International Civil Aviation Organization

Automatic Dependent Surveillance – Broadcast (ADS-B)
Study and Implementation Task Force

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Agenda Item 3: Evaluate information available on the selection of link technology as the preferred technology for Asia/Pacific Region

SUMMARY OF RECENT AMCP ACTIVITIES ON COMPARATIVE ANALYSIS OF ADS/B DATA LINK

SUMMARY

This paper presents AMCP activities on comparative analysis of ADS/B data links based on Report on Agenda Item 4 of the eighth meeting of the Aeronautical Mobile Communications Panel (AMCP/8), held in Montreal, from 4 to 13 February 2003.

(Presented by Secretariat)

1. Introduction

1.1 On 6 June 2002, the Air Navigation Commission requested that the agenda for the eighth meeting of the Aeronautical Mobile Communications Panel (AMCP/8). include the item "Comparative analysis of ADS-B data links". In preparation for AMCP/8, the analysis was referred to Working Group C, to be conducted on the basis of guidelines developed by the Secretariat.

1.2 AMCP/8 held in Montreal from 4 to 13 February 2003 reviewed a report from Working Group C on a draft comparative analysis of the three potential ADS-B data links, i.e. secondary surveillance radar (SSR) Mode S Extended Squitter (ES), VHF digital link (VDL) Mode 4 (VDL/4) and universal access transceiver (UAT). The **result of discussions by the meeting is provided in the AMCP/8 meeting report on Agenda Item 4**, which is subject to review by Air Navigation Commission during its next 163rd Session (14 April - 13 June 2003). Recognizing that the comparative analysis would be useful to other appropriate ICAO bodies, AMCP/8 also developed a recommendation to circulate the results of the comparative analysis of ADS-B data links to appropriate ICAO bodies for information.

2. Background

2.1 The second meeting of AMCP Working Group C (WGC/2) agreed in May 2001 that the working group should conduct a comparative analysis of candidate ADS-B data links in order to establish whether the need for UAT SARPs could be justified on the basis of any additional benefits that the UAT would be able to deliver over and above the existing ADS-B candidate links already included in Annex 10, conditional on the resolution of any associated substantive issues (including availability of spectrum).

2.2 WGC/2 also agreed that the comparative analysis should make use of the technical data collected during the ADS-B/situational awareness links assessment conducted by the joint FAA/Eurocontrol Technical Link Assessment Team (TLAT). WGC/3 (October 2001) identified a number of advantages of the UAT. The AMCP Working Group of the Whole (21 - 24 May 2002) reviewed a recommendation made by AMCP WGC to initiate development of UAT SARPs, and confirmed it. On the basis of the commitment by some members, Working Group C established a sub-working group to pursue the work related to the development of draft SARPs and guidance material for UAT (UAT SWG).

2.3 AMCP/8 reviewed documentation developed by the UAT SWG (including draft SARPs and guidance material, and draft requirements and desirable features) and confirmed the decision reached by the Working Group of the Whole as to the need for UAT SARPs. In particular, AMCP/8 recommended that the requirements and desirable **features for the UAT contained in Appendix A to the AMCP/8 Report on Agenda Item 3** be used as the basis for the development of UAT SARPs and be further coordinated with appropriate ICAO bodies, and that AMCP continue the development of the draft SARPs and guidance material for the UAT.

3. AMCP/8 Comparative Analysis of Candidate ADS-B Links

3.1 Guidelines for the comparative analysis were developed by the Secretariat in coordination with the WG-C Rapporteur and circulated to AMCP members and WG-C members. The document provided guidelines for the work on a comparative analysis of ADS-B data links in preparation for AMCP/8. The fifth meeting of AMCP WG-C (WG/5, October 2002) agreed that the document would be used as the guideline for the comparative analysis.

3.2 The goal of the comparative analysis was two-fold:

a) to update and finalize the comparative analysis already conducted by AMCP WG-C with the aim to assess the need for UAT Standards and Recommended Practices (SARPs); and

b) to provide material on the performance of each of the three ADS-B data links that can be used by States when implementing ADS-B.

3.3 The draft comparative analysis report developed by Working Group C was presented to AMCP/8, reviewed by a drafting group, and updated with appropriate changes. The meeting recognized that the comparative analysis had certain limitations, but there was general agreement that limitations were unavoidable in practice, due to the schedule and resource constraints naturally associated with this type of activity.

3.4 The comparative analysis finalized by AMCP/8 was based on the most recent system definitions available and on updated simulations and analyses of three ADS-B data links. Two of these links, the 1 090 MHz SSR Mode S extended squitter (1 090 ES) and universal access transceiver (UAT) are wide-band links operating in the L-Band. The third, VDL Mode 4, is implemented using multiple narrow-band channels in the VHF band.

3.4.1 The 1 090 ES has been developed as an extension of the SSR Mode S technology, which is going to be widely used for aeronautical secondary surveillance radar applications. Access to the 1 090 MHz is randomized, and the channel is shared with current SSR response to interrogations from ground-based radars and airborne collision avoidance systems (ACAS). The data rate used is 1 megabit per second, within a message.

3.4.2 UAT is a transceiver system (proposed frequency of operation: 978 MHz) designed specifically to support the function of ADS-B. In addition to ADS-B, UAT is intended to support uplink broadcast information from ground stations. Access to UAT medium is time-multiplexed within 1 second frame between ground-based broadcast services (the first 188 milliseconds of the frame) and an ADS-B segment. The UAT data rate is approximately 1 megabit/second within a message.

3.4.3 VDL Mode 4 provides a range of communication services including broadcast and point to point, air/ground and air/air. The services include ADS-B. VDL Mode 4 uses two separate 25 kHz global signaling channels (GSCs), with additional channels used in areas with medium to high aircraft density. Access to the VDL Mode 4 medium, within a channel, is time-multiplexed, with a data rate of 19.9 kilobits/second within a message. The self-organizing channel access scheme may reduce the need for higher bandwidth.

3.5 The data links were assessed and compared against a number of criteria:

a) the criteria considered in the assessments of data links for surveillance applications carried out by AMCP Working Group D in preparation to AMCP/5, (see AMCP/5-WP/4, also available on the AMCP web site as WGC1/WP12);

b) RTCA ADS-B minimum aviation system performance standards (MASPS) DO-242A criteria; and

c) additional Eurocontrol criteria supplied to the joint FAA/Eurocontrol Technical Link Assessment Team (TLAT) (see Technical Link Assessment Report[1], March 2001).

3.6 The criteria from AMCP/5-WP/4 referred to in 3.5 a) above included::

1) Interference Resistance;
2) System Availability;
3) System Integrity;
4) Acquisition Time;
5) Independent Validation of Position;
6) Functional Independence;
7) Autonomous Air-Air Operations;
8) Operational Aircraft Traffic Densities;
9) Operational Domain Radius;
10) Received Update Rates;
11) Barometric Altitude Resolution;
12) Geometric Altitude Resolution;
13) RF Frequency;
14) Antenna Requirements;
15) Spectrum Efficiency;
16) Support to All Classes of Users;
17) Support of Related Applications;
18) Minimal Complexity;
19) Non-Interference with Other Aeronautical Systems;

[1]The report is available on the following websites:
www.eurocontrol.int/ads/ and
www.faa.gov/safeflight21/

20) Transition Issues;
21) Fundamental Design: Frequency Band;
22) Fundamental Design: Modulation;
23) Fundamental Design: Multiple Access Technique;
24) Maturity of Technology;
25) ADS-B Related Activities and Time-Scales;
26) Interoperability;
27) Flexibility;
28) Non-Proprietary;
29) Robustness/Fallback States;
30) Future Suitability; and
31) Cost

3.7 In order to evaluate system performance in several different air traffic situations, two scenarios were chosen as representative of future environments, a high-density environment (2091 aircraft plus 500 ground vehicles within 300 NM) and a low-density environment (360 aircraft within a circle of 400 nautical miles).

4 Summary of results of the Comparative Analysis

4.1 Due to the relatively large number (>80) of criteria and parameters considered in the course of the analysis, the results do not lend themselves readily to the development of a concise summary. However, the following points emerge from the analysis:

4.2 Each of the three candidate ADS-B data links was seen to have relative advantages with regard to some criteria. For example, the 1090 MHz Extended Squitter is the only link candidate to have a globally allocated operational radio frequency (AMCP/8 Report, Appendix to the Report on Agenda Item 4, Paragraph 2.2.13.2 refers). VDL Mode 4 was evaluated as having particularly good results for airport surface operations (AMCP/8 Report, Appendix to the Report on Agenda Item 4, Paragraph 2.2.21.2 refers). For single-link implementations of ADS-B, UAT exhibits the longest air-to-air range, namely 125 NM vs. 70 NM for VDL Mode 4 and 40-50 NM for 1090 MHz Extended Squitter (AMCP/8 Report, Appendix to the Report on Agenda Item 4, discussion of criterion R3.9 in Paragraph 3.1, page 4A-44).

4.3 The results of the analysis with regard to one set of significant criteria (including performance, spectrum availability, and operational use/maturity of technology) extracted from among the criteria considered in the analysis are reviewed below. For a complete assessment of the results of the analysis, reference should be made the full set of results contained in the Appendix to AMCP/8 Report on Agenda Item 4.

4.4 Performance

4.4.1 The air-to-air performance of UAT was overall superior to the other two links in both high density and low density scenarios. The extended air-to-air ranges (with sufficiently frequent receipt of ADS-B messages) offered by UAT were achieved even though UAT was the only link configured to accommodate all intent information required and desired by the RTCA ADS-B MASPS (RTCA Document 242-A), thus accommodating a heavier ADS-B data loading than either of the other two data links in the comparative analysis (AMCP/8 Report, Appendix to the Report on Agenda Item 4, Paragraphs 3.2 to 3.4 and 4.2 to 4.4 as well as the performance graphs for the three candidate links in Attachments A through C of the Appendix refer).

4.4.2 Air-ground performance was simulated for the UAT, with the finding that all known update rate criteria were met out to at last 150 nm using a single antenna (in the absence of a colacted TACAN emitter). Air-ground performance for VDL4 and Extended Squitter was not simulated but system experts were of the view that all known requirements could be met with appropriate sectorized antennas.

4.5 Spectrum

4.5.1 The 1 090 MHz frequency has been approved for 1 090 ES operation on a global basis. 1090 ES is the only ADS-B data link with spectrum approval for global operation. Because of the safety aspects of surveillance operations, some national policies require that surveillance operations occur in frequency bands that are protected for aeronautical radionavigation service (ARNS). UAT is currently in the process of obtaining radio regulatory approval in the United States to operate on 978 MHz, which is currently used by DME and TACAN (AMCP/8 Report, Appendix on Agenda Item 4, Paragraph 2.2.13.1 refers). Only seven operational DME/TACAN stations have been identified worldwide as operating on 978 MHz. VDL Mode 4 SARPs specify operation in the VHF AM(R)S band (117.975 – 137 MHz). A European planning activity is proposing four channels for VDL Mode 4 use (AMCP/8 Report, Appendix to Agenda Item 4, Paragraph 2.2.13.2 refers). It is expected that ITU WRC-2003 will permit operation of VDL Mode 4 in the VHF ARNS band (108 – 117.975 MHz), in addition to the AM(R)S band.

4.6 Operational Use and Maturity of Technology

4.6.1 Of the three links, only UAT is being used operationally for airborne applications and has a certification baseline for airborne equipment consisting of both a Minimum Operational Performance Standard (MOPS RTCA DO-242A) and a Technical Standard Order (TSO C-154, issued by the FAA). The Capstone program has equipped 170 aircraft with the UAT system, and uses them to supply radar-like ATC services and improved situational awareness in the FAA Alaska region. The 1090 MHz Extended Squitter has a MOPS (but currently no Technical Standard Order). VDL Mode 4 has an Interim MOPS while having accomplished numerous trials and flights in various projects in Europe and having a local implementation of surface movement applications at Arlanda airport in Stockholm (AMCP/8 Report, Appendix to the Report on Agenda Item 4, Paragraph 2.2.24).

4.7 Functional independence

4.7.1 Aviation systems are typically developed to support one or another of the three functional areas of communications, navigation and surveillance. From a safety standpoint, it is important that aviation systems avoid a failure Mode whereby loss of one of these three elements leads directly to the loss of another.

4.7.2 The ADS-B concept relies on a navigation input to an ADS-B transmitter. UAT supports uplink broadcast of FIS by preserving a permanently dedicated channel resource for ADS-B. UAT ADS-B installations would also likely have no hardware elements in common with the ACAS system, minimizing any common-point failure scenarios between ACAS and ADS-B. VDL Mode 4 also requires timing information, generally derived from GNSS, although alternative timing sources may be used in the event of GNSS failure. VDL Mode 4 has no common components with current surveillance systems (SSR transponder, ACAS) minimizing any common-point failure scenarios. The 1090 ES does not rely upon precise timing that can only be provided by GNSS. While 1 090 ES implementation can take advantage of legacy Mode S avionics, this ADS-B alternative can be implemented in a manner independent of the SSR system.

4.8 Operational domain radius

4.8.1 In the absence of interference, the UAT link budget calculation indicates that a minimum transmit power A0/A1L category aircraft can be received at a range of about 50 NM, an A2 at about 74 NM, and an A3 at about 186 NM (Reference RTCA DO-282, Appendix F). Under the severe interference high-density air traffic scenario, A0 aircraft were received at greater than 10 NM, A1 at greater than 20 NM, A2 at greater than 40 NM, and A3 at around 125 NM. For VDL Mode 4 link budget calculation indicates that, minimum a transmit power aircraft can be received at a range of about 200 NM. This range is the same for all aircraft, since the system specified for study requires that all aircraft transmit with the same power. For 1 090 ES link budget calculation indicates that a minimum transmit power A0 category aircraft can be received at a range of about 14 NM, an A1 at about 21 NM, an A2 at about 38 NM, and an A3 at about 67 NM (RTCA DO-260A [Ref. 8], Appendix E). Under severe interference high-density air traffic scenario, A1and A2 category aircraft can be received at 40 NM, and A3 at around 40 - 50 NM. This range is sufficient for aircraft to perform many of the applications currently envisioned.

4.9 Transition issues

4.9.1 All ADS-B link will require new aircraft equipment and ground infrastructure. The transition process must take into account timescales for the introduction of ADS-B applications by air navigation service providers and aircraft equipage. TIS-B is an important application to support the transition process.

4.9.2 The design of the UAT Ground Uplink Segment furnishes an alternative implementation of transition services such as TIS-B that provides no interference to UAT transmissions from equipped aircraft, should such an alternative implementation become necessary in high-density airspace. Investigation of the use of a diplexer to permit the sharing of existing transponder antennas by UAT avionics is being undertaken. The protocol stack of VDL Mode 4 enables Ground-to-Air services (e.g. TIS-B) to be transmitted in either the pre-protected slots of the VDL Mode 4 timeframe or in protected slots assigned dynamically. It is also possible to transmit on dedicated channels.

4.9.3 The 1090 ES system has specific attributes that support transition to ADS-B in several important ways. First, early operational implementation of ADS-B on a worldwide basis can be supported at present, because of the worldwide frequency allocation and SARPS for the 1 090 ES system. In large part because of this attribute, as well as the synergy between 1090 ES and existing SSR/ACAS avionics, the 1 090 ES system has been selected by the FAA and is under consideration by Eurocontrol as the near-term ADS-B link for ADS-B implementation that is interoperable between the United States and Europe. The 1 090 ES system also supports TIS-B. Both Boeing and Airbus are expected to deliver their new commercial air transport aircraft with 1 090 ES installed beginning in 2003, using the initial 1 090 ES MOPS (DO-260 [Ref. 8]) as a baseline. TCAS/ACAS manufacturers are either currently shipping or have plans to offer by 2003 avionics that also incorporate 1 090 ES capability.
