International Civil Aviation Organization

Eight Meeting of the Communications/Navigation/Surveillance and Meteorology Sub-Group (CNS/MET SG/8) of APANPIRG

Bangkok, Thailand, 12-16 July 2004

Agenda Item 6: Surveillance

UNIVERSAL ACCESS TRANSCEIVER (UAT) USE FOR ADS-B

(Presented by the United States of America)

SUMMARY

The Universal Access Transceiver (UAT) is one of three candidate link technologies that is being considered to support Automatic Dependent Surveillance Broadcast (ADS-B) along with Mode S and Very High Frequency (VHF) Digital Link (VDL) Mode-4. UAT was conceptualized in 1994 with the purpose of initiation the development of a new broadband data link from a clean sheet, which would be designed specifically to address the requirements of the ADS-B functionality. The projected benefits envisioned from UAT have made it a serious candidate being considered by the U.S. and the international community. The system is currently being used operationally in Alaska with plans to introduce it into the lower continental U.S. This paper also includes as an attachment, a brief, titled: "Universal Access Transceiver (UAT)" dated July 2004; presented to the ICAO Aeronautical Communication Panel by the current U.S. Member to that panel. This briefing offers more detailed up-to-date information on UAT for ADS-B, current operational testing and status of ICAO and domestic standards. This paper and the accompanying briefing provide a technology overview and a status of the link decision and standardization process.

1. INTRODUCTION

1.1 The "Future Aeronautical Mobile Communications Scenarios" paper developed by member states of the International Civil Aviation Organization (ICAO) and presented at this ANC/11 Conference provides an inventory of Automatic Dependent Surveillance – Broadcast (ADS-B) solutions and potential scenarios which satisfy requirements for future surveillance functions. This document has the objective of providing guidance towards a harmonized global architecture. The United States (U.S.) Federal Aviation Administration (FAA) supports the surveillance concepts described in this document and is proceeding with an architecture which is in agreement with this document. The Eurocontrol and the FAA have worked very closely in the area of future surveillance planning in an effort to achieve international agreement on a direction which will help ensure international interoperability. This has resulted in the identification of 1090 MHz Mode S Extended Squitter (1090 ES) as a common ADS-B link to support near term
applications with the selection of a second future link if necessary.

2. LINK DECISION

2.1 The FAA announced its ADS-B link architecture decision which utilizes a combination of a 1090 ES ADS-B link for air carrier and private/commercial operators of high performance airframes and a Universal Access Transceiver (UAT) ADS-B link for the typical general aviation user. This decision commits the FAA to moving forward with the operational use of ADS-B

enabled capabilities within the U.S. It is anticipated that this decision will allow avionics manufacturers to move forward expeditiously with their plans to produce commercial ADS-B avionics and will allow airspace users to make investment decisions on ADS-B equipage. ADS-B is seen as a cornerstone enabler for Free Flight because it provides common situational awareness for more shared air and ground responsibility. ADS-B is expected to improve safety and to increase efficiency and capacity.

2.2 The U.S. ADS-B link decision is based in part on results from a technical performance assessment of three candidate link technologies: 1090 ES, UAT and VDL Mode 4. The assessment was performed by the Joint FAA/Eurocontrol Technical Link Assessment Team (TLAT) and follow-on work of the FAA and Eurocontrol. Comparisons of the links on a non-technical basis (e.g. cost, spectrum, transition issues) were also taken into consideration in the decision. ICAO's Aeronautical Mobile Communications Panel (AMCP) recently completed a similar link comparison at the request of the Air Navigation Commission (ANC). This study was initiated in response to modifications to the ADS-B system configurations and designs, which occurred after the TLAT report was issued. The results from this study have been used by the ANC to assess the need for UAT Standards and Recommended Practices (SARPs).

3. 1090 ES/UAT INTEROPERABILITY

3.1 The link decision is designed to satisfy short range (<40 nautical mile, nmi.) air-to-air applications and longer range (up to 200 nmi) air-to-ground ATC surveillance applications in the U.S. National Airspace System (NAS). Aircraft that fly in high altitude airspace would equip with 1090 ES. General Aviation aircraft that are not capable of high altitude operations would equip with UAT. Interoperability between the links will be provided within coverage of the ground ADS-B infrastructure using the multilink gateway service provided via the TIS-B uplink (ground-to-air). Traffic Information Service–B (TIS-B) is also used to provide "ADS-B reports" on aircraft that are not transmitting ADS-B information. The 1090 ES is selected for the airspace that is principally used by the domestic and international commercial aircraft. The FAA and Eurocontrol have coordinated on the selection of 1090 ES as the interoperable link for the U.S. and the core of Europe. The UAT is selected to provide ADS-B and associated services for the general aviation users because of its lower cost and greater uplink capacity, especially for Flight information Service Broadcast (FIS-B) services. If long range air-to-air applications are validated for use in the long-term that cannot be satisfied by 1090 ES alone, UAT would be a leading candidate to support these requirements. The U.S. supports progressing UAT ICAO SARPs so that UAT can be considered an international candidate for ADS-B.

4. SYSTEM ADVANTAGES

4.1 Performance

4.2 As part of the TLAT Assessment and the ICAO Comparative Analysis, the three candidate ADS-B data links were assessed and compared against a number of criteria. The criteria which discriminated among the links were in the areas of link performance, spectrum, and operational use. Each of the three candidate ADS-B data links was seen to have advantages. For example, the 1090 ES is the only link candidate to have a globally allocated operational radio frequency. VDL Mode 4 was evaluated as having particularly good results for airport surface operations. For single-link implementations of ADS-B, UAT exhibits the longest air-to-air range (125 nmi versus. 70 NM for VDL Mode 4 and 40-50 nmi for 1090 MHz Extended Squitter) to support air-to-air applications in future high density airspaces such as "Core Europe."

4.3 UAT is a broadcast data link system specifically designed for ADS-B, with no constraints from legacy-based systems. The performance of UAT was found to be superior to the other two links especially in future high density airspace. 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 Minimum Aviation System Performance Standards (MASPS) (RTCA Document 242-A), thus accommodating a heavier ADS-B data loading than either of the other two data links in the ICAO comparative analysis. Even though UAT performance was evaluated assuming high levels of interference from both distance measuring equipment (DME) and JTIDS/Link 16 sources, UAT still achieved greater compliance with RTCA MASPS air-air requirements for range of state vector and intent reception than the other data links. It has been suggested that a combination of data links, consisting of 1090 ES and VDL Mode 4, would achieve performance comparable to that of UAT in future high-density airspaces. Aside from the increased cost considerations, designing a single system combining two data links is a complex, difficult task. Despite the efforts of a number of experts, as of the date of this paper, there has been no combined 1090 ES/VDL Mode 4 system proposed which has been confirmed as being both implementable on air transport aircraft and able to achieve the level of performance of UAT. Also, UAT may serve in a role of complementing 1090 ES in a cost effective manner with the possible sharing of airborne resources (e.g. antennas).

4.4 Spectrum

4.5 As mentioned above, 1090 ES is the only ADS-B data link with spectrum approval for global operation. UAT is currently obtaining operational approval in the United States to operate in the L-band at 978 MHz. UAT operates outside of the highly congested VHF band which is favorable from a spectrum availability and interference mitigation perspective. A European planning activity is proposing four channels for VDL Mode 4 use—for the performance analysis in the high-density air traffic scenario presented in the ICAO comparative analysis, four channels were required for air-to-air ADS-B state vector transmissions alone (i.e., intent information was not included)

4.6 Operational Use and Maturity of Technology

4.7 Of the three links, only UAT is being used operationally for airborne applications. UAT has a certification baseline for airborne equipment consisting of both a Minimum Operational Performance Specifications (MOPS) and a Technical Standard Order (TSO C-154, issued by the FAA). The ICAO ANC is considering approval for the initiation of UAT SARPs development as part of the Aeronautical Communications Panel's (ACP) future work plan. A major part of the activity of the UAT MOPS working group was in selecting the operating frequency to minimize impact to DME worldwide and to ensure UAT was as robust as possible in its expected interference environment. Toward this end, much of the effort of the working group focused on the following actions:

- Extensive testing (of Capstone UAT hardware) to accurately characterize transmitter and receiver performance for incorporating into network-level simulations.

- Network-level simulations of UAT/ADS-B in a demanding future traffic environment to assess performance using metrics established in the ADS-B MASPS (RTCA DO-242A) and criteria provided by Eurocontrol.

- Development of extreme interference scenarios from outside sources of interference (DME and L16) for inclusion in the network-level models.

4.8 The 1090 MHz ES has a MOPS and approved ICAO SARPs. VDL Mode 4 has an Interim MOPS and approved ICAO SARPs.

5. CAPSTONE PROGRAM

5.1 Currently, there are over 180 UAT equipped aircraft, mostly air taxi operators with single and twin-engine aircraft as part of the US FAA's Capstone program. Additionally, 10 ground stations have been installed in Western Alaska. In January of 2001, the FAA approved the use of UAT/ADS-B to support "radar-like services" for equipped aircraft in areas of Western Alaska without

radar coverage. This represents the first operational use of ADS-B to support Air Traffic Services in the world. The Capstone program is currently planning to upgrade the installed avionics and ground stations to the recently completed standards documented in the UAT MOPS. Additionally, the program plans to award new contracts for another 200 avionics suites to equip aircraft (fixed wing and helicopter) in Southeast Alaska and for 30 new ground stations.

6. CONCLUSIONS

6.1 The FAA has announced a link decision which utilizes a combination of 1090 ES and UAT. The FAA and Eurocontrol have agreed on 1090 ES as a coordinated initial ADS-B link to support near term capabilities and to provide international interoperability. The UAT will be used to support general aviation and provides performance advantages over the other link candidates which makes it a leading candidate as the long-term ADS-B link for high performance air carriers.

6.2 It is recommended that the meeting:

- Note the decisions taken by various states and organizations in an attempt to achieve international interoperability
- Note the benefits of UAT to support a long-term ADS-B link requirements based on its simple design, performance and low cost.
- Note the attached briefing with more details specific to UAT, including a recent status update with operational testing, spectrum and other information.

Attachment to CNS/MET/SG/8 IP/15 titled:
"Universal Access Transceiver (UAT) use for ADS-B"

Universal Access Transceiver (UAT)

Brent Phillips
U.S. Member
ICAO ACP
July 2004

Outline

- History
- UAT Description
  - System Overview
  - Some Details
- Standards and Spectrum Planning Status

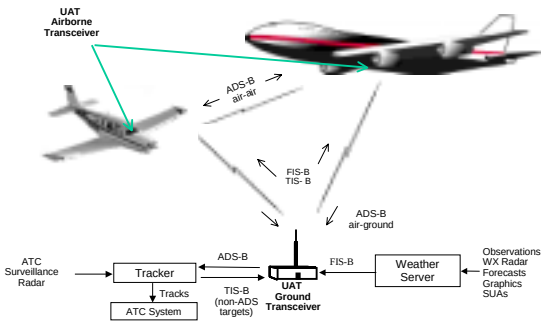
A Brief History of UAT

- Began around 1995 as part of an independent research project on broadcast data link
  - 6 prototype systems flown on small aircraft
  - ADS-B, TIS-B, and Wx uplink demonstrated
- Cargo Airlines incorporate UAT in their evaluation--UPS-AT develops UAT
- UAT becomes part of SF-21 Link Evaluation study
  - www.eurocontrol.int/ads/deliverables/01/tlat/FinalReport
- UAT part of winning bid for FAA's Capstone program

UAT Overview

- Designed specifically for ADS-B and Broadcast Uplink Surveillance-Related Services with no constraints from legacy systems
- Simplicity and robustness were paramount design objectives
- Operates on a single common wideband channel
- 1 Mbps channel rate
- Capable of supporting multiple broadcast applications to foster early equipage

UAT Applications and Connectivity



Waveform Selection

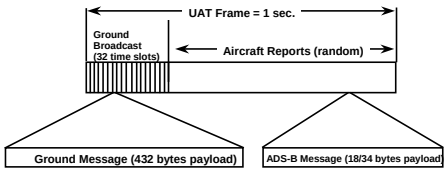
- Requirements
  - Good capture effect
  - relatively efficient and low cost power amplifier
  - simple/robust decoder
- Binary FM with high modulation index chosen

Frequency Band Selection

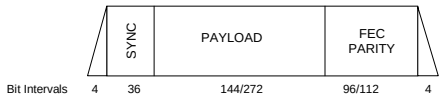
- Aeronautical band alternatives:
  - VHF: 108-118 MHz
  - L-band: 960-1215 MHz
  - C-band: 5000-5250 MHz
- Extremely difficult to assemble enough contiguous channels at VHF
- Propagation loss too high at C band
- 960-1215 MHz has best combination of:
  - channelization (1 MHz)
  - compatible current usage (pulsed systems)
  - and propagation characteristics

UAT Media Access Approach

- Requirement: Simple and Robust logic for aircraft media access
- ADS-B transmissions occur based on pseudorandom selection of one of 3200 Message Start Opportunities (MSO)



ADS-B Message Format



- Each aircraft transmits exactly one message each second
- Standard Forward Error Correction (FEC):
  - increases message robustness to pulsed interference and noise
  - provides an extremely low undetected message error rate ~10^{-9}

Independent ADS-B Report Validation: Aircraft Perspective

- ADS-B message payload includes the precise transmission time (MSO)
- Receiving aircraft UAT reports precise time of reception with decoded message payload
- Application can perform passive range verification of ADS-B reported position
- Flight test data showed time-based slant range estimates to be within 0.2 nmi of that indicated by ADS-B

Status of UAT Standards and Spectrum Planning

July 2004

UAT Standards and Recommended Practices (SARPs) and Technical Manual (TM)

- **UAT SARPS development added formally to ACP work program in May 2003 by the Air Navigation Commission**
- **Work on UAT SARPS began by ACP WG-C (formerly AMCP) in June 2002 (initially "at risk")**
- **Mature drafts of core SARPs and Technical Manual are available.**
- **SARPs and Tech Manual development entered a validation phase in Oct 2003 with completion and approval by the full panel targeted for 2005.**
  - **Validation will include some testing of FAA ground station equipment and certified avionics.**
  - **Frequency planning criteria for UAT will be finalized during validation period**

UAT SARPs and TM (Concluded)

- **SARPs and TM development build upon existing UAT equipment certification baseline (MOPS/TSO)and over 2 years of operational experience with UAT**
- **UAT frequency planning criteria are being developed based upon RTCA/FAA testing, amplified by ACP/UAT subgroup analysis for both enroute and terminal/approach scenarios.**

UAT Certification Baseline

- **Activities initiated by RTCA in December 2000 in response to high priority FAA request for industry-developed standards for UAT**
- **Tasked to develop Minimum Operational Performance Standards (MOPS) for a UAT-based ADS-B system on an accelerated schedule**
- **Document approved by PMC on August 2002 (DO-282)**
- **TSO-C154 approved Nov 2002 as basis for equipment certification**

Participants in Development of UAT MOPS/TSO

- FAA **(Certification, Spectrum, Technical Center, Flight Standards, Safe Flight 21 Program Office, Alaska Region)**
- Eurocontrol
- U.S. Department of Defense
- AOPA
- SSA/FAI
- UPSAT
- Rockwell Collins
- Garmin
- Boeing
- L3Comm Analytics
- BAE Systems
- Sensis
- Johns Hopkins APL Mitre
- Trios
- Titan
- PMEI

UAT MOPS

- **40 page compliance matrix for ADS-B MASPS (DO-242A) and FIS-B MASPS is available**
- **UAT also designed toward, and UAT performance assessed against, extended ADS-B air-to-air range criteria from Eurocontrol (A3-to-A3 air-to-air performance in Core Europe 2015 Scenario of TLAT estimated to be 120-125 miles)**
- **TIS-B requirements are expected to be accommodated by UAT**

UAT Frequency Planning Criteria (1)

- **978 MHz selected as candidate UAT frequency.**
  - **Worldwide assignments on this frequency consist of 7 DME/TACAN in Europe**
- **UAT design objective is compatibility with DME without impacting DME/TACAN assignments on channels other than 978**
  - **RTCA/FAA analysis indicates that this objective has been achieved**
  - **UAT subgroup performing further analysis**
- **For the UAT subgroup, DFS has performed a "worst case" enroute environment study on UAT compatibility with DME. DFS has proposed enroute frequency planning criteria that involves vacating only the 978 MHz channel**

UAT Frequency Planning Criteria (2)

- **UAT compatibility with JTIDS/MIDS system has also been achieved with analysis including both future high and low density airspace.**
- **US authorities approved 978 MHz UAT frequency for national use on 16 April 2003 based on the "aid to radionavigation" footnote for the 960-1215 band (Footnote 5.328).**
- **ICAO is seeking an opinion from ITU on the applicability of the above footnote. ITU opinion is that footnote applicable for surveillance functions of UAT. Radio Regulation changes to address UAT uplink (weather data) will be addressed under an existing agenda item at WRC 2007.**

Aircraft Integration of UAT Avionics

- **Integration into small aircraft has been demonstrated through FAA Capstone Program. Success of this integration is evidenced by over 2 years of successful operational use.**
- **Integration into air transport class aircraft through sharing of the SSR transponder antennas has been analyzed and tested in detail. Results are positive, and this potential integration path is being coordinated with ICAO SCRSP.**
- **SCRSP coordination for UAT/SSR antenna sharing and cosite compatibility is completed.**