS OF REFERENCE OF ADS-B STUDY AND IMPLEMENTATION TASK FORCE

- Compare currently available technologies with respect to concept of operations, relative costing, technical and operational performance and maturity of alternative technology/solutions (primary, secondary radar including Mode-S, ADS-B, multilateration, ADS-C);

- Develop an implementation plan for near term ADS-B applications in the Asia Pacific Region including implementation target dates taking into account:

  - available equipment standards;
  - readiness of airspace users and ATS providers;
  - identifying sub-regional areas (FIRs) where there is a positive cost/benefit for near-term implementation of ADS-B OUT;
  - developing a standardised and systematic task-list approach to ADS-B OUT implementation; and
  - holding educational seminars and provide guidance material to educate States and airspace users on what is required to implement ADS-B OUT.

- Study and identify applicable multilateration applications in the Asia and Pacific Region considering:

  - Concept of use/operation;
  - Required site and network architecture;
  - Expected surveillance coverage;
  - Cost of system;
  - Recommended separation minimums; and
  - If multilateration can be successfully integrated into an ADS-B OUT system for air traffic control

- Coordinate ADS-B implementation plan and concept of operations with other ICAO regions where ADS-B implementation is going on and with relevant external bodies such as EUROCONTROL, EUROCAE, RTCA and Industry.

Note: *The Task Force, while undertaking the tasks, should take into account of the work being undertaken by SAS, AS Panels with a view to avoid any duplication.*

The Task Force should report to the APANPIRG, through the CNS/MET Sub-group and provide briefing to the ATM/AIS/SAR Sub-group.

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INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

DRAFT

GUIDANCE MATERIAL ON COMPARISON OF SURVEILLANCE TECHNOLOGIES (GMST)

Version xx

27 April 2007

GUIDANCE MATERIAL ON COMPARISON OF SURVEILLANCE TECHNOLOGIES (GMST)

1 Introduction

A number of surveillance technologies suitable for the delivery of ATC services to separate aircraft are currently available.

This paper will concentrate on enroute, and terminal applications rather than airport surface surveillance. It will consider the sensor component of the ATC system only – and will ignore the ATC display system. These sensors can support simple display systems or sophisticated automation systems.

2 The need for ATC Surveillance

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

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

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

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

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

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

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

3 General Requirements of an Air - Ground Surveillance System

The most basic function of a surveillance system is to periodically provide an accurate estimate of the position, altitude and identity of aircraft. Depending on the ATC application that a surveillance system is intended to support, there will be other requirements of the system.

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

1. Coverage volume – the volume of airspace in which the system operates to specification.

2. Accuracy – a measure of the difference between the estimated and true position of an aircraft.

3. Integrity – an indication that the aircraft's estimated position is within a stated containment volume of its true position. Integrity includes the concept of an alarm being generated if this ceases to be the case, within a defined time to alarm. Integrity can be used to indicate whether the system is operating normally.

4. Update rate – the rate at which the aircraft's position is updated to users.

5. Reliability – the probability that the system will continue operating to specification within a defined period. Sometimes this is called continuity.

6. Availability – the percentage of the total operating time during which the system is performing to specification.

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

1. The ability to uniquely identify targets.

2. The impact of the loss of surveillance of individual aircraft both in the short (few seconds) and long term

3. The impact of the loss of surveillance over an extended area.

4. Backup or emergency procedures to be applied in the event of aircraft or ground system failure.

5. The ability to operate to specification with the expected traffic density.

6. The ability to operate in harmony with other systems such as the Airborne Collision Avoidance Systems (ACAS) and Airborne Separation Assistance Systems (ASAS).

7. The ability to obtain Aircraft Derived Data (ADD).

8. The interaction between communication, navigation, and surveillance functions.

4 A Surveillance Sensor is One Part of a Surveillance System

Whilst this paper concentrates on the possible surveillance sensors, they are just one part of an overall system that provides data for use in ATC. A complete system includes:

- Position and altitude sensors. Some of these sensors may be ground based (e.g. radars) or may be airborne (e.g. altitude sensors). Datalinks are used to transmit data from airborne sensors to the ground,

    - The Fundamental Data provided to the air traffic controller is aircraft position, aircraft identity and altitude. Further information such as aircraft direction, speed, the rate of climb may also be provided.

- A system to transmit the data from the reception point on the ground to the ATC centre,
- A display system or ATC automation system
  - Data from a sensor system may be presented on a standalone display or combined with data from other sensor(s) and/or other data in an automation system and then presented on a plan view situation display.
  - The situation display provides Air Traffic Controllers with plan view of the position of aircraft relative to each other and to geographic features. This supports controllers in providing Separation and other services to aircraft.
  - Automation systems may use surveillance data to implement automated safety net functions such as Route Adherence Monitoring, Cleared Level Alarm, Conflict Alert, Lowest Safe Altitude and Danger Area Infringement Warning. These facilities increase overall safety.
- Suitably trained air traffic controllers, aircrew and
- Suitable standards and procedures to use the system including separation minima
  - ICAO PANS-ATM (Doc.4444, Chapter 8) details radar separation minima of five (5) and three (3) nautical miles. These minima allow for a considerable increase in airspace utilisation compared to procedural control. Changes to ICAO documents are about to be published (2007) recognising ADS-B use to support 5 nautical mile separation standards. ICAO's Separation & Airspace Safety Panel (SASP) is working on proposals to allow 3 nautical mile separation standards using ADS-B and also on the use of multilateration to support both 3 and 5 nautical mile separation standards.
  - Due to the low update rate, ACARS based ADS-C is unlikely to ever support 3 and 5 nautical mile separation standards. However it is used to support 30/30 and 50/50 nautical mile procedures used in some regions. ATN and VDL2 based ADS-C may reduce the achievable separation standards in some regions.

5 The Technologies

Knowledge of the position of aircraft is essential to an Air Traffic Controller in the provision of most air traffic services. Certainly knowledge of aircraft position is required to provide separation services. The provision of knowledge regarding aircraft position is referred to as surveillance. Position reports from pilots can provide knowledge of aircraft position to a controller. However the inherent inaccuracy, infrequent updates and scope for error due to misunderstandings requires very large spacing between aircraft to maintain safety. This technique is known as procedural separation.

Today there are primarily four classes of surveillance technology available to support air traffic control services;

1. Radar
2. ADS-B alone
3. Wide Area Multilateration (typically with ADS-B but may be supplied without)
4. ADS-C

5.1 Radar

Radar provides the controller with an accurate, trustworthy on-screen plan view of the aircraft position in real-time. The required separation between aircraft for safe operation can be greatly reduced compared to procedural separation. It also allows vectoring, ATC directed terrain avoidance and the provision of safety nets.

Radar is a technology which detects the range and azimuth of an aircraft based upon the difference in time between transmission of pulses to the aircraft and the receipt of energy from the aircraft. Typically the technology uses a large rotating antenna and associated machinery.

A radar system requires a number of racks of equipment (normally on a plinth) normally in an air-conditioned shelter. A typical site consumes between 10 and 20 kWof electricity and this needs to be backed up by generators and battery backup Uninterruptible Power Supplies (UPS). A specialised tower installation is required.

A radar typically takes a number of months for site preparation and deployment unless special, transportable systems are deployed.

5.1.1 Primary Radar

Primary Surveillance Radar (PSR) transmits a high power signal, some of which is reflected by the aircraft back to the radar. The radar determines the aircraft's position in range from the elapsed time between transmission and reception of the reflection. The direction of the aircraft is the direction in which the narrow beam radar antenna is facing.

PSR does not provide the identity or the altitude of the aircraft. However, PSR does not require any specific equipment on the aircraft.

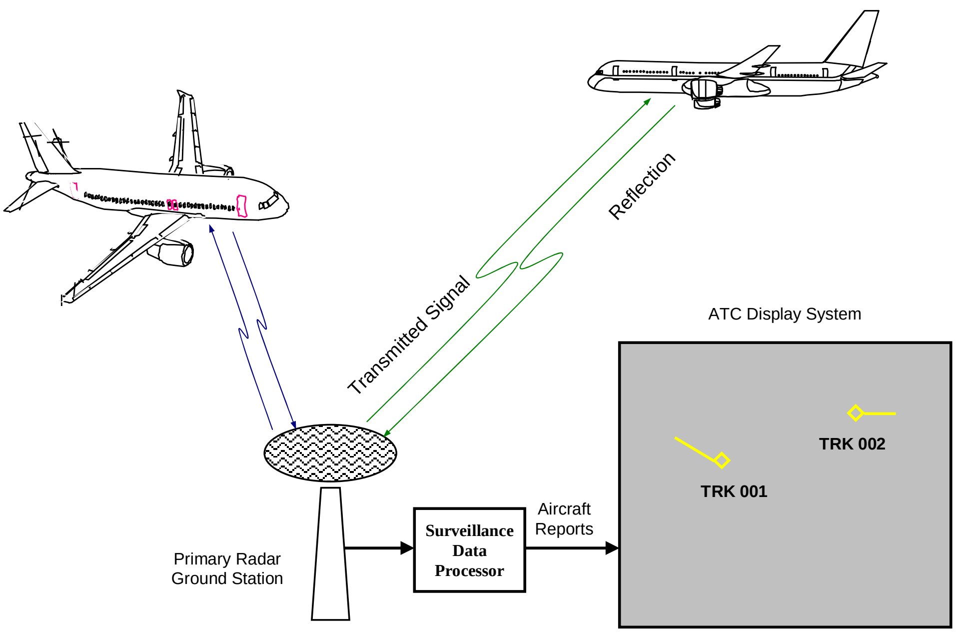

Figure 1 - Primary Radar

Strengths

- PSR does not require a transponder to be installed or operating on aircraft thus allowing the detection and management of non equipped/faulty aircraft or non co-operative aircraft[1]
- Can provide a weather channel output if display of weather is required.
- Well suited for aerodrome surface surveillance

Weaknesses

- PSR does not provide identity
- Does not provide altitude[2]
- Position is based on slant range measurement rather than true range (which presents some difficulties for multi-radar tracking systems)
- Can often report false targets (ground vehicles, weather, birds etc)
- Poor detection performance in the presence of ground and weather clutter especially for flight tangential to the radar
- Expensive compared to Secondary Surveillance Radar (SSR)
- A update rate between 4 and 12 seconds (longer than typical multilateration or ADS-B)
- High transmitter power required for long range performance – brings interference and environmental concerns
- Systems are very expensive to install and maintain
- Systems require optimum site with unobstructed view to aircraft, and with the minimum of ground clutter visible to the radar
- Cannot resolve two aircraft at a similar location at the same range, due to poor azimuth resolution performance.

5.1.2 Secondary Surveillance Radar

Secondary Surveillance Radar (SSR) systems consist of two main elements, a ground based interrogator/receiver and an aircraft transponder. The aircraft's transponder responds to interrogations from the ground station, enabling the aircraft's range and bearing from the ground station to be determined.

Refer to the ICAO Manual of Secondary Surveillance Radar (SSR) Systems (Doc 9684) for a detailed study of the subject.

The development of SSR evolved from military Identification Friend or Foe (IFF) systems and allows the use of the Mode A/C service for civil aviation. Since then it has been significantly developed to include the Mode S service. SSR frequencies of 1030 and 1090 MHz remain shared with the military.

In many cases SSR is co-located with a PSR, usually with the SSR mounted on the top of the PSR antenna.

Mode A/C transponders provide identification (Mode A code) and altitude (Mode C) data with 100 foot resolution information in reply to interrogations. Therefore in addition

[1] ICAO Annex 6 says at para 6.13.1 "From 1 January 2003, unless exempted by the appropriate authorities, all aeroplanes shall be equipped with a pressure-altitude reporting transponder which operates in accordance with the relevant provisions of Annex 10,Volume IV". A number of authorities provide exemptions.

[2] Some primary radars have height finder capabilities although these are normally too expensive for ATC use and have poor altitude accuracy with respect to civil aviation needs.

to being able to measure the aircraft's range and bearing, the Mode A/C system is also able to request the aircraft to provide its identity and altitude.

Mode S is an improvement of Mode A/C. It contains all the functions of Mode A/C, and also allows selective addressing of targets by the use of unique 24 bit aircraft addresses, and a two-way data link between the ground station and aircraft for the exchange of information. It provides the transponder capability to report altitude data with 25 foot resolution although accuracy and resolution also depend on the altitude sensor systems on board the aircraft.
SSR determines the aircraft's position in range from the elapsed time between the Interrogation and reception of the Reply. The direction of the aircraft is determined from the direction in which the narrow beam radar antenna is facing. The Reply contains the aircraft Identity and/or Altitude. The Identity information is able to be input by the pilot and the altitude information comes from a barometric encoder or air data computer on the aircraft. SSR will only detect an aircraft fitted with a functioning transponder. SSR with Mode S may also data-link many aircraft parameters such as heading, track, bank angle and selected altitude to the Radar.

Whilst SSR independently calculates geographical position, pressure altitude data, flight identity (4 digit octal code) and other data such as emergency flags are provided by airborne sensors or systems and datalinked to the ground.
SSRs transmit pulses on 1030 MHz to trigger transponders installed in aircraft to respond on 1090 MHz. This datalink can theoretically support 4 Mbits/second uplink and 1Mbits/second downlink.

There are two classes of SSR used today:

Classical SSR: typically uses a hog-trough antenna. This SSR system relies on the presence or absence of SSR transponder replies within the beamwidth. Performance can be quite poor, particularly azimuth accuracy and resolution. This type of system is also subject to significant multipath anomalies due to the poor antenna pattern. Range accuracy depends on variability of the fixed delay in the ATC transponder[3].

Monopulse SSR: Monopulse SSR systems measure the azimuth position of an aircraft within the horizontal antenna pattern using diffraction techniques. These techniques improve azimuth accuracy and resolution. In addition, these radars typically have large vertical aperture antennas and hence are less subject to multipath effects.

[3] Time allowed for transponder to reply : 3 uS +- 0.5 us as per SARPS

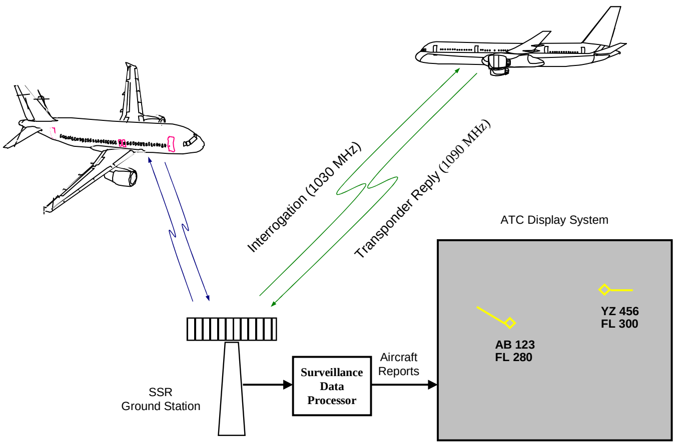

Figure 2 - Secondary Surveillance Radar

Strengths

- SSR allows communication of identity (4 digit octal codes) when matched with flight plan data held by the ground system
- Allows communication of altitude and emergency states to ground system
- Provides good detection capability independent of clutter and weather.
- Provides moderately high update rate.
- Provision of altitude allows correction for slant range error

Weakness

- Poor azimuth accuracy and resolution (particularly for classical SSR)
- Can sometimes report false targets or position (reflections, multipath)
- Can sometimes confuse Mode A replies as Mode C and vice versa
- Can sometimes report false altitude or 4 digit code
- No error detection provided in downlinked 4 digit code and altitude from Mode C transponders
- Systems are expensive to install and maintain
- Systems require optimum site with unobstructed view to aircraft
- Cannot resolve two aircraft at the same location (garbling/ resolution performance)
- Dependent on aircraft avionics
- Not accurate enough for aerodrome surface applications due to transponder delay uncertainty

5.1.3 Mode S Secondary Surveillance Radar

Mode S radars typically use monopulse techniques to measure the azimuth position of an aircraft and have large vertical aperture antennas and hence are less subject to multipath effects. In addition, they are able to discretely interrogate single aircraft transponders and hence can discriminate between two aircraft at the same geographical position.

Mode S has additional capabilities which provide:

- improved ability to distinguish between Mode S equipped aircraft (resolution performance)
- error detection and correction of downlinked data
- improved tracking relying on Mode S 24 bit address (reduced tracking ambiguity)
- improved altitude quantisation

- ability to downlink a wide variety of information from Mode S equipped aircraft

A Mode S radar is backwards compatible with a conventional SSR Mode A/C radar and the detection and processing of Mode A/C transponder replies is essentially identical. To achieve Mode S benefits, the aircraft transponders must be Mode S capable transponders.

All ACAS II (v6.04 or v7.0) equipped aircraft have mode S transponders.

Europe has issued Mode S mandates requiring all aircraft in certain airspace to be Mode S equipped. Some exemptions will exist.

The European mandate also requires support of

Elementary surveillance (ELS) which requires the aircraft to be able to downlink callsign in response to Mode S interrogations and

Enhanced surveillance (EHS) which requires the aircraft to be able to downlink

- Selected Altitude
- Roll Angle
- Track Angle Rate
- Track Angle
- Ground Speed
- Magnetic Heading
- Indicated Airspeed/Mach No
- Vertical Rate

Strengths

- Altitude and identity is protected and the downlink is error free (of course flight identity could have been entered incorrectly)
- Can resolve two aircraft at the same location
- Provides 25 foot altitude quantisation (instead of conventional 100 foot resolution)
- Operates with Mode A/C aircraft albeit with no advantages compared to a Mode A/C radar

Weakness

- Benefits apply only to Mode S equipped aircraft
- More complex to set up than SSR
- Some currently deployed Mode A/C transponders are non compliant with the standards and fail to respond to Mode S interrogations properly – whilst these transponders are tolerated by Mode A/C radars
- Dependent on aircraft avionics – but most **airliners** are equipped with Mode S as a result of ACAS mandates
- Systems require optimum site with unobstructed view to aircraft

5.1.4 Secondary Radar Alone

SSR alone is used for en route radar control in many States where intruder detection is not required. An SSR only installation is less expensive than a combined primary plus secondary radar, but involves a significant outlay for buildings, access roads, mains electrical power, standby generators, towers and turning gear to rotate a large elevated antenna etc.

ICAO Document 4444, Procedures for Air Traffic Services – Air Traffic Management, sets out the requirements for Radar Services in Chapter 8. An extract is copied at Attachment 1. In particular, Section 8.1.9 states:

"SSR systems, especially those with monopulse technique or Mode S capability, may be used alone, including in the provision of separation between aircraft, provided:

a) *The carriage of SSR transponders is mandatory within the area; and*
b) *Aircraft identification is established and maintained by use of assigned discrete SSR codes"*

5.1.5 Combined Primary plus Secondary Radar

Combined Primary & Secondary Radar makes use of the advantages of the two types of radar in one installation. Typically, the PSR antenna and the SSR antenna are mounted on the same turning gear and the associated processing performs filtering, combines the SSR and primary data and tracks the radar reports. One track message is output per aircraft each antenna rotation.

The primary radar provides detection of intruder aircraft and the SSR performs detection of co-operative aircraft as well as providing altitude and identity information.

Digital tracking systems gain significantly benefits from having SSR and PSR installed on the same rotating antenna. SSR can resolve tracking ambiguities that would exist in a PSR only solution and vice versa.

Some States choose to mount PSR and SSR systems at separate locations thus providing separate antenna platforms. This has the advantage of a level of redundancy since one antenna stops, a level of service can be provided from the other. However, in this case, the advantages of improved tracking performance are forgone – unless the antennas are nearby and antenna rotation is synchronised[4].

Combined PSR/SSR systems are usually provided to support approach departure ATC in terminal manoeuvring area airspace. It is in the busy terminal area airspace that the probability of general aviation aircraft straying into controlled airspace is higher – and therefore some States prefer to have PSR in these environments.

Often such systems are backed up by offsite SSR only systems.

5.2 ADS-B alone

ADS-B is a system that uses transmissions from aircraft to provide geographical position, pressure altitude data, positional integrity measures, flight identity, 24 bit aircraft address, velocity and other data which have been determined by airborne sensors.

Typically, the airborne position sensor is a GPS receiver, or the GPS output of a Multi-Mode Receiver (MMR). This sensor must provide integrity data that indicates the containment bound on positional errors. The altitude sensor is typically the same barometric source / air data computer source used for SSR. Integrated GPS and inertial systems are also used. Currently inertial only sensors do not provide the required integrity data although these are likely to be provided in the future.

[4] Mechanical slaving brings another degree of complexity and failure modes and is rarely implemented (for good reasons)

An ADS-B ground system uses a non-rotating antenna positioned within a coverage area, to receive messages transmitted by aircraft. Typically a simple pole (DME like) antenna can be used.

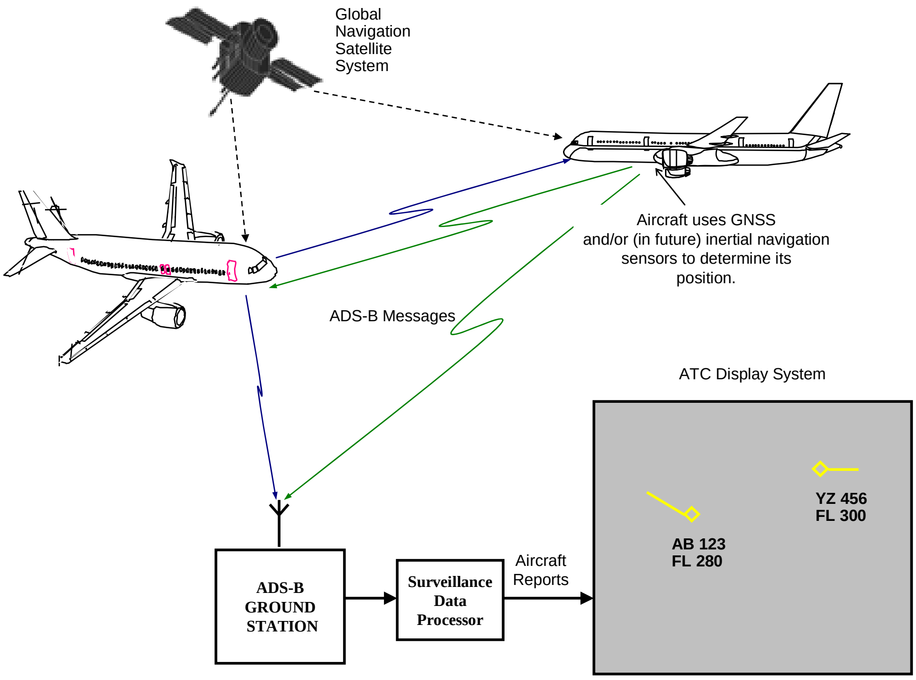

Figure 3 - Automatic Dependent Surveillance - Broadcast

The ADS-B ground system does not necessarily transmit anything. ADS-B receiver ground stations are the simplest and lowest cost installations of all options to provide air-ground surveillance, although costs may increase if ADS-B transmitter (to broadcast or rebroadcast ADS-B data e.g. TIS-B, ADS-R or FIS-B) capabilities are deemed necessary.

An ADS-B receiver is typically less than six inches high by nineteen inches wide and a duplicated site consumes less than 200 watts of electricity. An ADS-B ground station can normally be installed in an existing VHF communications facility.

The installed cost of a duplicated ADS-B ground station is lower than other alternatives. If it can be housed in an existing communications facility, installation can be as short as one week after delivery of equipment from the manufacturer.

While ADS-B has the advantage of quite low ground station cost, it has the disadvantage of requiring aircraft to equip with ADS-B transponders, which will take time. Voluntary equipage among jet airline fleets is still expected to be high, and ADS-B remains very attractive in the longer term.

Many avionics vendors have included ADS-B capability in the software release that supports ELS and EHS.

Some ATC systems can support ADS-B use, including delivery of separation services, when there is partial aircraft ADS-B equipage. Other ATC systems require complete equipage for ADS-B use to be viable.

The use of ADS-B along the Flight Information Region (FIR) boundary may be easily shared by the boundary States. ADS-B technology is generally not sensitive to military authorities because it is co-operative in nature and hence such authorities are less likely to block data sharing.

The low marginal cost of ground stations encourages FIR boundary data sharing where large parts of coverage benefit the adjacent FIR. This data sharing can be considered similar to the sharing of ADS-C data when adjacent Air Navigation Service Providers (ANSPs) use service providers to deliver ADS-C data.

Strengths

- Simple ground station design without transmitter
- Can be installed at sites shared with other users
- Very low ground station cost (but highly variable ADS-B avionics fitment cost)
- Very high update rate
- Almost perfect resolution
- High accuracy and integrity (airborne measurements)
- Higher performance velocity vector measured by avionics and then broadcast, rather than determined from positional data received on the ground
- Accuracy not dependent on range from ground station
- Facilitates exchange of surveillance data across FIR boundaries
- Can be easily deployed for temporary use (emergency, special events etc)
- Can support the display of callsigns on simple display systems without interfaces to flight planning systems since callsign is provided directly from the aircraft
- Facilitates future provision of innovative ATM services based on air-to-air ADS-B.

Weakness

- Dependent on aircraft avionics. This can be a major issue in some environments.
- Equipage rates are relatively low at this stage (2007)
- Systems require optimum site with unobstructed view to aircraft
- Some outages expected due to poor GPS geometry when satellites out of service, although exposure expected to reduce in the future with use of GNSS augmentation & internal support[5]
- ADS-B has the capacity to evolve towards the broadcast and use of other data, such as Trajectory Change Point (TCP) or others, already defined in the standard

ADS-B Critical issue

The critical issue for ADS-B is that it requires ADS-B avionics including GPS or similar in participating aircraft. Whilst many airliner manufacturers produce aircraft with ADS-B out avionics a large legacy fleet remains to be equipped.

The situation is different in different regions of the world. Some States have new airliner fleets which are growing rapidly – and the new aircraft are fitting with ADS-B. In other States very large numbers of legacy aircraft remain unequipped.

The situation is also different in different aviation segments.

[5] Analysis of 37 million ADS-B samples by one State over a 4 month period indicated that 99.8% of samples were acceptable for ATC 5 nautical mile separation. See ADS-B SITF/5-IP/8

Whilst large aircraft are equipping, few regional airliners are equipped.

General Aviation (GA) is another area that can be problematic. In some States the cost to equip the GA fleet is small. In others with a large fleet it can be very expensive. Some States envisage subsidies to assist GA equipage so that all aviation segments benefit. Some States also envisage the mandatory fitment of ADS-B with and without subsidies.

Timing of transition to match aircraft equipage of ADS-B will be critical for many States.

At the same time, the benefits of ADS-B equipage are significant and may allow other surveillance systems to be decommissioned and supports delivery of air-air surveillance applications. ADS-B avionics support the ADS-B application in all locations to which the aircraft travels.

5.3 Multilateration

Multilateration is a system that uses aircraft transponder transmissions (Mode A/C, Mode S or ADS-B) to calculate a 2D or 3D position.

Multilateration relies on signals from an aircraft’s transponder being detected at a number of receiving stations to locate the aircraft. It uses a technique known as Time Difference of Arrival (TDOA) to establish surfaces which represent constant differences in distance between the target and pairs of receiving stations, and determines the position of the aircraft by the intersection of these surfaces.

The accuracy of a multilateration system is dependent on the geometry of the target in relation to the receiving stations, and the accuracy to which the relative time of receipt of the signal at each station can be determined.

Multilateration is mainly used for airport surface and terminal area surveillance, although with careful design and deployment it may be used in segments of enroute airspace.

Multilateration independently calculates geographical position in 2D, or in 3D if more sensors are installed.

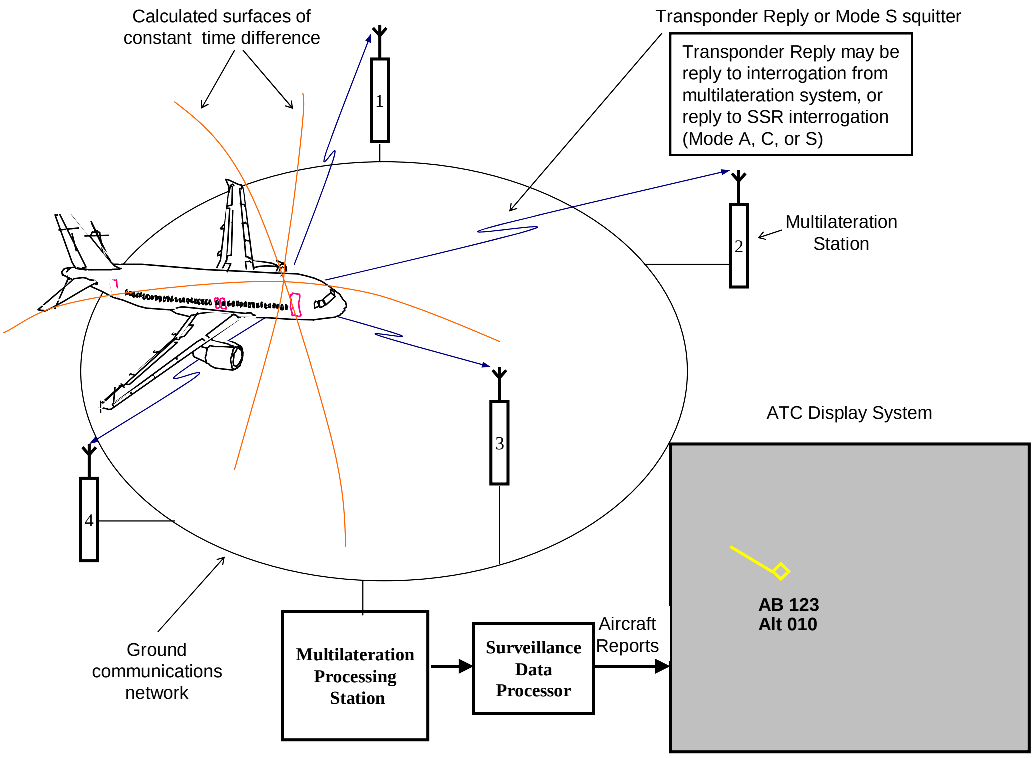

Figure 4 - Transponder Multilateration

Multilateration systems can be defined as being either passive or active. Passive systems require only ground receivers. An active system requires ground receivers and at least one interrogator. Multiple interrogators may be required to meet coverage requirements. The latter enables the system to be independent from other sources to trigger transmissions from aircraft. In most practical ATM applications multilateration systems are active and must interrogate aircraft to obtain altitude and identity data. Passive systems usually rely on nearby radars to perform interrogation[6]. They could operate on ADS-B signals which do not require interrogators.

Multilateration systems will provide a range of fundamental data items relative to a specific target depending on the airborne derivation of the data and if they are transmitted within the aircraft signal used by the multilateration system, i.e. MSSR Mode A or MSSR Mode C or 1090 MHz Extended Squitter (ADS-B). Derived data can include:

- Pressure altitude data derived from decoding ADS-B transmissions or replies to Mode C interrogations.

- Flight identity obtained by decoding ADS-B transmissions or replies to Mode A interrogations.

- 24-bit aircraft address obtained by decoding ADS-B transmissions, DF11 Mode S autonomous transmissions[7] or replies to Mode S interrogations.

[6] Difficulties in distinguishing between Mode A and Mode C replies will be experienced unless the interrogator pulses are available.

[7] DF11 is an autonomous transmission from a Mode S transponder which provides aircraft 24 bit code only. It was primarily designed to support self announcement to TCAS systems. Multilateration systems can

Additionally, multilateration systems can make use of position messages provided by ADS-B systems, i.e. each multilateration receiver can usually be configured to operate as an ADS-B receiver. These can be used as standalone ADS-B sensors.

Initially multilateration systems have been used for surface surveillance. More recently States have begun deploying multilateration for wide area applications of terminal area size. These wide areas tend to be smaller than the area covered by radars.

System performance in the service volume is determined primarily by the geometry of the ground station deployment. Therefore the number of sites and the geographical disposition of those sites (site selection) are the critical factors in achieved performance. The availability of such sites and reliable, high performance communications to the central processing system is required.

One requirement of multilateration systems is that the central processing must be able to determine the time DIFFERENCE of arrival of signals from aircraft. This requires a synchronisation of the ground stations typically using either:

a) A reference transmitter visible to multiple receiver stations, or
b) Use of common clock (GPS or other) to time synchronise the receptions, or
c) The transmission of the received signals by wideband datalink to the central processing system, or
d) Very accurate clocks at each sensor (atomic standard).

Mutilateration systems require a number of ground stations to detect each aircraft transmission.

- For surveillance of airborne aircraft a minimum of four ground stations must receive each message to determine a position.
  - Three ground stations can be used if pressure altitude is also used but the position accuracy will be adversely affected due to 100 foot barometric pressure altitude quantisation and because this altitude varies[8] and does not match the WGS84 geoid.
  - An additional ground station may be necessary to support the ability to continue operations with one ground station failed.
  - One less ground station is required if a ground station uses “radar ranging” to measure the distance of the aircraft from the interrogating station.

- For surface movement applications a minimum of three ground stations must receive each message to determine a position.

- “Ranging” via interrogation of SSR transponders can be used in some cases to improve accuracy.

Strengths

- Provides aircraft identification using 4 digit octal codes, 24 bit Mode S codes or Flight Identity (ADS-B or Mode S based) to ground system
- Allows communication of identity, altitude and emergency states downlinked from aircraft

determine position from DF11 transmissions. These transmissions do not provide altitude or flight ID data. Mode A/C transponders need to be interrogated to determine position.

[8] Due to atmospheric pressure

- Provides good detection capability independent of clutter and weather
- Is able to provide a high update rate
- Can resolve two aircraft at the same location (garbling / resolution performance) if aircraft are Mode S capable using selective address interrogation
- Can operate as a set of multiple ADS-B ground stations
- Can be installed at sites shared with other users
- Is an attractive transition path before widescale ADS-B equipage occurs in some States
- Lower cost than radar[9]
- Data feed can be made to resemble radar data (and hence can be used in some ATC automation systems that are not adapted to support native multilateration data)[10]
- In some locations, when existing infrastructure is available, the systems can be inexpensive to install and maintain compared to alternative systems.

Weakness

- Requires multiple sites
- Requires multiple communication links
- Sometimes reports false targets (reflections, multipath)
- No error detection provided in downlinked 4 digit code and altitude from Mode C transponders
- Systems can be moderately expensive to install and maintain because of the costs associated with the provision and maintenance of multiple sites especially if existing infrastructure is not available.
- Systems require multiple sites with unobstructed view to aircraft. This can be a significant problem in some environments
- Requires a transmitter to trigger aircraft to transmit the data required for ATC applications
- Not yet endorsed by ICAO
- Requires multiple transmitter sites for large coverage, due to the poor uplink antenna gain when omni-antenna used (compared to high gain radar antenna).

5.4 ADS-C

ADS-C (Contract) is also known as Automatic Dependent Surveillance – Addressed (ADS-A) or simply Automatic Dependent Surveillance (ADS). With ADS-C the aircraft uses on-board navigation systems to determine its position, velocity, and other data, and reports this information to the responsible air traffic control centre.

Information that may be sent in ADS-C reports includes:

a. Present position (latitude, longitude, altitude, time stamp, and FOM)
b. Predicted route in terms of next and (next + 1) waypoints
c. Velocity (ground or air referenced)
d. Meteorological data (wind speed, wind direction, and temperature)

ADS-C reports are sent by point to point satellite or VHF data links. The data links are typically provided by service providers. Typically fees are charged for the transmission of each message; as most of these costs are borne by the airlines, there is a reluctance to use ADS-C at

[9] There is a wide variability of the costs for multilateration since site costs typically dominate the total costs. In some environments multilat costs could approach those of radar

[10] Usually brings some additional inaccuracies that are tolerable.

higher rates than 10-15 minutes between messages]. Sometimes HF datalink is used, but with reduced performance.

With ADS-C the airborne and ground systems negotiate the conditions (the Contract) under which the aircraft submits reports (i.e. periodic reports, event reports, demand reports, and emergency reports). Reports received by the ground system are processed to track the aircraft on ATC displays in a similar way to surveillance data obtained from SSR.

ADS-C is typically used in oceanic and remote areas where there is no radar, and hence it is mainly fitted to long range air transport aircraft. The aircraft avionics chooses VHF communication when in coverage of the VHF network to lower costs and improve performance. Satellite data-communications is used at other times such as when the aircraft is over the ocean.

Typically messages are transmitted infrequently (~ each 15 minutes). The positional data is accompanied by a "figure of merit" value which indicates the accuracy. It is not an integrity value.

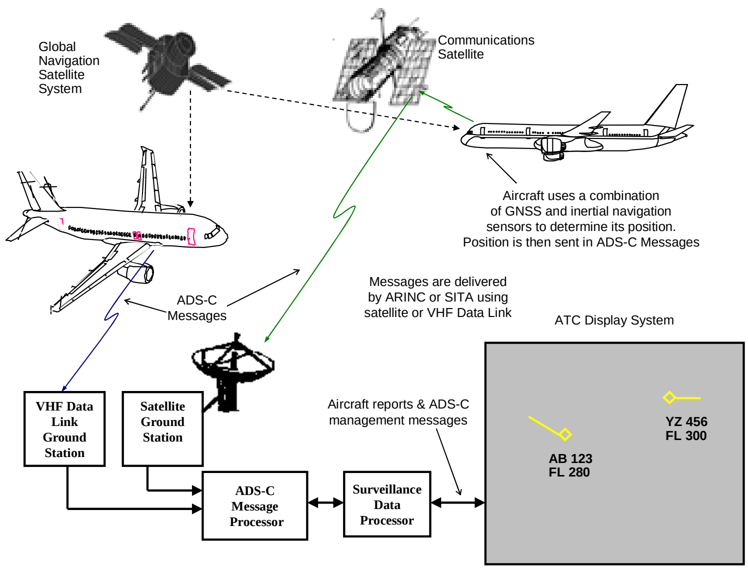

Figure 5 - Automatic Dependent Surveillance - Contract

Strengths

- Provides surveillance coverage over very remote regions and oceans except in the polar regions
- Supports a subset of the safety net applications (Cleared Level Adherence Monitoring : CLAM, Route adherence monitoring : RAM , and ADS Route conformance warning : ARCW[11]) but unable to support more tactical alerts like STCA
- Low capital cost for ANSP
- Minimal maintenance costs

Weakness

- High costs per report (service provider)
- Low reporting rates
- No ability to offer radar like separation services (vectoring etc)
- Expensive avionics fitment
- FANS-1/A is not ICAO-compliant, but has been accepted as a transition step
- ATN variant is not mature but will support higher reporting rates [12]
- Long latency when satellite communication link is used
- Availability not as high as other systems (not all elements are duplicated)
- Susceptibility to failure/overload at satellite earth stations
- Relatively low message delivery reliability

[11] This is the same as “FLIPCY” in the European context
[12] FANS1 standards limit reporting rates so that contracts can be supported over ACARS satellite (amongst other reasons)

6 COMPARISON

This section compares the various technologies

6.1 APPLICATIONS

PSR	**Enroute surveillance**: In the 1960s & 1970s PSR was widely used for ATC surveillance including in enroute airspace. In the late 1970s and following years many ANSPs have decided to discontinue the use of PSR in this application due to the high cost and due to mandatory requirements for SSR transponders in a lot of airspace. In many countries the use of PSR is retained for defence purposes rather than for provision of civil ATC services. The use of PSR for enroute ATS is expected to continue to decrease. **Terminal area surveillance**: PSR remains a useful tool in busy terminal areas to detect non transponder equipped aircraft and provide intruder protection of the terminal area airspace. Typically primary radars have co-mounted SSR to improve tracking performance and provide identity/altitude. In the next decades the use of primary radar is expected to commence to decrease. **Surface movement radar** application: PSR remains a significant tool in surveillance of airport surfaces. Its purpose is to detect vehicles and aircraft which are not detected by other cooperative surveillance means (eg aircraft and vehicles not equipped with transponder or equivalent). **Airborne:** no civil application.
SSR	**Enroute surveillance**: SSR only sensors often provide surveillance in enroute airspace when financially justified. In some States enroute radars rotate slowly (typically 5 rpm) and in others rotate at 16 rpm. In some regions (Europe) two SSR sensors are required to cover the airspace. In other regions, single SSR surveillance is used. **Terminal area surveillance**: SSR radars are currently critical to the effective provision of terminal area surveillance because they provide a moderate update rate of position (typically 15 rpm), identity (4 digit octal codes) and altitude. Typically a terminal area radar includes primary radar and SSR. **Precision Runway Monitor (PRM) - electronic scan**: Special SSR ground stations are used by a number of States to support precision runway approach monitoring to parallel runways. Typically these electronic scan sensors provide an update every 1 second, with an azimuth accuracy exceeding 1 milliradian. The objective of these radars is to detect divergence from the defined final approach path.

	Airborne: ACAS systems including TCAS 1, TCAS 2 and other products such as TCAD rely on SSR transmissions.
Mode S	**Terminal area & enroute surveillance** Mode S SSR sensors are being commissioned around the world to support both enroute and terminal area operations. Whilst the surveillance performance benefits (eg: resolution) of Mode S will be delivered to all Mode S equipped aircraft in the coverage of a Mode S radar, only ANSPs with updated ATC systems will be able to take advantage of many capabilities such as downlink of airborne parameters (DAP). The move away from the use of 4 digit SSR codes will be slow and driven by ATC automation changes as well as fitment of Mode S radar ground stations and transponders in aircraft. Europe's ELS/EHS mandate will speed this process in Europe and hence worldwide. Legacy ATC automation in other States will slow progress. **Airborne:** ACAS systems including TCAS 1, TCAS 2 and other products such as TCAD rely on SSR transmissions.
Multilateration	**Advanced Surface Movement Guidance and Control Systems (ASMGCS)**: Multilateration has been deployed at numerous locations for surface surveillance. Typically it supports a surface movement radar and provides highly accurate position and identity to these systems. Typically 10-20 ground stations are used to provide multilateration coverage over the whole airport surface. High update and high integrity positional data is provided for Mode S capable aircraft and for ADS-B equipped surface vehicles. Implementation requires new "transponder on" procedures to be followed by flight crew whilst taxing. Careful site selection and tuning of these systems has been found to be necessary to account for multipath, coverage obstructions and for aircraft that are not Mode S capable. Multilateration systems operate more efficiently the higher the Mode S transponder fitment rate. **Terminal area surveillance**: Multilateration shows promise for "wide area" application and a number of States have projects to deploy multilateration for this purpose. However, at this time, no ICAO approval has been obtained to use multilateration for this application. SASP is working on a proposal to use multilateration for 3 nautical mile separation. Austria is using multilateration in a specific terminal area application (Innsbruck) monitoring approaches and has authorised a 5 nautical mile separation standard. **Enroute surveillance**: Multilateration is likely to be able to be used in some "very wide area" applications. At this time, no ICAO approval has been obtained to use multilateration for this application. The Czech Republic has been using a specific type of multilateration for very wide area surveillance for some time in a search & rescue support role. "Very wide area" multilateration requires that multiple ground stations have the ability to "see" the aircraft over large areas. Typically this requires a high number of sites and hence makes multilateration a higher cost that anticipated because of site and

	data communication costs. A comprehensive site survey would be required to ensure that adequate coverage, geometry and site availability exists to meet the requirement. In States with particular requirements, a highly developed communications infrastructure, the cost of site development and data communication may be low enough for this to be preferred. Typically this may occur when terrain would prohibit cost effective radar coverage. **PRM**: Multilateration shows promise for use in PRM applications when sufficient aircraft are equipped because multilateration meets the accuracy and update requirements of PRM. However, at this time, no safety case or ICAO approval has been obtained to use Multilateration for this application. The USA and Australia envisage using multilateration for this purpose. **Airborne:** no application.
ADS-B	**Enroute surveillance**: ADS-B may be used in enroute airspace. Some States will require full ADS-B equipage whilst others will allow separation services without all aircraft being equipped largely dependent on their ATC automation system capabilities and traffic environment. ADS-B will bring safety improvements and automated safety nets where there is no surveillance today. ADS-B will be more readily used in ATC systems which can support low performance surveillance (eg voice reports) and high performance surveillance (eg radar or ADS-B) within a sector. Clearly benefits rise the higher the percentage of equipage. In many States, ADS-B will be used enroute in remote areas which have no radar surveillance. Other States will decommission enroute radars in lieu of ADS-B because of ADS-B's cost effectiveness. ICAO's SASP and OPLINK panels have agreed to the use of ADS-B to provide 5 nautical mile separation standards. The associated changes to PANS ATM doc 4444 are soon to be published. ADS-B may also be used in parallel with radar, improving overall performance by improving detection (coverage holes), improving tracking (using 24 bit code, using velocity vector), reducing latency and increasing update rate. **Terminal area surveillance**: ADS-B may be used in terminal area airspace to provide high quality surveillance data. The application of ADS-B in this domain is currently hindered by lack of equipage of ADS-B avionics. Comprehensive use in busy terminal areas will require a relatively high percentage of equipage because of the difficulties and workload associated with procedural terminal areas. However, in some States mixed equipage may be possible. ADS-B positional data accuracy and ADS-B's high integrity are major advantages as well as the better velocity vector performance of ADS-B compared to radar. No ICAO approval yet exists for the use of a 3 nautical mile separation standard using ADS-B although work is currently being progressed by SASP. **Surface movement**: ADS-B has potential for surveillance on airport surfaces. No States have yet deployed ADS-B alone for this application. However surface surveillance systems have been commissioned to provide identity and emergency flag data to surface movement displays.

	PRM: ADS-B shows promise for use in PRM applications when sufficient aircraft are equipped because ADS-B meets the accuracy, velocity vector performance and update requirements of PRM. However, at this time, no safety case nor ICAO approval has been obtained to use ADS-B for this application. **Air-Air Applications**: ADS-B shows promise for use a large number of air to air applications. A number of States are examining strategies to improve safety, efficiency and increase capacity using these applications. This feature has significant strategic impact on the choice of technology for some States. Applications include In Trail Procedure, Airborne situational awareness, Merging & Spacing etc **Airborne:** A significant number of airborne applications of ADS-B are envisaged by the international community including Air Traffic Situational awareness, In trail procedures, Merging & spacing etc. Airbourne applications are seen by FAA and Europe as key elements of the next generation of Air Traffic Management and are critical to provision of future capacity.
ADS-C	Enroute surveillance in remote or oceanic areas Due to the low update rate, the cost of ADS-C avionics and service provision, it will not be preferred when other technologies can support surveillance. However, over the ocean or remote areas, where other technologies cannot be used, ADS-C will remain as the preferred surveillance tool. ADS-B may compete in cases where ground stations can be installed, for example on islands, oil rigs etc. ADS-C does not support 3 nautical mile or 5 nautical mile separation standards. ADS-C does not support tactical ATC nor vectoring. **Airborne:** airborne equipment may be used for airline-specific communications such as systems monitoring, crew and airframe scheduling and customer care requirements.

6.2 PERFORMANCE CHARACTERISTICS

Since this document is aimed at discussing alternative technologies to be deployed in the future, the performance of new generation radars shall be assumed. This is in contrast to many comparative documents that compare existing (old) radar performance with new surveillance technologies to demonstrate that the new technology is safe.

	Range	Accuracy	Integrity	Resolution	Update period
Primary radar	S-band typically 60-80 NM L-band 160-220 NM	In range : 0.1 NM rms or 0.2 NM 2 σ In azimuth : 0.15 degrees rms or 0.3 degrees 2 σ .	No "message by message" integrity report provided. Range/Azimuth alignment can be assured through statistical comparison of SSR & primary radar reports. Alternatively special primary test units may operate like a SSR site monitor.	1 to 3 degrees in azimuth	Between 4 & 15 seconds
SSR	200 NM-250 NM	For a monopulse radar In range : 0.03 NM rms In azimuth : 0.07 degrees rms or 0.14 degrees 2 σ for random errors. [13]At 50 NM range the 0.14 degree error results in a position error of 0.12 NM. At 100 NM range : 0.24NM, At 200 NM : 0. 48 NM At 250 NM : 0.60 NM	No message by message integrity. Testing of site monitor provides integrity check in general. Downlinked data such as altitude & 4 digit identity is subject to transmission errors which are passed to controllers. Subject to mode A/C code garbling.Subject to confusion between mode A and Mode C data.	0.5 to 1 degree in azimuth	Between 4 & 15 seconds

[13] The range noise errors are 0.03 NM (1σ) and the noise errors in azimuth are 0.07 degrees (1σ). For comparison purposes, and since GPS (ADS-B) errors are expressed with respect to a positional error with 95% confidence, this paper will use 2 σ (95% assuming Gaussian distribution of errors) - namely a 0.14 degree error.
Taking into account the random noise errors only: At 50 NM the 0.14 degree error results in a position error of 0.12Nm. At 100 NM this error becomes 0. 24NM, 0.48 at 200 NM and 0.60Nm at 250 NM. In addition to these errors one must consider systematic errors of alignment. Radars can be maintained aligned accurate to +-0.05 degrees in azimuth. Azimuth errors are clearly the dominant error as range increases, and can be translated into positional errors as follows: Systematic errors of +- 0.2Nm at 250Nm from the radar also need to be considered when using Multi Radar to separate aircraft and when separating aircraft from terrain or geographical boundary.

	Range	Accuracy	Integrity	Resolution	Update period
ModeS	200 NM-250 NM	Same as SSR	No message-by-message positional data integrity. Testing of site monitor provides integrity check in general. Mode S downlinked data is subject to stringent transmission error detection algorithms virtually eliminating the risk of undetected false data.	Perfect for mode S avionics due to ability to uniquely interrogate one aircraft 1 degree in azimuth for mode A/C transponders	Between 4 & 15 seconds
ADS-B	200 NM-250 NM	Determined by the aircraft avionics and independent of range from sensor. For GPS, typically : 95% less than 0.1 NM	Position integrity guaranteed to $1*10^{-7}$ [14]due to RAIM algorithm in avionics. Integrity value is downlinked in the ADS-B message. A site monitor typically augments the integrity monitoring and often also supports GPS constellation monitoring. ADS-B downlinked data is subject to stringent transmission error detection algorithms virtually eliminating the risk of errors in the transmission medium	Perfect due to Mode S avionics unique 24 bit code and random transmission requirements	0.5 seconds from aircraft. Typically 1 second from ground station. In high density environments with significant 1090 Mhz FRUIT, the update rate may be reduced

[14] Sometimes limited to 10^{-5} to account for software assurance level

	Range	Accuracy	Integrity	Resolution	Update period
Multilateration	Determined by the geometry of the ground stations.	Determined by geometry of ground stations with respect to the aircraft. Therefore each multilateration system is designed to achieve a defined accuracy for the particular operational requirements of the service volume. Higher accuracy requires better geometry and typically more ground stations. Very high accuracy in some areas and low accuracy in others. A requirement for multilateration accuracy < 0.1 NM rms is reasonable for such a system. ie 0.2 NM at 2 σ The number and position of ground stations required to achieve this accuracy can then be determined. Processing systems need to filter received information based on geographical area and DOP of receiver system when accuracy of the report is less than that required for the operation.	Position integrity could in theory be guaranteed by reception algorithm if an overdetermined solution is available. This could operate like the RAIM algorithm in GPS. Current implementations do not require an overdetermined solution. Insistence on such a solution would require multilat systems to flag to downstream users whether or not an overdetermined solution is provided. It would also require additional ground stations and costs. Downlinked data from Mode S transponders (but not A/C transponders) is subject to stringent transmission error detection algorithms significantly reducing the risk of false data. Provision of a site monitor can provide a general system integrity check but does not provide integrity data relating to each aircraft.	Perfect for Mode S avionics due to unique 24 bit code and independence of transmission times. For Mode A/C transponders, position resolution is good due to multilateration technique. With Mode A/C avionics, aircraft at same range (and hence possibly garbled) from one ground station are not at the same range from other ground stations. Some multilateration implementations use whisper-shout techniques to resolve Mode A/C transponders.	Typically 1 second for Mode S aircraft. Typically 2.5 to 5 seconds for Mode C transponder aircraft.

	Range	Accuracy	Integrity	Resolution	Update period
ADS-C	200 NM from VHF ground station or via satellite (unrestricted except for polar regions)	Determined by the aircraft avionics. Typically 99% less than 0.2 NM	An Actual Navigation Performance (ANP) value is provided by avionics and generates FOM value to ATC. This is an "accuracy" value and no integrity measure is conveyed to the ATC centre. Downlinked data is subject to stringent transmission error detection algorithms (CRC) virtually eliminating the risk of false data.		Typically a report each 14 minutes. However, also supports event contracts which initiates unscheduled reports on occurrence of defined events.

	Availability	Typical Reliability – MTBF (Continuity) & Major factors	Maturity	Anomalies
		Reliability and availability are very specific to the deployment of concern because they depend on organisational factors, maintenance, telecoms infrastructure as well as hardware and software. Therefore the values shown are very generic.		
Primary radar	> 99% NB: Outages for routine antenna maintenance required	For duplicated system > 20,000 hours Modular and fail soft transmitter & reliance on single antenna. Relies on mechanical machinery for antenna rotation Duplicated receiver/processing	Very mature. Thousands of systems installed. Separation standards and procedures are established in PANS ATM Doc 4444	Affected by weather, "road traffic", multipath, and ground clutter
SSR	> 99 %[15] NB: Outages for routine antenna	For duplicated system > 20,000 hours	Very mature. Thousands of systems installed Separation standards and procedures	Affected by multipath, reflections, second time around replies, plot splits, garbling, resolution loss & data corruption

[15] Eurocontrol standard document for radar surveillance in enroute airspace and major terminal areas para 7.4 : <9 hours/ year = 99.9%
Australia : Planned outages over 10 years (inc major bearing refurbishment) 52 hours/pa average plus unplanned 9 hours = 99.3%

	Availability	**Typical Reliability – MTBF (Continuity) & Major factors**	**Maturity**	**Anomalies**
	maintenance required	Reliance on single antenna. Relies on mechanical machinery for antenna rotation. Duplicated transmitter/ receiver	are established in PANS ATM Doc 4444	
ModeS	> 99% NB: Outages for routine antenna maintenance required	Same as SSR For duplicated system > 20,000 hours	Reasonably mature. Deployments have occurred in Europe, UK & New Zealand although few are operating in purely ModeS modes. Most interrogate A/C as well. Few ATC systems are operationally using Mode S downliked parameters (DAPs). Separation standards and procedures are established in PANS ATM Doc 4444 since Mode S is treated in the same way as SSR. Operational procedures are still being developed for operational use of DAPs.	Similar to SSR for processing of Mode C transponders. Significantly less impact with Mode S transponders. Some new anomalies (loss of detection) associated with some older mode C transponders.

	Availability (of Service inc GPS & avionics)	**Typical Reliability – MTBF (Continuity) & Major factors**	**Maturity**	**Anomalies**
ADS-B	> 99 % NB: Some outages as a result of pre-alerted poor GPS geometry	Duplicated system >20,000 Hours Receiver only Dependence on GPS Duplicated receiver	Maturing. Operational in at least 1 State. SASP and OPLINK panels have agreed with proposed ADS-B separation standards. Procedures have been defined for PANS ATM Doc 4444 and are expected to be published soon.	Some avionics "bugs" identified.
Multilat	>99%	Duplicated system >20,000 Hours Requires multiple sites & multiple communication links Failure of 1 receiver has geography related impact on performance. However, assume that extra ground stations provided to support any one failure	Maturing. Operational in ASMGCS (airport surface) applications worldwide. Operational as WAM in at least 1 State. SASP has development of separation standards on the work program.	Some "teething" problems identified. Careful tuning of each site used to overcome these.
ADS-C	>99% Also constrained by service guarantee by service providers.	2,000 Hours (Low reliability due non duplicated system)	Mature. Used worldwide as FANS1A. Is not an "ICAO system". Yet to mature for ICAO/ATN variants.	FANS1A anomalies documented and managed by FANS1A Central reporting agencies (CRAs) on behalf of States in regions.

6.3 <u>DATA PROVIDED BY EACH TECHNOLOGY</u>

The following provides a brief overview of the information that may be received and processed by the relevant surveillance technologies

	No transponder	**Mode A/C transponder**	**Mode S transponder with DAPs**
Primary radar	Position, calculated velocity vector from these position reports	No data is able to be provided by this sensor	No data is able to be provided by this sensor
SSR	No data is able to be provided by this sensor	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector
Mode S	No data is able to be provided by this sensor	Position, flight level (barometric), 4 digit octal identity, calculated velocity vector	Position, flight level (barometric), 4 digit octal identity, 24 bit unique code, selected altitude, Flight ID, Selected Altitude, Roll Angle, Track Angle Rate, Track Angle, Ground Speed, Magnetic Heading, Indicated Airspeed/Mach No, Vertical Rate, calculated velocity vector[16]
Mulitlat	No data is able to be provided by this sensor	Position, flight level (barometric), calculated altitude, 4 digit octal identity, calculated velocity vector	Position, flight level (barometric), 4 digit octal identity, 24 bit unique code, selected altitude, Flight ID, Selected Altitude, Roll Angle, Track Angle Rate, Track Angle, Ground Speed, Magnetic Heading, Indicated Airspeed/Mach No, Vertical Rate, calculated velocity vector

[16] Based on European Mode S mandate for Elementary & Enhanced surveillance. Additional data block have been defined in Mode S standards and could be used in the future.

ADS-B	ADS-B Requires the aircraft to be equipped with either : - A Mode S transponder capable of ADS-B message transmission (appropriate transponder product and software version), plus appropriate data to be fed to this transponder, typically a GNSS receiver or - A standalone ADS-B transmitter device (perhaps independent of the transponder) able to transmit ADS-B messages according to the standards or - A Mode C transponder able to transmit ADS-B messages according to the standards.
	If ADS-B equipped : Current aircraft : Position, flight level (barometric), position integrity, geometric altitude (GPS altitude), 24 bit unique code, Flight ID, velocity vector, vertical rate, emergency flags, aircraft type category. Fully compliant DO260A[17] will add a number of data fields.

ADS-C	ADS-C Requires the aircraft to be equipped with either a) The FANS1/A package. This includes processing, GPS, ACARS VHF and satellite datalinks b) An ICAO ATN ADS-C avionics package
	If ADS-C FANS1/A equipped : Position, altitude, flight ID, emergency flags, waypoint events, waypoint estimates, limited “intent data”, limited wind speed data If ADS-C FANS1/A equipped : There are currently no aircraft providing ATN ADS-C

[17] RTCA DO260 : Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)

6.4 COST

The cost to deploy and maintain surveillance systems is high. The total cost includes much more than the ground based electronic equipment itself. Consideration of the following points is required when examining the total cost of various systems.

6.4.1 Aircraft owner/operator costs

In comparing the total cost of surveillance systems, some consideration must be given to airborne equipment requirements, which may be considerable for some technologies.

The total lifecycle cost should be considered. The timing of transition to new avionics is governed by numerous factors including the expected life of the aircraft, the cost, the benefit that can be obtained, available products and mandatory avionics requirements.

In considering the various ground based surveillance technologies it can be noted that:

- Primary radar surveillance does not require avionics deployed in aircraft.
- Multilateration surveillance can operate with Mode C, Mode S or ADS-B avionics. It operates better when aircraft are Mode S or ADS-B equipped.
- Mode C based surveillance requires either Mode S or Mode C transponders on board aircraft.
- Mode S based surveillance requires Mode S transponders supporting Elementary and/or Enhanced surveillance parameters if the DAPs benefits are to be realised.
- ADS-B surveillance requires either
  - A suitable Mode S transponder (hardware/software), or
  - A mode C transponder with capability to transmit ADS-B messages, or
  - A standalone avionics package able to transmit ADS-B messages.
  - In addition it requires the transmitter to be connected to appropriate GNSS receiver (or equivalent performance position source)

The costs associated with any aircraft equipage program (for new production aircraft, as well as for retrofit) are highly variable and airframe dependent. Hundredfold cost variations to fit the same avionics to different aircraft types are not uncommon. Operating costs are also highly dependent on aircraft type, fleet size and nature of operation but include

- Engineering support costs
- Scheduled & unscheduled Maintenance
- Flight crew training costs
- Costs associated with aircraft simulator upgrades

For these reasons avionics costs associated with each surveillance technology will be very FIR (or ANSP) specific. However, the nature of the aviation industry (in particular cross FIR and international operations, fleet turnover and the prevalence of aircraft leasing) mean that it is impossible – and unhelpful – to attribute the total cost of avionics equipage to any one FIR, ANSP or surveillance system. It must be noted that some of the avionics required to support surveillance – in particular ADS-B and ADS-C – have other applications and hence benefits to operators.

The current status (2007) of avionics equipage is :

	Mode S	**Mode C**	**ADS-B**
International air transport	Almost all aircraft are equipped with Mode S; ACAS equipped aircraft have Mode S transponders. A large percentage of aircraft that operate in and transit Europe are also equipped with DAP capability	Almost all are equipped with Mode C capability Most new aircraft delivered in the last 5 to10 years are equipped with GPS and most of these have the capability to output HPL integrity data for ADS-B. This is particularly true in Asia Pacific region with its new fleets.	A large percentage of new aircraft manufactured in the last 2 years are equipped. Many legacy aircraft are being equipped at the same time as the European Mode S mandate is implemented.
Domestic major airline air transport	Almost all aircraft are equipped with Mode S; ACAS equipped aircraft have Mode S transponders	Almost all are equipped with Mode C capability. Many aircraft are equipped with GPS and most of these have the capability to output HPL integrity data for ADS-B	New aircraft from Boeing & Airbus are equipped. Many legacy aircraft are not equipped.
Regional aircraft	Many regional aircraft are equipped with Mode S	Almost all are equipped with Mode C capability Many aircraft are equipped with GPS but only some have the capability to output HPL integrity data for ADS-B	Very few are equipped with ADS-B capability because Regional Airliner OEMs have not embraced ADS-B
General aviation	Few general aviation aircraft are equipped with Mode S	Many are equipped with Mode C capability. Many aircraft are equipped with GPS but few with capability to output HPL integrity data for ADS-B	A few are equipped with ADS-B capability using a single GA product. There is insufficient choice in ADS-B products available today for this market.

Taking the above into account, it is very difficult to allocate a cost to equip with any avionics type. Clearly the transition to ADS-B equipage is the most significant and expensive of the alternatives in terms of aircraft equipage).

The APANPIRG meeting report of 2006 states that

> *"IATA noted that much of the business case is complicated by the problems of quantifying the cost of ADS-B avionics fitment by airlines. In this regard, IATA recommended that APANPIRG should simply assume that all aircraft will be equipped as a consequence of the worldwide move towards ADS-B OUT and Mode S Enhanced Surveillance."*

6.4.2 ANSP costs

ANSP costs include:

- Equipment purchase
- Installation costs and system testing
- Project costs including planning, procurement activities etc
- Site costs including
  - land
  - environment impact statement preparation
  - power provision
  - UPS and batteries
  - airconditioning
  - roads
  - shelters
  - racks in which to install main and ancillary equipment
  - towers
  - fencing
  - land clearing
  - security
  - telecommunication lines
- Operating costs
  - Engineering support costs
  - Scheduled and unscheduled Maintenance
  - Power and airconditioning running costs
  - Telecommunication operating costs

Taking the above factors into account and using experience of the technologies to date, the cost of surveillance to support enroute and TMA airspace is shown in the following table.

This table assumes that the selected sites are **NOT** “Greenfield” sites and hence do not include land purchase, environmental clearance, shelter and road building costs.

The table does NOT include avionics costs.

	Major cost factors	**Cost for TMA (60NM radius) $ Australian**	**Cost for Enroute (200NM radius) $ Australian**
Primary radar	Site costs, capital cost, ongoing maintenance & management costs, large UPS & power supply especially for antenna. No avionics required.	$8M	$10-14M

	Major cost factors	Cost for TMA (60NM radius) $ Australian	Cost for Enroute (200NM radius) $ Australian
SSR	Site costs, capital cost, large UPS & power supply especially for antenna, ongoing maintenance & management costs. SSR Mode C avionics required. In some regions the majority are required to be Mode C equipped.	$6M	$6M
Mode S	Same as SSR. Most vendors offer ModeS radars as “standard” at a similar price to SSR. Mode S avionics required.. Air transport already have Mode S to support ACAS in most parts of the world.	$6M	$6M
ADS-B	Apart from avionics installation, major items are site related costs and ongoing telecommunication costs. ADS-B avionics fitment is not included in estimate here because of difficulty in attribution of cost especially for international aircraft where the fitment supports surveillance in all ADS-B capable FIRs/ANSPs. Major airframe manufacturers fit ADS-B in the factory. IATA has recommended at APANPIRG that APANPIRG members ignore fitment costs be ignored in business case development.	$380K	$380K
Mulitlat	Major items are site related costs and ongoing telecommunication costs. If the operational requirement does not demand coverage extended range coverage (eg say coverage is only required to 40 nautical miles) then multilateration is a stronger competitor. Ie: it may not be warranted paying the extra costs for long range performance provided by radar . Of course each individual case must be considered because the costs are highly dependent on the environment, cost and infrastructure in the country of deployment. Multilateration is a stronger competitor against radar when the required area of coverage is small. Use of Greenfield sites could dramatically increase costs due to development and possibly the number of sites required. Site development costs can easily exceed equipment costs. At least SSR Mode C avionics are required but Mode S avionics are required for best performance.	>$1-$3 M	$2M - $5M

	Major cost factors	**Cost for TMA (60NM radius) $ Australian**	**Cost for Enroute (200NM radius) $ Australian**
ADS-C	No sensor cost. Minimal setup cost for ANSP. Large cost of FANS1/A avionics and associated equipment for new aircraft (and very large for retrofit)..	N/A	N/A

Some further details are provided in **Appendix A**

7 ISSUES IN CHOICE OF SURVEILLANCE TECHNOLOGY

In the deployment of ATC surveillance technologies care is required to match the chosen technology to the operational need and environment. In some cases a clear choice will emerge for a particular State. In other cases a mixed solution may be best.

Some factors to consider are as follows :

7.1 COST

The cost of surveillance systems can be a major determinant of whether surveillance is deployed, and if it is deployed, which technology is chosen. In many States the availability of lower cost surveillance (compared to radar) has allowed surveillance to be provided in areas where surveillance was previously uneconomical.

In States where there is significant traffic, the operational need and the ability to use funds from airways charges will determine the deployment of surveillance.

The lowest cost surveillance to meet the particular operational needs in the particular environment will be chosen.

The issue of who bears the cost and who benefits also needs to be considered.

> For example : Safety benefits may be provided to the whole community. Efficiency benefits may be provided to the airlines and their customers. Costs of surveillance system delivery are usually borne by the ANSP and sometimes passed to airspace users in charges. If new avionics are needed to be fitted to aircraft consideration of who pays for that equipment is required. In some cases the ANSP may be able to subsidise some segments of the industry to equip their fleet. In other cases airlines and aircraft owners bear the entire equipment cost.

Cost is further examined in Paragraph 6.4 as well as in Appendix 1.

7.2 MARKET SEGMENT MIX

The nature of the aircraft to be subject to surveillance is a determinant of the best technology to use

- non cooperative aircraft (targets) can only be detected by primary radar
- cooperative air transport aircraft can be expected to have Mode S or ADS-B equipment and hence ADS-B or SSR/Mode S may be the most appropriate technology
- If general aviation aircraft are to be detected, SSR or ADS-B avionics may need to be installed in those aircraft. This issue can become problematic if a large general aviation fleet operates in the State. If the general aviation fleet is small, it may be cost effective to use ADS-B and pay to fit the small number of aircraft with ADS-B.

In some States the market mix, and which part of the market would pay for avionics fitment is a critical issue.

Equipage of military aircraft can be problematic. However, each State needs to consider the role of the ANSP in the provision of surveillance facilities to support the military.

7.3 Airspace segregation

In some States, airspace can be segregated so that equipped aircraft are able to access defined airspace whilst non equipped aircraft are permitted to operate in different airspace.

7.4 GEOGRAPHY

The decision making needs to consider the obstacles to radio propagation for all relevant technologies. In some cases the geography may favour radar, in other cases it may favour multilateration.

SSR/Mode S radar has a long range capability from a single site due to its high gain antenna. It is well tailored for upper airspace detection up to 250 NM if the geographical location is free from close obstacles.

Multilateration is particularly effective in areas of constrained line of sight situations, due to its ability and adaptability to fill smaller specific area of surveillance. Ie: in places where the benefits of long range radar performance cannot be realised.

The choice of ADS-B is not really affected by geographic considerations because it achieves coverage as good as either multilateration or radar from fewer sites.

In the case of very remote or oceanic regions, there may be no choice apart from ADS-C.

7.5 EXISTING TELECOMMUNICATIONS INFRASTRUCTURE

In cases where there is comprehensive telecommunications infrastructure it will be more easy (and hence less expensive) to install ADS-B and multilateration ground station sites. When telecommunications infrastructure does not exist it can be costly to establish.

7.6 EXISTING SURVEILLANCE & ATC AUTOMATION INFRASTRUCTURE

There are significant benefits of a homogeneous surveillance infrastructure. If one technology (and one vendor) is chosen there are savings in engineering support, training, documentation management and system planning. This can impact on the choice to support additional or new technologies.

The ATC system used by a State may need to be upgraded to support any or all of the technologies listed in this paper. The cost of performing these upgrades needs to be considered. There may also be lower overall costs if the ATC automation system only needs to support the one surveillance technology, although there are operational advantages if the ATC system can support multiple surveillance technologies.

Some ATC systems and associated operational procedures can support ADS-B use, including delivery of separation services, when there is partial aircraft ADS-B equipage. Typically such systems support the graphical display of ADS-B, radar and flight plan tracks.

Other ATC systems and/or operational procedures require complete equipage for ADS-B use to be viable.

7.7 REQUIRED FUNCTIONALITY

Depending on the State’s functional needs, different technologies may be chosen. Each technology has different functional capabilities beyond detection and provision of position and altitude data. Eg: Mode S is able to provide readout of selected altitude; some multilateration systems are able to provide a precise position report independent of GPS; ADS-B is able to provide a high update of high accuracy velocity vector.

Some States require the use of primary radars to support Defence needs rather than Air Traffic Management requirements.

7.8 ABILITY TO MANDATE EQUIPAGE

The choice of SSR, Mode S, multilateration or ADS-B may depend on the State's ability to mandate that aircraft operating in the airspace must be equipped with the required avionics. The State's ability to issue a mandate may depend on many factors.

7.9 AIRSPACE CAPACITY REQUIREMENTS

The capacity of airspace can be increased through the provision of high quality surveillance. This is achieved through the application of reduced separation standards.

At this time ICAO recognises that 3 nautical mile and 5 nautical mile separation standards may be used using primary radar, SSR, and Mode S radar. Changes to ICAO documents are about to be published recognising ADS-B use to support 5 nautical mile separation standards. SASP is working on proposals to allow 3 nautical mile separation standards using ADS-B and also on the use of multilateration to support both 3 and 5 nautical mile separation standards.

ADS-C is unlikely to ever support 3 and 5 nautical mile separation standards. However it is used to support 30/30 and 50/50 nautical mile procedures used in some regions.

7.10 STRATEGIC NATURE OF TRANSITION TO ADS-B

It is widely recognised that ADS-B will eventually become the preferred surveillance technology worldwide, although this will take time.

ICAO, at ANC11 resolved that

"*ICAO and States recognize ADS-B as an enabler of the global ATM operational concept bringing substantial safety and capacity benefits*"

Therefore decision making by States will consider the long term enabling of ADS-B balanced against short term requirements.

For some States it may be too difficult to fit enough aircraft with ADS-B avionics and radar or multilateration may be necessary until ADS-B fitment occurs.

Some States may view the benefits of ADS-B as so large that strategically they move to this technology as soon as possible. Typically this is because in the long term, once aircraft are equipped, ADS-B has strong performance in numerous areas :

- lowest cost of additional surveillance coverage
- **allows air-air surveillance benefits**
- allows low cost surveillance for 3rd party applications (flying schools, Search & Rescue…)

The issue of enabling air-air surveillance is significant since it has the potential to change the way in which ATM is performed. The ability for aircraft pilots to electronically "see" nearby aircraft changes the risks encountered in certain airspace compared to today's practice where pilots use the human eye. ADS-B technology has the potential to significantly influence airspace classification, ATC procedures and system efficiency.

For the airline community, the future air-air applications promise increased capacity, functionality, reduced cost. Some see that they will only be able to cope with future air traffic needs by using aircraft centric – network enabled aircraft. ADS-B is a key component of such a vision. The airline UPS is pioneering considerable work in this area along with the work of the FAA-Eurocontrol Requirements Focus Group.

It is interesting to review the views of a major ANSP customer IATA. The meeting report of APANPIRG 2006 states :

> *"IATA noted that much of the business case is complicated by the problems of quantifying the cost of ADS-B avionics fitment by airlines. In this regard, IATA recommended that APANPIRG should simply assume that all aircraft will be equipped as a consequence of the worldwide move towards ADS-B OUT and Mode S Enhanced Surveillance."*
>
> *It was also informed that as indicated in its CNS/ATM road map published in 2005, IATA supported to mandate the use of ADS-B OUT from 2010 and simultaneously avoid the installation of new or replacement ATC radar facilities where there are demonstrated operational and cost benefits"*

7.11 VERIFICATION OF ADS-B

Some commentators have promoted the use of multilateration as a means of ensuring the validity of received ADS-B data. Technically this is possible. Radar could also be used to verify the integrity of ADS-B data. If radar and/or multilateration in **all** areas of ADS-B coverage is required, then the most advantages of ADS-B are significantly diminished and the ADS-B deployment becomes unlikely. Verification could perhaps be achieved at major airport hubs aimed at detecting non compliant avionics and triggering corrective action – perhaps in the same manner as Mode S and RVSM monitoring stations.

Periodic verification could perhaps be performed by ramp check units in the same manner as SSR transponder verification.

It must be recognised that integrity monitoring of ADS-B positional data is performed by the GPS integrity monitoring function within the aircraft avionics. This is the same monitoring function used to ensure that aircraft may safely conduct non precision landings with GPS – and associated "separation" from terrain.

The only envisaged integrity check for ADS-B air to air applications will be to monitor the ADS-B integrity data transmitted with the ADS-B message.

Regulations can require that aircraft owners provide high quality ADS-B data together with the appropriate integrity qualifiers. In the same way that airworthiness authorities ensure that Mode C data is trustworthy, authorities need to ensure that ADS-B data is trustworthy. Verification of ADS-B data using radar or multilateration is neither required nor justified in most States.

7.12 ADS-B MULTILATERATION MIXED SOLUTION

In some environments a mixed solution may be appropriate whereby multilateration is used to provide coverage in a "central" area, typically at an airport, for both equipped and non ADS-B equipped aircraft. In addition, each multilateration ground station supports ADS-B only coverage to a larger coverage volume surrounding the "central" area.

In this environment. the central area could be a Terminal Manoeuvring Area (TMA) where both airlines and general aviation co-exist at lower flight levels. Outside this area, services are only provided to ADS-B equipped aircraft outside coverage of multilateration.

A number of existing ASMGCS systems using multilateration are able to support this mixed technology solution.

8 SURVEILLANCE INTEGRATION

There are a number of ways that surveillance data from different sensors can be incorporated into an ATC system. Typically these can be :

- A separate display for each technology, although this approach is not desireable it has been used in a number of cases for demonstration or to build operational experience before further integration is performed.

- A priority system whereby one technology (or data from a particular site) is displayed and other data sources discarded whilst the priority source provides useable data

- A fully fused position calculation whereby data from different technologies are used to calculate a best estimate of aircraft position,

All solutions need to consider how best to present the data including consideration of the following :

- What position symbols will be presented?

- Will different symbols be used to indicate data quality or data source

- Will the data be used for situational awareness or for execution of ATC separation services?
- Will a prediction system advise users of potential radar, multilateration or ADS-B outages
- Will coasting of positional data be used? Will "smoothed" data be presented?
- What update rate is displayed to the user ? Is the update synchronised to a particular sensor or is independent of any sensor input?
- How is alignment maintained and monitored between various position sensors?
- Does the controller have the ability to select/deselect a sensor or technology?

9 SURVEILLANCE TECHNOLOGY SELECTION

This section outlines some indicative cases where the environment may suggest particular solutions. It needs to be clear that the total environment including available funding, politics, and numerous other factors also impact on the choice of technology, therefore the solutions presented can only be indicative :

	Solution	Reason
State has a large fleet equipped with Mode C ATC transponders and surveillance is needed in the near term. Intruder protection not required	Multilat (WAM) with ADS-B capability to support future ADS-B equipage	Near term requirement makes it difficult to fit many aircraft with ADS-B
State requires surveillance on a busy airport surface. Detection of vehicles is also required	Multilat and primary radar. ADS-B as part of multilat could used to detect & identify vehicles some of which are itinerant	Effective multilat surveillance with good accuracy and provides identity. Primary radar used for vehicles without transmitters
State has requirement for surveillance of air transport aircraft (small GA fleet) and has an ATC system able to support ADS-B mixed equipage.	ADS-B only with optional fitment.	Percentage of air transport aircraft that are equipped is rising. Could encourage ADS-B equipage by giving improved services & priority to equipped aircraft. Allows non equipped aircraft to operate. ANSP could purchase ADS-B avionics for small fleet.
State has requirement for surveillance of air transport aircraft (minimal GA aircraft) and does not have an ATC system able to support ADS-B mixed equipage.	ADS-B only but equipage mandatory in designated airspace	Percentage of air transport aircraft that are equipped is rising. Can mandate ADS-B in relevant airspace to provide surveillance at minimum cost to ANSP
State provides ATM services to a large number of operators that are unable to fit ADS-B, but already have SSR transponders – surveillance is required enroute	SSR only sensors	Cost of equipping a large number of air transport carriers may be cost prohibitive to Industry

Surveillance needed in relatively small geographical area – without concern of non transponder equipped intruder aircraft, but Air transport also operate into area with ADS-B. GA aircraft that may operate into area not able to be fitted with ADS-B	Multilat (WAM) with ADS-B capability	Multilat can serve the small area with the benefits of ADS-B delivered for air transport operating in a larger area of coverage.
High density airport with need for airspace intruder protection (ie: to detect violations of controller airspace)	Primary & co-mounted Mode S radar	Primary radar for intruder protection. Mode S to maximise resolution and position display performance and to maximise benefits of investment in SSR – even if ATC system cannot yet process Mode S DAPS
Surveillance needed for small GA domestic fleet plus some international carriers. Limited funds available.	ADS-B only but perhaps subsidise fitment of GA if required. Mandate ADS-B equipage	Subsidy cost may be less than cost of multilat or radar
State requires surveillance for a very large airspace and has minimal funds available and there is no surveillance today	ADS-B only	Most effective solution.
State requires surveillance over an ocean without islands for radar or ADS-B stations.	ADS-C	Only alternative
State requires surveillance at an FIR boundary but has no site for radar or ADS-B – and has limited capital funds – typically for FIR boundary safety.	Service provider provision of ADS-B surveillance or If adjacent FIR has surveillance negotiate an agreement for data sharing	Cost effective surveillance without capital cost
State has coverage requirements that are complicated by terrain restrictions that would have previously required multiple radars to solve – and has good physical and telecommunications infrastructure	WAM multilat with ADS-B support	Cost of site preparation and installation and support of radars would be cost prohibitive. Multilat and/or ADS-B offers the only cost effective solution to meet the requirement. Good infrastructure allows multilateration to be deployed cost effectively.

CONCLUSION

The optimum choice of surveillance technology depends on the operational requirements and environment.

As recognised by ICAO at ANC11, ADS-B is a technology of the future. States will work towards its deployment but will consider alternative technology, when cost effective.

ADS-B is the only technology which supports future applications of air to air surveillance. Some states see this as a decisive strategic factor in moving towards ADS-B.

1 APPENDIX A : Cost comparison multilateration and radar

The following examines the costs of radar and multilateration in two scenarios; one where surveillance coverage is needed in an area of radius of 200 NM and another when coverage is needed for a 40 MN radius.

Case 1 : Area of 200 NM radius

In this short analysis it is **assumed** that only 9 multilateration ground stations are required to achieve a coverage of 200 NM in accord with a NLR report[18]

The NLR report presented a 9 ground station multilateration solution designed to provide 200NM coverage (125,663 sq NM) to approximate a 250 NM (196,349 sq NM) coverage of a radar.

It is far from clear whether a realistic multilateration system can be built to support a 200 NM radius area with 9 ground stations. Such a "paper design" does not examine the issues of terrain, site availability and product availability with high power interrogators. Of course the operational coverage needs would also need to be considered, and it is likely that coverage at lower flight levels would bring the need for additional multilateration sites.

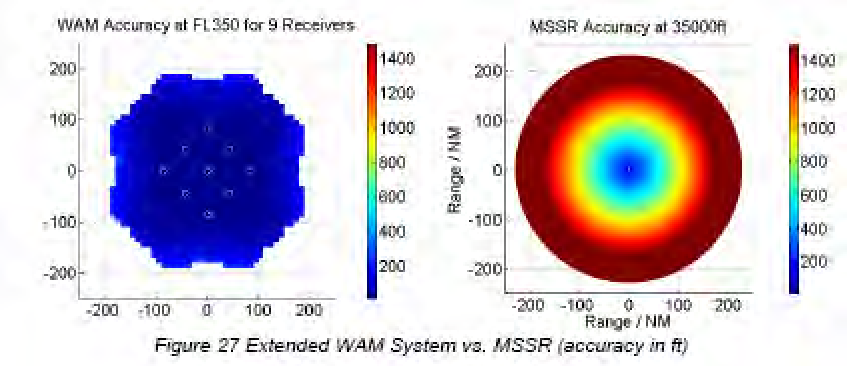

Figure 27 of NLR report

This analysis has been conducted using very approximate estimates of costs.

	Multilat system Assume 9 sites (4 tx/rx, 5 rx)	Radar
Equipment cost	$1.05M	$6M
Tower and antenna mounting[19]	$0.36M	included
Power supply and backup if required	$180K	included
Telecommunications establishment	$90K	$10K

18 National Aerospace Laboratory NLR report prepared for Eurocontrol : NLR-CR-2004-472 "Wide Area Multilateration Report on EATMP TRS 131/04 Version 1.1 August 2005 available at http://www.eurocontrol.int/surveillance/gallery/content/public/documents/WAM_study_report_1_1.pdf Used with permission of Eurocontrol.

19 Tower expected to achieve maximum line of sight and minimise number of sites

Telecommunications ongoing costs ($15K/pa = assume 10 years)	$1.35M	$150K
Installation activity (planning, travel, testing)	$90K	$20K
TOTALS	**$3,120K**	**$6,190K**
For maximum range radius of	200 NM	250NM

If one assumes that an enroute WAM is based on a set of 9 ground stations using existing sites (as described above) then the cost per square nautical mile of coverage is

C(mlat) = $3,120/125,663 = $24.82 per square NM

C(radar) = $6,190,000 / 196,349 = $31.52 per square NM

It must be remembered that these estimates are highly dependent on the environment, cost and infrastructure in the country of deployment. However, these figures indicate that multilat could approach or even exceed the cost of radar in some environments.

If "greenfield sites"[20] are assumed the comparison moves in favour of radar.

	Multilat system(9*)	Radar
Land purchase or lease	$90K	
Environmental impact study/ statement/clearances	$720K	$200K
Shelters or building including fencing & security	$450K	$50K
New road cost if required (very site dependent).	9 * M$x	M$x
TOTAL	**$1260K + road**	**$250K + road**

[20] sites that do not have a building, road, shelter or other infrastructure

Case 2 : Area of 200 NM radius

If the coverage requirement is for a terminal area of say 40 Nautical miles radius then less multilateration ground stations would be required. Lower power interrogation units would be required.

Assuming a more realistic 7 sites (in a location without terrain issues) and the analysis could look like

	Multilat system Assume 7 sites (3 tx/rx, 4 rx)	Radar
Equipment cost	$0.86M	$6M
Tower and antenna mounting[21]	$0.28M	included
Power supply and backup if required	$140K	included
Telecommunications establishment	$70K	$10K
Telecommunications ongoing costs ($15K/pa = assume 10 years)	$1.05M	$150K
Installation activity (planning, travel, testing)	$70K	$20K
TOTALS	**$2,426K**	**$6,190K**
For maximum range radius of	40 NM	250NM

In this case, if the operational requirement does not demand coverage beyond 40 nautical miles it does not warrant paying the extra costs for a radar (even if it provides 250 NM.

Of course each individual case must be considered because the costs are highly dependent on the environment, cost and infrastructure in the country of deployment. Multilateration is a stronger competitor against radar when the required area of coverage is small.

21 Tower expected to achieve maximum line of sight and minimise number of sites

THE SECOND AMENDMENT TO THE AIGD

(Insert new subparagraph 5.8.2 into the AIGD as follows)

5.8.2 It should be noted that independent operations of Mode S transponder and ADS-B may not be possible in all aircraft (e.g. where ADS-B is solely provided by 1090 MHz extended squitter emitted from the transponder). Additionally, some desirable but optional features of ADS-B transmitters may not be fitted in some aircraft. Controller training on this issue, as it relates to the following examples of radio telephony and/or CPDLC phraseology is recommended.

5.8.2.1 STOP ADSB TRANSMISSION or STOP SQUAWK

Issue: In most commercial aircraft a common "transponder control head" is used for SSR transponder, ACAS and ADS-B functionality. In this case, a pilot who complies with the instruction to stop operation of one system will also need to stop operation of the other systems – resulting in a loss of surveillance not intended or expected by the controller.

ATC need to be aware that an instruction to "Stop ADS-B Transmission" may require the pilot to switch off their transponder that will then stop all other functions associated with the transponder operations (such as ACARs etc). Pilots need to be aware of their aircraft's equipment limitations, the consequences of complying with this ATC instruction, and be aware of their company policy in regard to this. As with any ATC instruction issued, the pilot should advise ATC if they are unable to comply.

Recommendation: It is recommended that the concatenated phrases STOP ADSB TRANSMISSION, SQUAWK (code) ONLY or STOP SQUAWK, TRANSMIT ADSB ONLY are used. It is recommended that controller training highlights the possible consequences of **issuing** these instructions and that pilot training highlights the consequences of **complying** with this instruction. It is also recommended that aircraft operators have a clearly stated policy on procedures for this situation. Should a pilot respond with UNABLE then the controller should consider alternative solutions to the problem that do not remove the safety defences of the other surveillance technologies. This might include manual changes to flight data, coordination with other controllers and/or change of assigned codes or callsigns.

5.8.2.2 STOP ADSB ALTITUDE TRANSMISSION [WRONG INDICATION or reason] and TRANSMIT ADSB ALTITUDE

Issue: Some aircraft may not have separate control of ADSB altitude transmission. In such cases compliance with the instruction may require the pilot to stop transmission of all ADSB data – resulting in a loss of surveillance not intended or expected by the controller.

Recommendation: It is recommended that, should the pilot respond with UNABLE, the controller should consider alternative solutions to the problem that do not remove the safety defences of other surveillance data. This might include a procedure that continues the display of incorrect level information but uses pilot reported levels with manual changes to flight data and coordination with other controllers.

5.8.2.3 TRANSMIT ADSB IDENT

Issue: Some aircraft may not be capable or the ADSB SPI IDENT control may be shared with the SSR SPI IDENT function.

Recommendation: It is recommended that controllers are made aware that some pilots are unable to comply with this instruction. An alternative means of identification that does not rely on the ADSB SPI IDENT function should be used.

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CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
AUSTRALIA	ATN tests were conducted. BIS Router and Backbone BIS Router and AMHS will be implemented by 2006.	AFTN based AIDC Implemented between Brisbane and Melbourne, Auckland, Nadi and Auckland. AIDC is also in use between Melbourne and Mauritius.	Implemented and integrated with ATM systems to support FANS1/A equipped aircraft.	Implemented.	Implemented.	5 ADS-B sites are operational. A total of 28 ground stations are expected to become operational throughout 2007. Additional 20 stations will be delivered in June 2007 for installation at enroute radar site and other sites. 5NM Separation service being introduced. NFRM on the carriage and use of ADS-B avionics to be issued in Apr.07	FANS 1/A ADS-C implemented.	
BANGLADESH	BIS Router and AMHS planned for 2007.							

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
BHUTAN	ATN BIS Router and UA service 2008.			Procedures developed for NPA.				
BRUNEI DARUSSALAM	ATN BIS Router and AMSH planned 2007.							
CAMBODIA	BIS Router and AMHS planned for 2007			Procedure developed for NPA				

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
CHINA	ATN BIS Router AMHS will be implemented from 2006. - Tripartite BBIS trial completed with Bangkok and Hong Kong, China in Jan. 2003. - ATN trial with Hong Kong, China conducted 2003/2004. - AMHS with Hong Kong, China planned to conduct in 2006. - AMHS/ATN trial with Macau is under planning. - AMHS/ATN trial with Kuwait is under planning.	AIDC between some of ACCs within China has been implemented. AIDC between several other ACCs are being implemented. Operational trial on the AFTN based AIDC between Sanya and Hong Kong commenced on Aug. 2006 and put into operational use in 2007.	Implemented to support certain AIS Rout. - L888 route, polar routes and Chengdu-Lhasa route. - Trial on HF data link conducted for use in western China.	RNAV (GNSS) implemented in certain airports. - Beijing, Guangzhou, Tianjin and Lhasa airports.	Implemented in certain airspace. - L888, Y1 and Y2 routes.	ADS-B trial has been conducted in 2006. 5 UAT ADS-B sites are operational and used for flight training of CAFUC. Another ADS-B of 1090ES trial will be commenced in 2007.	FANS 1/A ADS-C implemented to support certain routes. - L888 route polar routes and Chengdu-Lhasa route.	

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
HONG KONG, CHINA	- Tripartite BBIS trial with Beijing and Bangkok completed in Jan 2003; -64 Kbps ATN Link with Bangkok put into operational use in June 2004. -ATN trials with China and Japan commenced in 2003/04; -AMHS trials with China and Japan conducted. Further trials and implementation with China, Japan and Thailand planned. - ATN/AMHS trials with Viet Nam, Philippines, Macao China and Taibei planned in late 2007/2008.	Trial on the AFTN based AIDC with Guangzhou and Sanya, China commenced. Operational trial with Sanya commenced in Aug. 2006 and put into operational use in Feb. 2007.	FANS 1/A based CPDLC conducted. D-ATIS D-VOLMET and PDC implemented. VDL Mode-2 technical trial completed in Dec. 2002 and planning on further trials is in progress.	RNAV (GNSS) departure procedures implemented in July 2005.	Implemented in certain airspace.	ADS-B trial using “ASMGCS” trial system commenced in 2004/2005. A separate dedicated ADS-B trial evaluation system was installed in early April 2007	FANS 1/A trials for ADS-C conducted.	

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
MACAO, CHINA	ATN BIS router and AMHS planned for 2007. Trial with China and Hong Kong, China in planning stage.					"A-SMGCS" being planned with ADS-B as option for consideration.		ATZ within Hong Kong and Guangzhou FIRs. In ATZ full VHF coverage exist. Radar coverage for monitoring purposes.
COOK ISLANDS								
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA								
FIJI	AMHS in-house trials completed in 2006. AMHS trials completed in 2007. ATN BIS Router and AMHS plans to be implemented in 2008.	AFTN based AIDC with Brisbane and Auckland operational in 2005.	FANS-1 implemented	NPA procedures for (S) completed in Dec. 2002.	Implemented as (S).	ADS-B implementation in 2008/2009. Estimate 10 Ground Stations	ADS-C implemented in oceanic airspace using EUROCAT 2000 X.	

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
FRANCE (French Polynesia Tahiti)		Implementation of limited message sets with adjacent centres under discussion.	FANS-1. Implemented since 1996.			-Multilateration in use in Paris CDG and Orly Airport; -Multilateration and ADS-B planned for Lyon AP in 2007, for Toulouse in 2008, Marseille 2009; -ADS-B in La Reunion: Ground station installed in 2007, non integrated ADS-B display in 2007, integrated ADS-B system in 2009; -ADS-B ground in Ajaccio in 2007, non integrated ADS-B display in 2007, integrated ADS-B system planned for 2010.	FANS 1/A ADS-C implemented since March 1999.	
INDIA	ATN BBIS router and AMHS planned for implementation at Mumbai in 2007.		FANS-1 implemented at Kolkata and Chennai. Trial in progress in Mumbai and Delhi.		SBAS - Technical developments in 2007. - Implementation planed for 2009.	Trial planned for 2006. ASMGCS Implemented at IGI Airport New Delhi.	FANS 1/A ADS-C implemented at Kolkata and Chennai. Trial in progress in Delhi and Mumbai.	

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
INDONESIA	ATN BIS Router and AMHS planned for trial in 2006.	AFTN based AIDC planned for implementation between Brisbane and Jakarta in 2006. Brisbane and Makassar in 2008.	FANS-1/A. CPDLC in Jakarta, Ujung Pandang FIRs trial planned for 2005.	Procedure to be completed in 2006 for NPA.		2 ADS-B ground stations to be installed in 2007. Upgrading ATC automation at Makasar for ADS-B application capabilities in 2007.	FANS 1/A ADS-C trial planned at Jakarta and Ujung Pandang ACC in 2007.	
JAPAN	ATN BBIS already implemented. AMHS implemented between Japan and USA in 2005 and between Japan and Hong Kong, China planned for 2008.	AIDC based. AFTN procedure implemented with Oakland and Anchorage.	FANS1/A system Implemented in Fukuoka FIR	NPA implemented at 4 aerodromes.	SBAS Operational In 2007	Amendment work to be radio law regulations for using ADS-B out (1090 MHz ES) is under way.	FANS 1/A. ADS-C implemented in Fukuoka FIR	
KIRIBATI								

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
LAO PDR	ATN BIS Router and AMHS planned for implementation with Bangkok in 2006.	AIDC with Bangkok planned for 2008	FANS-1/A Planned for Bay of Bengal and South China Sea areas. Equipment is under test operation.		Implemented.		FANS-1/A. ADS-C planned for Bay of Bengal and South China Sea areas. Equipment under test operation.	
MALAYSIA	ATN BIS Router expected to be completed 2007. AMHS planned in 2008.	AFTN AIDC planned with Bangkok ACC in 2010.	Planned for Bay of Bengal and South China Sea areas in 2006.	NPA at KLIA implemented.		Implementation of ADS-B proposed in 2008-2010.	FANS 1/A ADS-C planned for Bay of Bengal and South China Sea areas in 2006.	
MALDIVES	BIS Router/AMHS planned for implementation in 2007.	Planned for 2007.	FANS1/A now installed and to be implemented in 2007.		Trials planned for 2005-2008. Implementation in 2008.	Trials planned for 2007-2008. Implementation in 2008.		
MARSHALL ISLANDS				NPA implemented at Majuro Atoll.				
MICRONESIA FEDERATED STATES OF								

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
Chuuk				Implemented				
Kosrae				Implemented				
Pohnpei				Implemented				
Yap				Implemented				
MONGOLIA	ATN BIS Router and AMHS planned for 2005 and 2006. Trial with Bangkok conducted		Function available. Regular trials are conducted.	GPS procedures are being developed and implemented at 10 airports.	Implemented.	ADS-B trial in progress implementation planned for 2006.	FANS 1/A ADS-C implemented since August 1998.	
MYANMAR	Trial for ATN BIS Router with Thailand planned for 2006. Test with China planned for 2006.		Implemented since August 1998				Implemented since August 1998	
NAURU								
NEPAL	BIS Router and AMHS planned for 2007.			Development of arrival procedure and NPA completed. Departure procedure is being developed.	Implemented.	ADS-B feasibility study planned for 2007		

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
NEW CALEDONIA						Tontouta ACC 2009 Tontouta APP 2009		
NEW ZEALAND	BIS Router and AMHS implementation planned for 2008.	AFTN based AIDC implemented between New Zealand, Australia, Fiji, Tahiti, Chile and USA.	FANS/1A. Implemented	Implemented.	will be implemented as required.	Domestic trial was conducted in 2005. Use will be re-evaluated in 2008. Trial of Area MLAT conducted in 2006. ADS-B planned as an element of MLAT at specific sites for domestic use.	FANS 1/A Implemented.	
PAKISTAN	Implementation of ATN considered for Phase II (2005-2010).	Implemented between Karachi and Lahore ACCs	Implementation planned from 2005-2010.	Arrival and departure NPA procedure are being developed.	Planned for 2005-2010.	Feasibility study for using ADS-B is in hand. One station planned for 2009 to establish confidence.	Planned for 2005-2010	Existing Radar system being upgraded.
PAPUA NEW GUINEA				Implemented at certain aerodromes.	Implemented.			

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
PHILIPPINES	ATN BIS Router planned for AMHS trials in April 2007.	Planned for 2007-2008.	CPDLC Planned for 2008.			ADS-B is under preliminary study for inclusion in CNS/ATM project.	FANS 1/A ADS-C planned for 2008.	
REPUBLIC OF KOREA	ATN BIS Router/AMHS planned for 2005-2010.	AFTN based AIDC implemented between Incheon ACC and Seoul APP.	PDC & D-ATIS implemented 2003.			ADS-B trials planned for 2008.	Trial for FANS 1/A ADS-C implemented since 2003.	
SINGAPORE	ATN BBIS Router trial with Hong Kong conducted between April and June 2003. Planned for ATN and AMHS implementation in 2006.		Implemented since 1997. Integrated in the ATC system in 1999.	NPA procedure developed. RNAV (SID/STAR) in 2005	Implemented.	Trial commenced in 2006. Operational in 2010. 2007 for ASMGCS	FANS 1/A ADS-C implemented since 1997. Integrated with ATC system in 1999.	
SRI LANKA	ATN BIS Router Planned for 2006. AMHS planned along with BIS in 2006.		PDLC in trial operation since November 2000.			ADS-B Trials planned for 2010 and implementation in 2011.	FANS 1 /A ADS-C trial since November 2000.	GPS based domestic route structure being developed.

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
THAILAND	BBIS/BIS Routers already implemented. Target date for AMHS in 2007.	AFTN based AIDC planned for 2010.	FANS-1/A Implemented .		Implemented.	Multilateration implemented in 2006 at Suvarnbhumi Intl. Airport. 22 ADS-B ground Stations will be implemented in 2008	FANS 1/A ADS-C Implemented.	
TONGA	AMHS planned for 2008.			NPA planned for 2007.		Trial planned for 2010		CPDLC and ADS-C is not considered for lower airspace
UNITED STATES					About 75 UAT ground stations installed. All ASDE-X locations have 1090 ES capability around 400 ground stations purchased (200 installed and operational) Note: 1090ES is NOT used for separation services only feeding ASDE-X fusion Tracker.			

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
Anchorage			FANS1/A based CPDLC implemented.	Implemented.	5 UAT ground stations are in operational use in ALASKA for ADS-B surveillance service. Separate ADS-B from Radar 5 NM only.	ADS-B trials continuing.	FANS/1-ADS-C 2006.	
Fairbanks				Implemented.		Trials continuing		
Oakland		AFTN based AIDC implemented. ATN AIDC planned for 2007.	FANS-1/A based CPDLC implemented.	Implemented.	Implemented.		FANS-1/A ADS-C implemented.	
Salt Lake City (Network Centre)	AMHS implemented between Japan and USA scheduled in 2005. USA/Fiji AMHS testing to be determined.				50 UAT ground stations being used in the continental U.S. for FIS-B TIS-B and ADS-B.			

CNS/ATM IMPLEMENTATION PLANNING MATRIX								
State/ Organization	**ATN G/G Boundary Intermediate System (BIS) Router/AMHS**	**AIDC**	**CPDLC**	**GNSS**		**ADS-B**	**ADS-C**	**Remarks**
				RNAV (GNSS)	**En-route**			
VANUATU								
VIET NAM	BIS Routers planned for 2009.	AFTN based AIDC planned in 2009 Trial for ATN based AIDC planned in 2010.	CPDLC operational trial conducted in early 2007.	RNAV	For en-route TBD.	TBD	FANS 1/A ADS-C operational trial conducted for oceanic area of Ho Chi Minh FIR since March 2002.	

BASELINE ADS-B SERVICE PERFORMANCE PARAMETERS

The following table provides guidelines for various performance requirements of ADS-B Category (Tier) 1, 2 or 3 services that States may consider when acquisition of an ADS-B managed service agreement with a service provider:

Service Parameter	**Category 1 (Tier 1)** **5nm separation capable commensurate with Radars (separation/vectoring/high performance with reliability, integrity & latency)**	**Category 2 (Tier 2)** **Situational awareness similar to ADS-C (safety net alerts, SAR, supports procedural separation without voice, not 5nm separation)**	**Category 3 (Tier 3)** **Position Reporting with Enhanced Flight Operation**
Aircraft Updates	1 second < Rate < 5 seconds as Operationally required	1 second < Rate < 20 seconds as Operationally required	1 second < Rate < 60 seconds as Operationally required
Network Latency	95%: < 2 seconds of ground-station output	95%: < 15 seconds of ground-station output	95%: < 60 seconds of ground-station output
Reliability 1	2 autonomous ground-stations including antenna, each providing data, no common point of failure	1 unduplicated ground-station including antenna	1 unduplicated ground-station including antenna
Reliability 2 - MTBF	Each ground-station including antenna to have MTBF >10,000 hrs	Each ground-station including antenna to have MTBF >10,000 hrs	Each ground-station including antenna to have MTBF >10,000 hrs
Reliability – Communications Infrastructure	Completely duplicated, no common point of failure	Unduplicated, MTBF > 400 hrs	Unduplicated, MTBF > 200 hrs
Reliability – Total ADS-B Service	Total Service MTBF > 50,000 hrs	Total Service MTBF > 400 hrs	Total Service MTBF > 200 hrs
Availability – Total ADS-B Service	Total Service Availability > .999	Total Service Availability > .95	Total Service Availability > .90
Integrity – Ground Station	Site monitor, including GPS RAIM, monitored by RCMS	Site monitor, including GPS RAIM, monitored by RCMS	Site monitor, including GPS RAIM, monitored by RCMS
Integrity – Data Communications & Processing	All systems up to ATM system, errors < 1 x 10E-6	All systems up to ATM system, errors < 1 x 10E-6	All systems up to ATM system, errors < 1 x 10E-6

The choice of category (tier) could be based upon a number of factors including the following,

a) The desired service
b) The available budget
c) The available ATC automation system & its capabilities and/or interim display systems
d) ATC training and ratings
e) Availability of appropriately tailored ATC procedures

States could initially choose one level and transition to another at a later time. For example, Category (Tier) 2 could be used to add additional safety nets/situational awareness and gain operational experience during the initial stage, moving later to a full separation service using Category (Tier) 1.

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REPORTS OF THE AD HOC WORKING GROUPS

Report of the South-East Asia Group

Countries included in the South-East Asia group:

Australia
Cambodia
Indonesia
Malaysia
Singapore
Thailand

Australia: Five stations are installed and operational. A further 23 stations will provide upper airspace coverage over the entire mainland above FL300. Additional 20 ground stations are to be purchased for improvement of the reliability of surveillance by SSR and Defence radars as well as a number at other locations. Data sharing with the Indonesian station at Kupang is being trialled before operational use.

Cambodia: The entire Cambodian FIR has existing radar coverage. Accordingly there are no plans for ADS-B installation in the short term. The provision of ADS-B data sharing with Thailand would be desirable for co-ordination at the Thai/Cambodia FIR interface. However there have not been any discussions between the countries at this time.

Indonesia: Indonesian trials involve the installation of ADS-B ground stations at three strategically selected locations, these being Bali, Kupang, and Natuna Island. Data from Kupang and Bali will be for sharing with the Brisbane FIR in Australia. Indonesia plans to install 2 ADS-B stations in 2007 at Makassar and Sorong. In 2008, there are plans to insall ADS-B ground stations at Kupang,, Saumlaki and Merauke.

Malaysia: Widespread radar coverage exists. With one exception, there is no need for ADS-B installations at this time. An installation at Port Blair Island in the Chenai (India) FIR for co-ordination of aircraft operating to/from the Bay of Bengal would assist in FIR boundary co-ordination. The sharing of data from Natuna will be beneficial for the safe follow of traffic in the South China Sea region.

Singapore: Radar coverage and FANS 1/A services exist. It is operationally desirable for data from the ADS-B ground station at Natuna Island (presently being trialled as part of Indonesia ADS-B Trial project) to be used to provide coverage beyond radar. However, Singapore plans to install an ADS-B station in Singapore over the next two years.

Thailand: Twenty two (22) ADS-B ground stations are to be installed commencing 2007, for commissioning 2008. The installations will provide complete coverage of Thailand and back-up to existing civil radar coverage.

General comments

The South East Asia area has large ocean expanses where ADS-B is not an appropriate surveillance solution. ADS-C is more appropriate and is operational or on operational trial in many of these areas.

States of the region prefer an incremental approach to ADS-B capability, utilizing specific installations to resolve particular control or co-ordination problems.

Sharing of surveillance data would enhance operational services across most regional FIR boundaries.

Report of the South Asia Group

Countries included in the South Asia group:

India
Maldives
Nepal
Pakistan
Sri Lanka

India: India proposes to install one or two ADS-B ground stations. The proposed locations so selected shall have overlapping coverage with the existing MSSR at Delhi for validation of ADS-B inputs. Proposal from Malaysia for installation of ADS-B ground station at Port Blair will also be considered after feasibility study.

Maldives: Maldives is planning to conduct technical and feasibility studies of ADS-B during later part of 2007. Maldives is looking forward for assistance from ICAO as well as from Airservices Australia. Regarding the ADS-B trials to be conducted, getting test trials done through SITA is also an option. During the test trials, the data received will be exchanged with adjacent FIR's in the region namely India and Sri Lanka.

Nepal: Feasibility study is planned for 2007. If feasibility study shows satisfactory results ADS-B will be installed earliest by 2010.

Pakistan: Pakistan proposes to install one or two ADS-B ground station at location either near Delhi/Karachi FIR or Muscat/Karachi FIR boundaries where SSR coverage in certain portion of airspace is not available. This arrangement is subject to approval by regulatory authority of Pakistan.

Sri Lanka: At present, Sri Lanka has 2 MSSR stations which covers an area of 200 NM radius circle and ADS-C. Sri Lanka has planned to conduct ADS-B trials in 2010 and implement in 2011 as a backup facility to existing radar.

Report of the Pacific Group

Countries in the Pacific group were as follows:

Australia
Fiji
France
New Caledonia

Three major conclusions:

1) Australia, Fiji and New Caledonia have plans in place to provide ADS-B service. Area for cooperation (Australia and New Caledonia): There are gaps between islands and
Other islands should also be considered in the cooperative area;

2) Exchanging and sharing data would be benefit.

3) In order to achieve more benefits, it would be more desirable to achieve 100% equipage. Fiji shares the view. Retrofit would be costly for existing aircraft. It needs a recommendation which would assist States for mandate equipage. It was indicated that IATA in a position like to see early

mandate in the Region as there are a lot of holes in communications in the Region. There are a safety issues.

<u>Report of the North Asia Group</u>

Countries included in the North Asia group:

China
Hong Kong, China
Japan
Philippines
Republic of Korea
Thailand
Viet Nam

Three main items discussed were as follows:

1) To consider ADS-B in each States; 2) Sharing data; 3) Any future plan for ADS-B

China: China has plan to install two 1090 ES ground stations in Chengdu and Jiu Zhaigou for ADS-B trials in the next two years. The trial is scheduled to be completed by end of 2008

Hong Kong China: Hong Kong China started ADS-B trials 3 years ago in 2004. As the airspace is not completely covered by Radar. Further trials being conducted.

Japan: The main airspace is covered by Radar. Japan is thinking to improve the surveillance situation for the airspace between China and Japan.

Philippines: The Philippines has plan to install 3 radars. ADS-B plans are being considered in areas not covered by radar. Implementation of ADS-B is being studied for inclusion in the CNS/ATM project but largely depends on availability of standards for ground station (ADS-B alone and for multilatereation), aircraft avionics and the automation/display (fusion with radar data)

Republic of Korea: The Republic of Korea has full radar coverage and has plan in place to install ADS-B ground stations although full airspace is covered by radar.

Thailand: Thailand plans to install 22 ADS-B ground stations. The airspace is fully covered by radar including surveillance capability from military radar. Thailand is satisfactory with current ADS-C trial.

Viet Nam: informed that almost all of airspace in Viet Nam is covered by radar. ADS-C has been conducting for oceanic area by Ho Chi Minh FIR since March 2002. ADS-B implementation is under consideration.

No State has intension to share surveillance data except Hong Kong, China.

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THE RESULTS OF READINESS SURVEY

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
Australia	No. of major airports with A-SMGCS (with ADS-B)	0	3	3	3	3	3	8	
	No. of major airports with A-SMGCS (without ADS-B)	1	0	0	0	0	0		
	No. of major airports without A-SMGCS	7	5	5	5	5	5		
	No. of ADS-B stations* ready for operational use	5	20	28	48	48	48	?	
	No. of automation systems ready to process ADS-B data (standalone system)	0	6	6	8	10	12		Towers
	No. of automation systems ready to process ADS-B data (integrated system)	2	2	6	6	6	6	6	
	No. of automation systems not ready to process ADS-B data	4	4	0	0	0	0	0	
	Completion of controller training for ADS-B operations	2007							
Cambodia	No. of major airports with A-SMGCS (with ADS-B)	0	0	0	0	0	0	0	
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0	0	0	0	0	
	No. of major airports without A-SMGCS	0	0	0	0	0	0	0	
	No. of ADS-B stations* ready for operational use	0	0	0	0	0	0	0	
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	0	0	0	0	0	
	No. of automation systems ready to process ADS-B data (integrated system)	0	0	0	0	0	0	0	
	No. of automation systems not ready to process ADS-B data	0	0	0	0	0	0	0	
	Completion of controller training for ADS-B operations	NA							
China	No. of major airports with A-SMGCS (with ADS-B)	1	1						
	No. of major airports with A-SMGCS (without ADS-B)	3	7						
	No. of major airports without A-SMGCS	7	3						
	No. of ADS-B stations* ready for operational use								
	No. of automation systems ready to process ADS-B data (standalone system)	0	1						
	No. of automation systems ready to process ADS-B data (integrated system)	3	3						
	No. of automation systems not ready to process ADS-B data	35	32						
	Completion of controller training for ADS-B operations	??							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
Hong Kong China	No. of major airports with A-SMGCS (with ADS-B)	1							
	No. of major airports with A-SMGCS (without ADS-B)	0							
	No. of major airports without A-SMGCS	0							
	No. of ADS-B stations* ready for operational use								
	No. of automation systems ready to process ADS-B data (standalone system)	1							
	No. of automation systems ready to process ADS-B data (integrated system)	0							
	No. of automation systems not ready to process ADS-B data	1							
	Completion of controller training for ADS-B operations	2012							
Fiji Islands	No. of major airports with A-SMGCS (with ADS-B)	0							
	No. of major airports with A-SMGCS (without ADS-B)	0							
	No. of major airports without A-SMGCS	2	2	2	2	2	2	2	
	No. of ADS-B stations* ready for operational use	0	0	8					
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	1					
	No. of automation systems ready to process ADS-B data (integrated system)	0	0						
	No. of automation systems not ready to process ADS-B data	1							
	Completion of controller training for ADS-B operations	2009							
France (New Celedonia and French Polynesia)	No. of major airports with A-SMGCS (with ADS-B)	0							
	No. of major airports with A-SMGCS (without ADS-B)	0							
	No. of major airports without A-SMGCS	2							
	No. of ADS-B stations* ready for operational use			2					
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	1					
	No. of automation systems ready to process ADS-B data (integrated system)	0	1	1					
	No. of automation systems not ready to process ADS-B data	2	1	0					
	Completion of controller training for ADS-B operations	2009							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
India	No. of major airports with A-SMGCS (with ADS-B)	1							
	No. of major airports with A-SMGCS (without ADS-B)	0							
	No. of major airports without A-SMGCS								
	No. of ADS-B stations* ready for operational use	0	0	0	0	0	0	0	
	No. of automation systems ready to process ADS-B data (standalone system)	0							
	No. of automation systems ready to process ADS-B data (integrated system)	0							
	No. of automation systems not ready to process ADS-B data	2							
	Completion of controller training for ADS-B operations	NA							
Indonesia	No. of major airports with A-SMGCS (with ADS-B)	0	0	1					
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0					
	No. of major airports without A-SMGCS	23	23	22					
	No. of ADS-B stations* ready for operational use	0	2	3					
	No. of automation systems ready to process ADS-B data (standalone system)	0	1						
	No. of automation systems ready to process ADS-B data (integrated system)	1							
	No. of automation systems not ready to process ADS-B data	4							
	Completion of controller training for ADS-B operations	2010							
Japan	No. of major airports with A-SMGCS (with ADS-B)	0							
	No. of major airports without A-SMGCS (with ADS-B)	0	0	1	2				
	No. of major airports without A-SMGCS	0							
	No. of ADS-B stations* ready for operational use	0							
	No. of automation systems ready to process ADS-B data (standalone system)	0							
	No. of automation systems ready to process ADS-B data (integrated system)	0							
	No. of automation systems not ready to process ADS-B data	9							
	Completion of controller training for ADS-B operations	??							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
Malaysia	No. of major airports with A-SMGCS (with ADS-B)	0	0	1					
	No. of major airports with A-SMGCS (without ADS-B)	1							
	No. of major airports without A-SMGCS	4	4	4	4	4	4	4	
	No. of ADS-B stations* ready for operational use	0	0	1					
	No. of automation systems ready to process ADS-B data (standalone system)	0	1	2	2	2	2	2	
	No. of automation systems ready to process ADS-B data (integrated system)	0	0	0	1	1	1	2	
	No. of automation systems not ready to process ADS-B data	3	3	3	2	2	2	1	
	Completion of controller training for ADS-B operations	2009							
Maldives	No. of major airports with A-SMGCS (with ADS-B)	0							
	No. of major airports with A-SMGCS (without ADS-B)	1							
	No. of major airports without A-SMGCS	1							
	No. of ADS-B stations* ready for operational use	0							
	No. of automation systems ready to process ADS-B data (standalone system)	0							
	No. of automation systems ready to process ADS-B data (integrated system)	0							
	No. of automation systems not ready to process ADS-B data	0							
	Completion of controller training for ADS-B operations	??							
Nepal	No. of major airports with A-SMGCS (with ADS-B)	0	0	0	0				
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0	0				
	No. of major airports without A-SMGCS	1	1	1	1				
	No. of ADS-B stations* ready for operational use	0	0	0	1				
	No. of automation systems ready to process ADS-B data (standalone system)				1				
	No. of automation systems ready to process ADS-B data (integrated system)								
	No. of automation systems not ready to process ADS-B data	1	1	1	1				
	Completion of controller training for ADS-B operations	2010							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
Pakistan	No. of major airports with A-SMGCS (with ADS-B)	0	0	0	3				
	No. of major airports with A-SMGCS (without ADS-B)								
	No. of major airports without A-SMGCS	5	5	5	2				
	No. of ADS-B stations* ready for operational use			1	1	3			
	No. of automation systems ready to process ADS-B data (standalone system)			1					
	No. of automation systems ready to process ADS-B data (integrated system)				1				
	No. of automation systems not ready to process ADS-B data	3	3	3	2				
	Completion of controller training for ADS-B operations	2009							
Philippines	No. of major airports with A-SMGCS (with ADS-B)	0	0	0					
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0					
	No. of major airports without A-SMGCS	4	4	4					
	No. of ADS-B stations* ready for operational use	0	0	0					
	No. of automation systems ready to process ADS-B data (standalone system)	0	0						
	No. of automation systems ready to process ADS-B data (integrated system)	0	0						
	No. of automation systems not ready to process ADS-B data	1	1						
	Completion of controller training for ADS-B operations	5 years after ADS-B installation							
Republic of Korea	No. of major airports with A-SMGCS (with ADS-B)	0	1						
	No. of major airports with A-SMGCS (without ADS-B)	2	1						
	No. of major airports without A-SMGCS	5							
	No. of ADS-B stations* ready for operational use		2						
	No. of automation systems ready to process ADS-B data (standalone system)	0	0						
	No. of automation systems ready to process ADS-B data (integrated system)		1						
	No. of automation systems not ready to process ADS-B data	7	6						
	Completion of controller training for ADS-B operations	2008							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
Singapore	No. of major airports with A-SMGCS (with ADS-B)	1	1	1	1	1	1	1	
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0	0	0	0	0	
	No. of major airports without A-SMGCS	0	0	0	0	0	0	0	
	No. of ADS-B stations* ready for operational use	0	0	1	1	1	1	1	
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	0	0	0	0	0	
	No. of automation systems ready to process ADS-B data (integrated system)	0	0	0	1	1	1	1	
	No. of automation systems not ready to process ADS-B data	1	1	1	0	0	0	0	
	Completion of controller training for ADS-B operations	2010							
Sri Lanka	No. of major airports with A-SMGCS (with ADS-B)	0	0	0					
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0					
	No. of major airports without A-SMGCS	1	1	1	1	2	2	2	
	No. of ADS-B stations* ready for operational use								
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	0	≥1	≥1	≥1	≥1	
	No. of automation systems ready to process ADS-B data (integrated system)								Not decided
	No. of automation systems not ready to process ADS-B data	0	2	2	≥2	≥2	≥2	≥2	
	Completion of controller training for ADS-B operations	2011							
Thailand	No. of major airports with A-SMGCS (with ADS-B)	1	1	1					
	No. of major airports with A-SMGCS (without ADS-B)	0	0	0	0				
	No. of major airports without A-SMGCS	3	3	3	3				
	No. of ADS-B stations* ready for operational use	0	22	22	22	22	22	22	
	No. of automation systems ready to process ADS-B data (standalone system)	0	0	0	0				
	No. of automation systems ready to process ADS-B data (integrated system)	0	4	4	4	4	4	4	
	No. of automation systems not ready to process ADS-B data								
	Completion of controller training for ADS-B operations	2008							

	Equipment	Yr 2007	Yr 2008	Yr 2009	Yr 2010	Yr 2011	Yr 2012	Beyond 2012	Remark
USA	No. of major airports with A-SMGCS (with ADS-B)	20	24	32	40				
	No. of major airports with A-SMGCS (without ADS-B)	20	16	8	0				
	No. of major airports without A-SMGCS	0	0	0	0				Top 40 airports
	No. of ADS-B stations* ready for operational use	300	300	400	500				
	No. of automation systems ready to process ADS-B data (standalone system)	1	2	4	65	80			
	No. of automation systems ready to process ADS-B data (integrated system)	1	2	4	65	80			
	No. of automation systems not ready to process ADS-B data	79	78	76					
	Completion of controller training for ADS-B operations	Completed							
Vietnam	No. of major airports with A-SMGCS (with ADS-B)								
	No. of major airports with A-SMGCS (without ADS-B)	0	0	2					
	No. of major airports without A-SMGCS	22	22	20					
	No. of ADS-B stations* ready for operational use								
	No. of automation systems ready to process ADS-B data (standalone system)								
	No. of automation systems ready to process ADS-B data (integrated system)								
	No. of automation systems not ready to process ADS-B data	2							
	Completion of controller training for ADS-B operations								

INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

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Multilateration (MLAT) Concept of Use

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MULTILATERATION (MLAT) CONCEPT OF USE

Table of Contents

List of Acronyms

ADS-B	automatic dependent surveillance — broadcast
ADS-C	automatic dependent surveillance — contract (also known as ADS or ADS-A)
ADSP	ADS Panel (of ICAO)
AIGD	ADS-B Implementation and Operations Guidance Document
AIRSCENE	Trade name for Rannoch Multilateration
AIS	aeronautical information services
APANPIRG	Asia-Pacific Air Navigation Planning and Implementation Regional Group
APW	area proximity warning
ASAS	airborne separation assistance system
ASDE	airport surface detection equipment
ASM	airspace management
ATC	air traffic control
ATFM	air traffic flow management
ATM	air traffic management
ATMCP	Air Traffic Management Operational Concept Panel
CAP	controller access parameters
CDTI	cockpit display of traffic information
CNS	communications, navigation and surveillance
CPDLC	controller-pilot data link communications
DLIC	data link initiation capability
ELT	emergency locator transmitter
ETA	estimated time of arrival
FANS	future air navigation systems

F&CM	flow and capacity management
FIS-B	flight information service — broadcast
FMS	flight management system
GNSS	global navigation satellite system
GPW	ground proximity warning
HF	high frequency
HMI	human-machine interface
IAF	initial approach fix
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
MDS	Multistatic Dependent Surveillance: Sensis trade name for multilateration
MLAT	Multilateration
MSAW	minimum safe altitude warning
MTCD	medium term conflict detection
OPLINKP	ICAO's Operational Data Link Panel
PSR	primary surveillance radar
RPT	regular passenger transport
SAR	search and rescue
SARPs	Standards and Recommended Practices
SASP	ICAO's separation and airspace safety panel
SMC	surface movement control
SSR	secondary surveillance radar
STCA	short term conflict alert
TCAS	Traffic alert and collision avoidance system
TIS-B	traffic information service — broadcast
VFR	visual flight rules
VMC	visual meteorological conditions
WAM	Wide Area Multilateration

Foreword

1.1. This document presents the Multilateration Surveillance (MLAT) concept of use and therefore provides a description of MLAT systems and their detailed role as an application enabling important changes to the future communications, navigation, and surveillance/air traffic management (CNS/ATM) system.

1.2. The description of the role of MLAT takes into account the heterogeneous and evolving situation with respect to the available ground infrastructure, aircraft capabilities, airspace regimes, the coincidence with Automatic Dependent Surveillance – Broadcast (ADS-B) systems, and interface with legacy surveillance systems.

1.3. Wide Area Multilateration (WAM) implementations are an opportunity to provide useful ATC surveillance where it is required and concurrently introduce ADS-B for partial use. This forms a graduated transition from the current global environments to a future ADS-B based system.

1.4. The MLAT concept of use is described to show potential use in the wide area and airport surface operations, and that it is able to be considered both as an independent system and as complementary to other enablers such as secondary surveillance radar (SSR), SSR Mode S, ADS-B or ADS-C.

1.5 The impacts on operational and organizational levels arising from the introduction of MLAT systems is noted for consideration.

Glossary of Terms

In this document:

ADS-B IN means the reception of ADS-B position reports by an aircraft.

ADS-B OUT means the transmission of ADS-B position reports.

Surveillance System means an airborne or ground system used for monitoring the positions of aircraft and other objects for the purpose of air traffic management.

Chapter 1. Introduction

1.1. Purpose and scope

1.1.1. The purpose of this document is to develop a concept of use for MLAT. This technology is being developed, tested and is also used operationally in several areas of the world. However, international standards to incorporate MLAT into the future global CNS/ATM system have not yet been completely developed. This document is a step in this ICAO process.

1.1.2 The work to develop SARPs and guidance material for ADS-B was based upon a concept of use for the technology, as agreed by the 11th Air Navigation Conference in 2003. Since that time a major conceptual change has occurred with the term “radar” now being replaced in many ICAO documents with the term “ATS Surveillance System” and an associated performance-based definition; a recognition that ADS-B and other technologies can provide ‘radar-like’ services.

1.1.3 APANPIRG has chosen to follow a similar procedure to that successfully used for ADS-B; to develop a Concept of Use so observers and participants have a common understanding, and then to update the ADS-B Implementation and Operational Guidelines Document (AIGD) to include MLAT. The scope of this document is restricted to the concept of use portion of the task. It does not contain specific operational requirements, although its contents will lead naturally to the development of operational practices for MLAT.

1.2. Background

1.2.1. In the early 1990’s, ICAO approved the concept of the Future Air Navigation System (FANS) based on satellite and datalink technology, which later became known as CNS/ATM. It was recognised that the traditional ATC surveillance system has limitations that constrained its capabilities in the existing and future ATM environment.

The limitations identified include the following:

- *limited or no conventional surveillance* - including non-equipped continental areas, low altitudes, non-continental areas, surface movements, silence cones, blind areas, antenna screening, etc. In some cases (e.g. oceanic areas), this will result in the need for procedural control, using voice position reports;
- *electro-mechanical rotation of the classical radar antennas*, not only with high power demand and RF output, but also inefficient scanning periods and limited ability to adapt the reporting rate to suit ATC needs.
  (Note: E-SCAN antennas may offer an alternative in this case);
- *radar garbling, fruit and splitting*;
- *unavailability of aircraft derived data*, beyond the Mode A/C identification and altitude data;
- *non-homogeneous operation*, caused by the current existence of a diversity of systems with different performance and capabilities;

- increasingly some regions have a *shortage of Mode A codes* (a maximum of 4096 available) requiring frequent changes of code during the flight or duplicate use which can create identification ambiguities;
- *lack of capability to fully support future airborne situation awareness* applications, because the corresponding surveillance data are not available to the aircrew; and
- *lack of capability to fully support airport surface surveillance* applications.

1.2.2. Due to constraints like these and to a large extent driven by cost, the necessary levels of capacity, flexibility and efficiency required to meet the future predicted air traffic growth, will not be met by the traditional surveillance systems alone. Various surveillance technologies have been developed to address these limitations. These include Mode S secondary surveillance radar (SSR) with enhanced services, ADS-contract (ADS-C), ADS-broadcast (ADS-B), and Multilateration (MLAT).

1.3. Concept overview

1.3.1. ICAO Global ATM Operational Concept (Doc 9854) describes the services that will be required to operate the global air traffic system up to and beyond 2025. The operational concept addresses what is needed to increase user flexibility and maximize operating efficiencies in order to increase system capacity and improve safety levels in the future air traffic management system. The extensive work which has taken place or is currently underway has convinced ICAO that ADS-B functionality has the potential to be one of the key elements necessary in achieving these operational concept goals.

1.3.2. Early implementations of ADS-B have been supported by the developed ICAO standards for airborne equipment and for ATC separation. Where ADS-B OUT performance is readily achievable for the majority of aircraft, the benefits of this surveillance are quickly achieved. MLAT is a related alternative technology that will suit many States' surveillance needs for the medium term. The receipt and processing of ADS-B as part of an MLAT system encourages progressive installation of ADS-B avionics and thereby increases the benefits achievable with ADS-B.

1.3.3. The ADS-B Concept of Use document describes the role of ADS-B as one of the enablers of this future global CNS/ATM system. This MLAT Concept of Use is supplementary to that document, indicating the place of Multilateration usage.

1.3.4. The description of MLAT in this context is addressed in Chapter 2. It includes functionality, the role of MLAT and ADS-B in ATM, operational improvements, and typical applications. The applications can support all phases of flight gate-to-gate.
Chapter 4 addresses important issues for consideration, and Chapter 5 addresses implementation considerations for States.

1.3.5. During the development of the MLAT concept of use, considerations were made for other co-existing enablers (*inter-alia* ADS-B, ADS-C, TIS-B and CPDLC) in order to identify their complementary roles in the various operational scenarios.

1.3.6. The overall objective is to develop a common understanding of terms, definitions and possible uses of MLAT in the future environment. A secondary objective is to do this early enough in the various stages of development to assist efforts to influence and facilitate that development.

Chapter 2. Concept for Surveillance Using Multilateration

2.1. General

2.1.1 Surveillance is used in civil aviation for many purposes, including ATM, weather reporting, terrain avoidance, and search and rescue. A variety of technologies are used to provide surveillance data for ATM, but for full independence (of the targets under surveillance - which may include aircraft, vehicles and a variety of other “traffic”) the techniques available are visual acquisition, primary surveillance radar (PSR), and millimetric PSR (for debris, animals, birds).

2.1.2 All other techniques, including MLAT, SSR, ADS-C, ADS-B, CPDLC and voice position reporting, require varying degrees of cooperation from the target and the carriage of serviceable equipment to facilitate the exchange of data. For example, both voice and CPDLC position reporting mandate the use of specific communication equipment and are “dependent” on the 4-D navigation data determined by the avionics.

2.1.3 Multilateration is a co-operative system also, but one which can utilise data received from an aircraft that may be transmitted in response to different technologies. The minimum level of avionics to enable Multilateration with interrogation is a Mode A/C transponder. SSR Mode S or ADS-B avionics will enhance the performance of the system and may remove the need for interrogation.

2.1.4 While ADS-B transmissions contain the position data and may be received directly by other aircraft, MLAT surveillance data is processed by the ground system and typically provided only to an ATS facility, although rebroadcast to ADS-B equipped aircraft within a TIS-B service volume is potentially possible.

2.2. MLAT functionality

2.2.1 MLAT is a surveillance application that accurately establishes the position of transmissions, matches any identity data (octal code, aircraft address or flight identification) that is part of the transmission and sends it to the ATM system

2.2.2 Like SSR, MLAT is considered to be a co-operative surveillance technique, combining a dependence on target-derived data for identification and altitude with ground based calculation of position. MLAT can achieve a higher update rate than a typical rotating radar, determined by the intervals between aircraft transmissions (responses).

2.2.3 An MLAT system consists of the following components:

- A transmitting subsystem that includes interrogation message generation and transmission function;

- An optional Intelligent Interrogation process that determines whether an MLAT interrogation is required (in an area being interrogated by TCAS and SSR systems)
- A receiving antenna array subsystem that receives the transmissions from the target and timestamps receipt at each antenna; and
- A central processor that calculates and outputs the MLAT (and ADS-B) tracks.

Note - Having an interrogation transmitter ensures regularity of responses from the target aircraft/vehicle. The target aircraft/vehicle/obstacle must have a subsystem that will respond to an interrogation OR is automatically generating a transmission on the 1090MHz frequency.

2.2.4. The fitment of transponders in target aircraft or vehicles is essential for SSR Mode A/C/S radar, Multilateration, and ADS-B systems. The types can be summarised as follows:
2.2.4.1. Mode A/C Transponder - needs interrogation from radar, a multilat System, or TCAS. Special processing is used to manage matching of individual replies when received at multiple ground stations.
2.2.4.2. Mode S transponder - transmits DF11 download format automatically without radar interrogation and allows unique matching of messages received at all ground stations. Mode S provides error free mode C data.
2.2.4.3. ADS-B transmitter - transmits DF17/18 download formats automatically without radar interrogation and allows unique matching of messages received at all ground stations. Mode S provides error free mode C data

2.2.5. The airborne sources of the position, navigation or intent data in ADS-B and Mode S transmissions are not considered to be part of the MLAT system. Mode A/C transponder standards are the minimum applicable for MLAT surveillance.

2.3 The role of MLAT in Air Traffic Management (ATM)

2.3.1 ATM is described in the ICAO Global ATM operational Concept (Doc 9854) as the dynamic, integrated management of air traffic and airspace in a safe, economical and efficient manner through the provision of facilities and seamless services in collaboration with all parties. The operational concept also describes a system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground and/or space-based communications, navigation and surveillance.

2.3.2 This operational concept identifies seven interdependent components of the future ATM system. They comprise:

a) airspace organization and management;
b) aerodrome operations;
c) demand and capacity balancing;
d) traffic synchronization;
e) conflict management;
f) airspace user operations; and
g) ATM service delivery management.

2.3.3 Inherent to this concept are the characteristics of scalability and adaptability, according to the specific needs and operational environment of each State and region.

MLAT shares these characteristics in that specific applications of the technology may be implemented according to need.

2.3.4 MLAT is an enabling technology that will enhance the provision of ATM in a variety of applications, from “radar-like” air traffic control purposes to enhanced situational awareness of surface movements. MLAT offers most advantages in situations where other surveillance systems (eg radar) are not available. It can also be combined with other surveillance systems, such as radar and ADS-B, to improve the total surveillance picture.

2.3.5 MLAT applications will have a direct effect upon aerodrome operations, traffic synchronization, airspace user operations, and conflict management. These effects will then influence the nature of airspace organization and management, demand and capacity balancing, and ATM service delivery management.

2.4. ATM improvements and benefits

2.4.1. MLAT applications, particularly when combined with ADS-B, are expected to provide important operational improvements by addressing some of the limitations of the traditional radar surveillance system, optimize the controller workload and provide benefits in the areas of safety, capacity, efficiency and environmental impact, thus contributing to the overall CNS/ATM objectives. These benefits include the following:

a) low cost extension of the surveillance coverage for low altitudes (below existing radar coverage) and areas where no radar coverage currently exists, leading to more efficient use of airspace;
b) enabling airports to obtain surface and local surveillance including general aviation and military operations;
c) use of aircraft-derived data in a variety of systems e.g. ground-based conflict alert, minimum safe altitude warning, danger area proximity warning, automated support tools, surveillance data processing and distribution.
d) increasing airport safety and capacity, especially under low visibility conditions, by providing airport surface surveillance and, at the same time, protecting against runway incursions by aircraft and vehicles.
e) changes to airspace sectorization and route structure resulting from improved surveillance should provide more efficient routing;
f) reduced infrastructure costs in airspace in which MLAT coverage is provided. It may be possible to decommission some radar equipment. Where multiple surveillance coverage is presently required, optimization of the surveillance infrastructure should be achieved by the implementation of the most efficient mix of radar sensors, MLAT and ADS-B; and
g) cost savings achieved from the implementation of an MLAT and ADS-B based surveillance system rather than the life cycle expenses associated with installing, maintaining, and extending existing radar-based surveillance systems.

2.4.2. Valid reasons exist for a State having some SSR and PSR or other technologies for civil air traffic surveillance coverage. For example, Mode S enhanced surveillance, ADS-C and other systems can also be used to deliver some of the above benefits.

2.5. MLAT applications

2.5.1 Overview

In an effort to provide the operational improvements identified above, a number of applications are already developed and being operated.

2.5.2. MLAT ATM Applications

Broadly speaking, the air traffic control application of MLAT fall under the following headings:

- Airport surface surveillance applications for ground and aerodrome control
- Area and Approach surveillance in airspace with radar coverage;
- Area and Approach surveillance in airspace without radar coverage;
- ATM system technical improvements including sampling of RVSM performance and sampling ADS-B performance.

2.5.3. MLAT Specific Use Applications

- Airport surface surveillance; and aircraft derived data for ground-based ATM tools.
- Situational awareness
- Airport Low Visibility Operations (e.g. CATIIIB)
- Parallel Runway Approach Monitoring
- Other applications Ramp control/gate management
- Noise monitoring data provision
- Airport usage data (for Billing)
- Airways usage data (for Billing)
- Flight following (for AOC, flying schools)
- Enhanced ATS situational awareness (tagging obstacles, restricted areas)
- Enhanced overall flight data for improved SAR activity

2.5.4. Ground-based surveillance applications

4.5.4.1 This application provides a source of airport surveillance information for safer and more efficient ground movement management at airports. Relevant airport ground vehicles need to also be equipped and displayed, together with aircraft, on a situation display.

4.5.4.2 MLAT supports ground conflict detection by providing frequent updates of aircraft and vehicle positions, enabling the monitoring of aircraft and vehicles to protect against runway incursions, and to monitor taxiing operations in low visibility operations such as CATIIIB minima conditions. It is an essential part of some A-SMGCS systems.

2.5.5. Other uses

2.5.5.1 ATC surveillance for airspace where there is no radar coverage, or where radar coverage exists, as a backup and possible replacement for SSR.

2.5.5.2 The higher update rate available with MLAT reports, in combination with other capabilities, may enhance surveillance services and allow the application of reduced separation standards. ICAO’s Separation and Airspace Safety Panel (SASP) is currently examining the introduction of MLAT separation standards, and at least one State already provides ATC separation services with MLAT.

2.5.5.3. This application can support ATC surveillance currently provided by radar, in Terminal or wider airspace. An example is the case of surveillance in areas where single radar coverage is provided. Where SSR is used, MLAT can provide a backup system and supplement radar position updates through additional position reports. Where PSR is used MLAT can provide additional data, such as aircraft identification.

2.5.5.4. ATC surveillance in airspace without radar coverage. This application will provide ATC surveillance in non-radar areas, (e.g. remote approach control areas). While ADS-B alone could provide surveillance coverage from “gate-to-gate”, MLAT will be able to ensure the surveillance of aircraft equipped only with SSR transponders in those areas closer to the airport where traffic levels justify ATC surveillance, but radar is not feasible or affordable.

2.5.5.5. Other MLAT applications being considered or used to varying degrees include:

- monitoring of aircraft to ensure that flight trajectories comply with noise sensitive environments (e.g. curfew);
- facilitating the collection of data for the issuing of aviation charges in remote areas where this may be applicable;
- enabling the display of temporary obstacles — e.g. a construction crane equipped with a transponder or ADS-B emitter;
- validation of ADS-B transponder performances; and
- Search and rescue (SAR) and emergency response.

Chapter 3. Operational Deployments

3.1 Description of MLAT potential benefits

3.1.1 The operational environments in which MLAT will be used may include any of the following characteristics:

- varying infrastructure capabilities, ranging from the lack of any surveillance means up to the co-existence of ADS-B and MLAT with different types of conventional data sources such as primary and secondary surveillance radars. Some MLAT vendors can deliver a pseudo rotational ‘radar like’ ASTERIX Cat 1 / 48 output to minimise the initial setup adaptation required. It is expected that a variety of other technologies such as ADS-C and CPDLC will play a complementary role in the provision of ATC service;
- mixed aircraft equipage levels, at least in the transition period;
- varying airspace types (e.g. different traffic density levels);
- varying flight phases, e.g. airport surface, TMA, en-route, non-continental, continental; and
- varying types of application/services in different environments.

3.1.2. MLAT can detect ADS-B reports generated and also manipulate report rates by the transmission rate of interrogations, and in processing to output at a rate that suits the communications network and ATM system.

3.1.3. Compared to radar sensors, an MLAT system for an aerodrome surface application or for a local area around an aerodrome is less than half the cost. A Dual ADS-B location

with power and communications is about half to two-thirds the cost of a full MLAT system, excluding the cost of transponder upgrades.
Other than cost, another important advantage of both ADS-B and MLAT are the degrees of redundancy which a single radar does not have.
An MLAT system configuration can allow staged degradation before the system would become unusable.

3.2 Users of MLAT

The users of MLAT will primarily be in ATC roles, from gate to gate. Here are some examples:

3.2.2 ATC Ground

Ground Tower and Surface Movement controllers will use MLAT for surface surveillance of aircraft and vehicles on the apron and or manoeuvring area. This is most desirable when the airport layout is complex (assessed by the configuration of buildings, the number of runways and taxiways) and where airports are capable of conducting operations out of visual range of the air traffic controller responsible (CAT II and III ILS operations and vertically-guided GNS approaches to similar minima are likely to fall in this category).

3.2.3 ATC Aerodrome

Aerodrome controllers will utilise the surveillance to assist with runway utilisation, and confirm that traffic is following instructions to and from the runway. Final approach monitoring using the high update available from an MLAT system providing more precision to discern whether an aircraft is lining up to land on the wrong runway, and to automate the alerting of such a situation. For departing flights in an environment where Tower initiated departures applies, the high update rate will provide a smoother and instantaneous turn of a lead aircraft as observed on the display so minimising waiting time for a following departure.

3.2.4 ATC Approach

MLAT for approach control will be useful in ATM system software to smooth the turns of displayed tracks, and can be used for Terminal area ATC surveillance in place of SSR or as a backup to SSR.

3.2.5 ATC Area control

Wide Area Multilateration (WAM) can extend beyond the Terminal area, depending on the configuration of the sensors. In this respect MLAT can provide a backup for SSR for a specific area, as a fill in to a specific airspace where surveillance is required and aircraft equipped only with Mode A/C transponders are common, in both cases the benefit of ADS-B data being received from each single site greatly improve the coverage for suitably equipped aircraft.

Chapter 4. Issues

4.1 Issues to consider

There are many issues associated with the introduction of MLAT to the air traffic management operational concept. The following are technical and operational issues to consider during development and implementation of MLAT. This list is not exhaustive, but serves as a guide for States considering MLAT systems for their surveillance needs.

4.2 Technical issues

4.2.1 Technical standards

4.2.1.1 As 1090MHz Extended Squitter (also known as 1090ES or Mode S data link) ADS-B and MLAT technology matures, the technical standards for the airborne as well as the ground systems are being refined. This leads to the need to potentially upgrade these systems to meet new national and international requirements. Efforts are underway within ICAO to ensure global interoperability.

4.2.1.2. Multiple Sites each require power and data communication paths. Site access, land rental or ownership, and technical maintenance capability to add multiple sites are issues to consider.

4.2.1.3 VHF coverage of the airspace may be coincident with a MLAT interrogation site to ensure best coverage. As with ADS-B the preferred situation is for the responsible controller to have reliable radio access to any flights within the controlled airspace.

4.2.2 Aircraft installation

Various types of aircraft have different installation certification and integration requirements. Consequently there are differences in costs. Antenna placement in relation to ground system sensors is a similar consideration as for SSR. Where ADS-B data received by the MLAT system is to be used alone, the issues regarding transponders and the GNSS systems must be considered. Specifically issues such as the navigation system integration to ADS-B or Mode S, compatibility with various link technologies, and cockpit controls and displays issues all have to be considered. Certification will also vary with intended function (e.g. ATC surveillance services, TIS-B situational awareness) as well as aircraft type (e.g. single engine aircraft versus heavy jet aircraft).

4.2.3 Remote ground stations

Installation, certification, and maintenance monitoring of remote MLAT ground stations to meet intended level of service raise their own issues. These include leasing agreements, power requirements, communication to a central facility (e.g. air traffic control centre), installation remote control features, accessibility and security. Remote switching and monitoring is an important consideration.

4.2.4 Automation system adaptation

Ground-based air traffic control system adaptation to facilitate the acquisition, processing and distribution of MLAT data is a significant issue. The automation’s capacity for handling the data (e.g. processing power available, local area network, data storage capacity), maintenance monitoring, correlation between various surveillance sources and integration into existing safety functions (e.g. conflict alert, minimum safe altitude warning) are a few areas to consider. Employing a Service Provider to deliver the system outputs is another option.

4.2.5 Technical Maintenance

For a new surveillance area, increased provision of Technical Maintenance support is likely to be required given the multiple remote sites inherent with MLAT configurations, and similarly maintenance for power supply and network communications personnel.

4.2.6 Security

4.2.6.1 The flexibility and versatility of the proposed MLAT systems will allow for many safety and capacity enhancing applications in the short and long term. As applications approach maturity and their requirements become more complex, they also become more sensitive to some outside interference, a risk not dissimilar to current systems using SSR Mode A/C.

4.2.6.2 1090MHz interference sources can be malicious or accidental and can occur intermittently or for an extended period. The interference can be a localized source causing for example a “co-channel interference” problem up to a military denial of airspace operation involving active jamming. The sources, causes, and effects of an interference event can be broadly categorized into several groups. There are practical limits that must be recognized due to technological, political, and fiscal reasons. Not all solutions will be technical - that is, come from a box. Some of the solutions may be procedural, legal, technical or a combination of all. In short, States will need to consider the likelihood and severity of interference by conducting appropriate hazard and safety assessments as a means of developing mitigation strategies.

4.2.7 Performance of the data link

4.2.7.1 Bandwidth and performance of the 1090 MHz data link is dependant upon the complexity of the scenarios that are envisaged and could be a significant issue in high density areas.

4.2.7.2 For example, the level of equipage (i.e. which airport vehicles and/or obstacles are fitted with transponders or ADS-B emitters), the number of aircraft involved and possible use of TIS-B to rebroadcast data from another surveillance source will need to be considered.

4.3 Operational issues

4.3.1 Human factors issues

4.3.1.1 The human factors considerations associated with surveillance systems are dependent not on the technology, but on the specific applications. That is, the issues are dependent upon the answers to questions, such as:

- what is the information to be displayed (e.g. aircraft position data or derived aircraft intent)?
- how are the input systems different and what is the appropriate way to show differences that may be important to operators?
- who (e.g. tower, ACC, airline operations) is the user of this information? Displays will need to be developed and evaluated for different applications;
- how will the information be used? The information and the way in which it is displayed must be capable of supporting the decisions that the users will make based on the MLAT information.

4.3.1.2 While the specific issues will depend on the specific applications, there are general issues that should be anticipated. These include:

- *effective integration of MLAT information into the situation display*. The position determined by MLAT can be different to the position reported by radar or other systems. When more than one input type is received, these positions will need to be reconciled so that only one position (preferably the most accurate position possible) is displayed for a single aircraft. This can be achieved by the use of a multi sensor (e.g. MLAT, ADS-B, SMR, ASR) data processor. Controllers need to know which aircraft are being tracked by which system when the type of surveillance affects how they control that aircraft, or the quality of the reported position, so that appropriate separation standards can be applied. Depending on the application and the limit of MLAT coverage, controllers may also need to know other capabilities of the displayed aircraft, such as RNP, ADS-B and CDTI. All of this adds information to be integrated into the present displays;

- *limitations of the technology*. Users will need to fully understand the limitations of the information presented and be informed of any known degradations or failures.
- *degree to which the displayed information supports the application*. The degree to which the MLAT information supports spacing and separation tasks and the degree to which flight crews and controllers are expected to successfully accomplish and integrate these tasks is being assessed in different ICAO forums. How the information is displayed is as important as the integrity of the information in supporting the user's confidence in the system. A concept under active development is to provide improvements to HFOM, for example elevating an GPS derived ADS-B position FOM that is marginal for use - by supporting MLAT FOM; and
- *effects on workload*. The effects of the additional information, and the procedures associated with specific applications, on the workload of the user need to be assessed. The information needs to be integrated so that it is unambiguous, immediately useful, and does not interfere with other critical information.

4.3.2 Procedures development, separation standards, airspace design, and training issues

In support of new operations, appropriate procedures, separation standards, airspace design, and training are being developed to effectively utilize MLAT and its applications. Controllers, pilots, and maintenance technicians, as well as others who may use MLAT or be impacted by the procedures need proper training on coverage issues, normal and failure mode operations. In addition, airspace design (e.g. size of ATC sectors) will need to be considered for the types of services provided.

4.3.3 Fleet equipage

With the availability of various ADS-B and SSR technologies and the cost of equipping or re-equipping aircraft with new avionics, it is unlikely that aircraft will have homogeneous equipment. The introduction of MLAT allows the system to have full surveillance of all transponder equipped aircraft without the hurdle of making the carriage of ADS-B transponders mandatory for a State or large airspace area.

It should be remembered that in some MLAT systems, ADS-B is an integral part, so aircraft operators should be encouraged to install ADS-B OUT capability which will benefit the whole airspace system in time, and which can benefit the operator and ATS system directly through improved coverage in areas beyond the MLAT high performance area.

The design configuration of the MLAT system may have only some or no MLAT receivers detecting ADS-B. In the cockpit, the traffic information service — broadcast (TIS-B), may evolve to be of particular importance, ensuring consistency on both air and ground traffic situation displays.

4.3.4 Transition issues

One of the main issues with regard to the impact from the transition towards an ADS-B-based surveillance system is that MLAT extends out the time when full capability of ADS-B is needed. In the foreseeable future, the systems have to be capable of coping with a heterogeneous set of aircraft capabilities, types of surveillance sensors, local system sophistication etc. and should be capable of providing the required quality of service both on the ground and on board the aircraft. This quality of service should be at least equal to that of the current system in place. MLAT is often seen as a ‘transitional technology’ that caters for legacy aircraft while also being capable of processing ADS-B transmissions.

4.3.5 Institutional

There are common types of institutional issues regardless of the State implementing MLAT. These include such things as legal issues (e.g. separation standards), radio spectrum allocation/management, and certification issues. Each State will have to resolve these, but global harmonization needs to be considered for consistency.

4.3.6 Environmental issues

4.3.6.1 With any new system, environmental issues need to be considered to include noise abatement, airspace constraints, and remote ground system installations.

4.3.6.2 The ADS-B processing capability of MLAT systems enables new or improved applications which are expected to contribute significantly to these savings by providing more direct or efficient routings, and easier access to the optimum altitudes and airspeeds.

Chapter 5. Implementation

5.1 Planning

There is a range of activity that needs to take place to bring an application from initial concept to operational use. This section documents these activity areas under the topics of collaborative planning and decision making, system compatibility and integration, while the second section of this chapter provides a checklist to assist States with the management of MLAT implementation activities.

5.1.2 Implementation team to ensure international coordination

5.1.2.1 From the ICAO perspective, when a State decides to implement a new technology it benefits the wider ATM community if they consult and advise the wider ATM community of plans and implementation issues encountered. Moreover, the implementation should also be coordinated between States and Regions as appropriate, in order to achieve maximum benefits for airspace users and service providers.

5.1.2.2 An effective means of coordinating the various demands of the affected organizations is to establish an implementation team. Team composition may vary by State or Region, but the core group responsible for MLAT implementation planning should include members with operational expertise in aviation disciplines, with access to other specialists as may be required. Where both MLAT and ADS-B services are being introduced at the same time, or being considered, a single team should seek a harmonised approach for both systems.

5.1.2.3 Ideally, such a team should comprise representatives from the ATS providers, regulators and airspace users, as well as other stakeholders likely to be influenced by the introduction of MLAT and ADS-B, including manufacturers and military authorities. All identified stakeholders should participate as early as possible in this process so that demands are identified prior to the making of schedules or contracts.

5.1.2.4 The role of the implementation team is to consult widely with stakeholders, identify operational needs, resolve conflicting demands and make recommendations to the various stakeholders managing the implementation. To this end, the implementation team should have high-level access to the decision-makers.

5.1.3 System compatibility

5.1.3.1 ADS-B has potential use in almost all environments and operations and is likely to become a mainstay of the future ATM system. MLAT is able to fill in the gaps for areas where surveillance is needed, but where targets / aircraft have only Mode A/C or Mode S short squitter transponders. Engineering and operational trials of both systems have been conducted and operational implementations have occurred, and ADS-B now has a comprehensive set of internationally accepted standards. Generally first applications are in niche areas where radar surveillance is not available or possible. ICAO Regional cooperation and alignment are important.

5.1.3.2 Given the international nature of aviation, special efforts should be taken to ensure harmonization though compliance with ICAO Standards and Recommended Practices (SARPs). The choice of actual technologies to implement MLAT (and ADS-B) should consider not only the required performance of individual components, but also their compatibility with other CNS systems.

5.1.3.3 The future concept of ATM encompasses the advantages of interoperable and seamless transition across flight information region (FIR) boundaries and MLAT/ADS-B implementation teams should include simulations, trials and cost/benefit analysis to support these objectives.

5.1.4 Integration

5.1.4.1 MLAT implementation plans will include the development of both business and safety cases. The adoption of any new CNS system has major implications for service providers, regulators and airspace users and special planning should be considered for the integration into the existing and foreseen CNS/ATM systems. The following briefly discusses each element.

5.1.4.2 The communication system is an essential element within CNS. An air traffic controller can now monitor an aircraft using MLAT and ADS-B in non-radar areas where previously only voice position reports were available. However, a communication system that will support the new services resulting from the improved surveillance will be necessary.

5.1.4.3 Where MLAT is being introduced to perform A-SMGCS or PRM functions, consideration must be given to the supporting navigational systems such as ILS, GLS, airport lighting, taxiway markings, etc

5.1.4.4 MLAT and ADS-B may be used to supplement existing surveillance systems or as the principal source of surveillance data. Ideally, surveillance systems will incorporate all available data to provide a coherent picture that improves both the amount and utility of surveillance data to the user. The choice of the optimal mix of data sources will be defined on the basis of operational demands, available technology, safety and cost-benefit considerations.

5.1.4.4.2 MLAT is dependent on the aircraft having at least a Mode A/C transponder. It can receive identity through correlation of a code with the flight plan, or the flight identification transmitted by ADS-B or Mode S transponder

5.2. Implementation checklist

5.2.1 The purpose of this implementation checklist is to document the range of activities that need to take place to bring an MLAT application from an initial concept to operational use. This checklist may form the basis of the terms of reference for an MLAT implementation team, although some activities may be specific to individual stakeholders. *Note - When completed, the MLAT/ADS-B Implementation and Operations Guidance Document will be more prescriptive of these headings.*

5.2.2 The activities are listed in an approximate sequential order. However, each activity does not have to be completed prior to starting the next activity. In many cases, a parallel and iterative process should be used to feed data and experience from one activity to another. It should be noted that not all activities will be required for all applications.

5.2.3 Concept phase

construct operational concept for the airport or airspace:

- define the purpose of MLAT and ADS-B;
- operational environment;
- ATM functionality that will be affected
- ATM system modifications necessary (and cost estimates)
- infrastructure;
- identify benefits:
- safety enhancements;
- efficiency;
- capacity;
- environmental;
- physical and electronic (remote control) access; and
- other metrics (e.g. predictability, flexibility, usefulness);
- identify constraints:
- pair-wise equipage; need for exclusive airspace;
- required coverage
- required configuration /ground infrastructure;
- RF spectrum;
- define airspace area within which MLAT accuracy is acceptable
- integration with existing technology; and
- technology reliability / availability (system, communications, power);
- contingency systems / procedures
- prepare business case:
- cost benefit analysis; and
- demand and justification.

5.2.4 Design phase

identify operational requirements:

- security;

- systems interoperability;
- identify human factors issues:
- human-machine interfaces;
- training development, delivery and license validation;
- workload demands;
- role of automation vs. role of human;
- crew coordination/pilot decision-making interactions; and
- ATM collaborative decision-making;
- identify technical requirements:
- site selection
- standards development;
- data required;
- functional processing;
- functional performance; and
- required certification levels;
- equipment development, test, and evaluation:
- prototype systems built to existing or draft standards/specifications;
- methodology required by the ANSP safety management system
- developmental bench and flight tests if sufficient data not already provided;
- select technology;
- develop procedures:
- pilot and controller actions and responsibilities;
- phraseologies;
- separation/spacing criteria and requirements;
- controller's responsibility to maintain a monitoring function, if appropriate;
- identify any controller issues for operations at the transition between types of surveillance.
- contingency procedures; and
- emergency procedures;
- prepare design phase safety case:
- safety rationale;
- safety budget and allocation; and
- functional hazard assessment.

5.2.5 Implementation phase

prepare implementation phase safety case;

- Obtain acceptance as necessary of safety case
- Include any safety mitigation that is required into system design or procedures.

Prepare the sites:

- communication, power and physical preparation for remote and central equipment sites;

conduct operational test and evaluation:

- flight deck and ATC validation simulations; and
- flight tests and operational trials;
- obtain systems certification:
- aircraft equipment performance checks; and
- ground system deployment and checking;
- obtain regulatory approvals: flight operations; and air traffic;
- implementation transition:
- continue data collection and analysis;

- continue feedback into standards development processes; and
- performance monitoring to ensure agreed performance is maintained.

5.2.5.1 Once the implementation phase is complete, the ongoing maintenance and upgrading of both MLAT and ADS-B operations and infrastructure should continue to be monitored, measured and reported on – both internally and externally, through the appropriate forums.

ADS-B SEMINAR AND THE SIXTH MEETING OF ADS-B STUDY AND IMPLEMENTATION TASK FORCE (ADS-B SITF/6)

Seoul, Republic of Korea, 23-27 April 2007

Attachment 1 to the Report

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Attachment 2 to the Report

International Civil Aviation Organization

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B) SEMINAR AND THE SIXTH MEETING OF ADS-B STUDY AND IMPLEMENTATION TASK FORCE (ADS-B SITF/6)

Seoul, Republic of Korea, 23 – 27 April 2007

LIST OF WORKING & INFORMATION PAPERS

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1	1	Provisional Agenda	Secretariat
2	2	Outcome of APANPIRG/17 on ADS-B Issues	Secretariat
3	3	Global Air Navigation Plan (Doc 9750) and Development by Panels	Secretariat
4	7	Update to ADS-B Trial and Implementation Status	Secretariat
5	5	The new Terms of Reference of ADS-B Study and Implementation Task Force	Secretariat
6	10	Consideration of Existing ADS-B Avionics	Greg Dunstone, Airservices Australia
7	6	Comparison of Surveillance Technologies	Greg Dunstone Kojo Owusu Katrin Hewitt Airservices Australia
8	8	Concept of Use for Multilateration	Howard Anderson, Nick King, Greg Dunstone, Airservices Australia
9	6	The Proposed Changes to AIGD	Greg Dunstone, Airservices Australia

WP No.	Agenda Item	Subject	Presented by
10	7	Benefits of an ADS-B Managed Service Model for Regions	SITA
11	4	Subject/Tasks list based on the revised TOR	Secretariat
IP No.	**Agenda Item**	**Subject**	**Presented by**
1	-	Meeting Bulletin	Secretariat
2	7	Workshop on Business Case for CNS/ATM Implementation	Secretariat
3	10	ADS-B Issues	Greg Dunstone Kojo Owusu Airservices Australia
4	10	Use of RMK/ADS-B in ATS Flight Notifications	Greg Dunstone Donna Willis Airservices Australia
5	9	ATC System Requirements for ADS-B	Greg Dunstone Airservices Australia
6	9	Additional ADS-B Ground Stations for Australia	Greg Dunstone, Airservices Australia
7	9	Issues for Consideration in Establishing Regulatory Standards for the Carriage and Use of ADS-B Avionics	Brian Harris, Civil Aviation Safety Authority, Australia
8	8	Evaluation Results of Multilateration at Tokyo international Airport	Hiromi Miyazaki, ENRI
9	9	Australian ADS-B Programme Update	Greg Dunstone, Katrin Hewitt and Donna Willis
10	9	Upper Airspace Programme Operations Update	Donna Willis, Greg Dunstone Airservices Australia
11	9	Trial & Evaluation Project in China	Shi Jian Hua, ATMB, CAAC

IP No.	Agenda Item	Subject	Presented by
12	9	ADS-B Implementation for Europe	Eurocontrol
13	7	FASID Table CNS 4 – Surveillance Systems	Secretariat
14	9	ADS-B Systems Implementation & Operational Plan in the Incheon International Airport	Republic of Korea
15	9	ADS-B Trial in Natuna - Indonesia	Indonesia and Singapore
16	9	ADS-B Trial in Indonesia	Indonesia and Australia
17	9	ADS-B Trials Conducted by Civil Aviation Department Hong Kong China	Hong Kong China
18	9	Surveillance Systems for Fiji	Fiji