Findings of the ADS-B Technical Link Assessment Team

presented by N. Fistas, Eurocontrol

prepared by the TLAT Co-Chairs

Constantine Tamvaclis
Eurocontrol Experimental Centre
ATM/CNS System Engineering
ADS Studies and Trials Project Manager
33-1-6988-7419
constantine.tamvaclis@eurocontrol.fr

Ann Tedford
Federal Aviation Administration
Architecture and System Engineering
Deputy Program Director
1-202-358-5300
ann.tedford@faa.gov

RTCA's Safe Flight 21 Steering Committee and Eurocontrol's Automatic Dependent Surveillance (ADS) Programme Steering Group jointly sponsored the Automatic Dependent Surveillance-Broadcast (ADS-B) Technical Link Assessment Team (TLAT) .

The TLAT was requested to continue technical evaluation of three ADS-B and situational awareness link candidates, 1090 MHz Extended Squitter, VHF Digital Link (VDL) Mode 4, and Universal Access Transceiver (UAT), initiated by its precursor, the Safe Flight 21 Technical ADS-B Link Evaluation Team. The candidate links were to be technically characterized in a common manner and evaluated, in a reference set of traffic scenarios, to a common set of technical link assessment criteria derived from the need to support both the Free Flight Operational Enhancements specified in August 1998 by the RTCA Free Flight Select Committee and further applications as designated by the Eurocontrol ADS Programme.

The TLAT's report summarizes the technical assessment of the above three candidate ADS-B/situational awareness links. The TLAT was not directed to provide an ADS-B link recommendation, and as such, the TLAT's report does NOT contain an ADS-B link recommendation.

This presentation addresses the following:

- Evaluation Criteria
- Team Membership
- Report Contents
- Findings
- What's Next? for Eurocontrol? for the FAA?

Most of the annotations in this presentation are direct excerpts from the TLAT's report. The report is available at the following web sites:

- www.eurocontrol.fr/eatchip/projects/ads
- www.faa.gov/safeflight21/

Evaluation Criteria - 1

- Applications from the Joint Government/Industry Plan for Free Flight Operational Enhancements
  - 7 ADS-B air-to-air applications
  - Traffic Information Services-Broadcast (TIS-B)
  - Flight Information Services-Broadcast (FIS-B)
  - plus the simultaneous approach application
- Technical Requirements
  - RTCA ADS-B MASPS (DO-242)

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The TLAT link evaluation criteria provide the metrics by which the ADS-B/situational awareness link candidates have been assessed. These criteria include the criteria originally developed by the SF21 Link Evaluation Team (LET), additional criteria proposed by Eurocontrol, and other considerations specified in the TLAT terms of reference. The report is intended to document the performance of the candidate datalinks in relation to the different criteria and to provide the ability to assess technical aspects of the various options.

The LET developed a set of technical link performance criteria to evaluate the candidate ADS-B/situational awareness links. These were based primarily upon two industry-consensus RTCA documents:

• the Joint Government/Industry Plan for Free Flight Operational Enhancements

• the RTCA ADS-B Minimum Aviation System Performance Standards (MASPS) DO-242

Using the description of the nine operational enhancements defined in the operational enhancements document, the LET determined that all link-related requirements in the ADS-B MASPS were applicable to the evaluation of the links.

Furthermore, the consideration of the above operational enhancements made it clear that requirements relating to support of Traffic Information Services-Broadcast (TIS-B) and Flight Information Services-Broadcast (FIS-B) services needs to be taken into account in order to support the identified operational enhancements. These requirements are not covered in the ADS-B MASPS. The LET developed additional performance requirements for TIS-B and FIS-B.

The LET also decided that in addition to the ADS-B, TIS-B, and FIS-B related criteria, there should be some “implied” criteria that need to be considered in order to evaluate comprehensively the candidate links and provide the complete picture. Two categories of such criteria were identified assessing the overall implementation feasibility and maturity and the integration/interoperation of the candidates with existing systems.

It is important to note that the LET criteria did not include considerations for the provision of Differential GNSS (DGNSS) or two-way (including air-to-air) addressed aeronautical communications services over the ADS-B/Situational Awareness link. While these services are very important in the complete picture of the aircraft equipage and they should be considered in the overall aircraft architecture, TLAT concentrated on ADS-B/situational awareness and directly linked issues.

Evaluation Criteria - 2

- Additional applications from Eurocontrol
  - overlay of monopulse Secondary Surveillance Radar (SSR) with ADS-B
  - overlay of Mode S Enhanced Surveillance with ADS-B
- Additional technical requirements or assessments
  - extension of long-range deconfliction from Eurocontrol
  - multiple ADS-B link considerations
  - any link dependent criteria resulting from ADS-B Operational Safety Assessment
  - expandability and excess capacity

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In addition to the previous criteria, the TLAT used further criteria--approved by both the Safe Flight 21 Steering Committee and the Eurocontrol ADS Programme Steering Group.

The further criteria from Eurocontrol stem from European ADS requirements development that has occurred subsequent to the adoption of the ADS-B MASPS by RTCA. The ADS-B MASPS could not be endorsed by EUROCAE because European ADS requirements were not sufficiently mature. The Eurocontrol criteria are being considered for incorporation in the MASPS by the SC-186 working group formed to update the RTCA ADS-B MASPS.

Since the European ADS-B requirements are not yet finalized, the Eurocontrol criteria represent a snapshot of the ongoing discussions in Europe in relation to ADS-B requirements. These criteria aim to assess the margin that the candidate datalinks are able to provide to allow for the fulfillment of potential additional or differing ADS-B requirements. The assessment of this margin, if any, is an important element of any link decision, as it can safely be assumed that the ADS-B system as currently envisaged may differ from the implemented system.

The Eurocontrol criteria cover two air/ground surveillance scenarios, which may be implemented in Europe. The first scenario is the overlay of monopulse Secondary Surveillance Radar (SSR) with ADS-B, where the latter serves as gap filler and also supplies trajectory intent information. This first scenario is applicable to airspace of medium and low-density traffic. The second scenario is the overlay of Mode S Enhanced Surveillance services with ADS-B, where ADS-B provides state vector and trajectory intent information as well as serves as a gap filler or extender for enhanced surveillance. This second scenario is applicable to airspace of high-density traffic (e.g., Core Europe).

Furthermore, the TLAT's terms of reference required the group to develop criteria to evaluate the candidate datalinks against some issues that are not covered by the criteria described previously:

•to evaluate the technical aspects of using multiple ADS-B datalinks potentially in different airspace or aircraft types

•to identify and evaluate any link dependent criteria originating from operational safety assessments

•to assess the expandability and excess capacity of the candidate datalinks.

Traffic Scenarios

- Los Angeles Basin in 2020
- Core Europe in 2015
- Low Density

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The traffic scenarios are important to put into perspective the performance that the candidate links will achieve in a realistic environment. The scenarios describe the physical distribution of aircraft that must be considered in the simulations, which will complement the other investigation in lab and flight-testing.

The Los Angeles Basin 2020 scenario was generated using as a baseline the Los Angeles Basin 1999 scenario with the aircraft densities increased by 50 percent.

The Core Europe 2015 scenario assumes a traffic increase of 73 percent in comparison to 1999 traffic levels and is focused around five major TMAs in the busiest European area (Brussels, Amsterdam, London, Paris, and Frankfurt) with the Brussels TMA in its centre.

The low-density scenario has been developed by scaling downward the Los Angeles Basin scenario.

Membership

- Co-chairs
  - Constantine Tamvaclis, EEC
  - Ann Tedford, FAA
- Facilitator
  - George Ligler, PMEI
- Team Members
  - Larry Bachman, JHU/APL
  - Nikos Fistas, Eurocontrol
  - John Gonda, DoD/USAF
  - Stan Jones, MITRE
  - Vince Nyugen, FAA/AND-500
  - Tom Pagano, FAA/ACT-300
  - Rich Weathers, DoD/JCS
  - Don Willis, FAA/ASR-100
  - Ray Yuan, JHU/APL
- Subject Matter Experts
  - 1090 MHz Extended Squitter
    - Jonathan Bernays, LL
    - Bill Harman, LL
  - UAT
    - Chris Moody, MITRE
  - VDL Mode 4
    - Christian Axelsson, Swedish CAA
    - Johnny Nilsson, Swedish CAA
    - Armin Schlereth, DFS

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The TLAT was jointly co-chaired by Eurocontrol and the FAA. Team members represented the technical offices, spectrum engineering, test, and Department of Defense (DoD). Many team members have participated in development of ADS-B specifications in various fora. The Subject Matter Experts provided system descriptions of their respective systems. As noted in the Terms of Reference the Subject Matter Experts "… of each radio-link technology will maintain regular contact with all relevant avionics manufacturers active in the relevant technology field and airframe manufacturers."

The TLAT co-chairs wish to express their appreciation for the work contributions of all team members and many others who provided information, briefings, and data to the TLAT.

Meetings were held as noted below. The TLAT co-chairs again thank our hosts for their hospitality and the opportunity to understand all aspects of implementing ADS-B.

- May 23-26, FAA Portals, Washington, DC
- June 27-30, Eurocontrol Headquarters, Brussels, Belgium
- August 8-11, Federal Express, Memphis, Tennessee
- September 12-15, DERA, Malvern, England
- October 17-20, FAA Portals, Washington, DC
- November 14-17, Eurocontrol Experimental Centre, Bretigny, France
- December 5-8, United Airlines, Denver, Colorado
- January 16-19, DFS, Frankfurt, Germany
- February 13-16, JHU/APL, Laurel, Maryland
- March 13-16, Eurocontrol Headquarters, Brussels, Belgium

Report Contents

- Introduction
- Overview of ADS-B/ Situational Awareness Link Candidates
- TLAT Evaluation Criteria for ADS-B/Situational Awareness Links and Traffic Scenarios
- Technical Assessment Approach
- Technical Assessment
- References
- Key Appendices
  - System Descriptions
  - Link Evaluation Criteria
  - Traffic Scenarios
  - Data Link Receiver Performance Models
  - Summary of Link Modeling and Simulation
  - Trials and Simulation Results
  - Multi-Link Considerations
  - Further Analyses
  - Areas for Potential Further Study

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The format of this report is similar to the phase 1 (LET) report. The main body of the report is 25 pages, with the details of the TLAT's work included in the referenced appendices. While the system descriptions of the candidate links have been reviewed by the TLAT and many TLAT comments have been incorporated, the development of the system descriptions has been the responsibility of the subject matter experts.

Section 1 of the TLAT's report addresses the objectives of the TLAT and scope of the report. Section 2 provides an overview of the three candidate ADS-B/situational awareness links. Section 3 discusses the Technical Link Assessment Criteria approved by the Safe Flight 21 Steering Committee and the Eurocontrol ADS Programme Steering Group. Section 4 discusses the technical assessment approach taken by the TLAT. Section 5 summarizes TLAT findings and areas for potential further study.

Appendices to the report provide detailed system descriptions of the candidate links and significant supporting information for the Technical Link Assessment Criteria, traffic scenarios, simulation tools, and TLAT simulations/analyses.

The report is available at the following websites:

•www.eurocontrol.be/projects/eatchip/ads

•www.faa.gov/safeflight21/

Application Performance Results - 1

Low Density Scenario

	1090 Extended Squitter	UAT	VDL Mode 4
SF21 Performance Criteria			
Aid to visual Acquisition (SV Update Rates to 10 nm)	Supported (by analysis)	Supported (by analysis)	Not supported (by analysis)
Conflict and Collision Avoidance (SV Update Rates to 20 nm)	Supported (by analysis)	Supported	Not supported (all a/c in scenario are en route and above 10000ft)
Separation Assurance and Sequencing (SV and 1 TCP Update Rates to 40 nm)	Likely to be supported (by analysis)	Supported	SV updates supported in 20 to 40 nm and TMAs; TCP change is likely to be met (by analysis); Acquisition was not evaluated;
Flight path de-confliction planning (SV and 2 TCP Update Rates to 90 nm)	Likely to be supported (by analysis)	Supported	SV updates supported TCP change is likely to be met (by analysis); Acquisition was not evaluated;
Airport Surface	Not applicable	Not applicable	Not applicable
Simultaneous approaches (SV Update Rates based upon physical runway separation)	Not applicable	Not applicable	Not applicable

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The TLAT developed findings based on the terms of reference and agreed link evaluation criteria. Section 5.1.1 of the report presents findings related to state vector and intent information update periods at specified ranges for applications selected by RTCA's Free Flight Select Committee and Eurocontrol's ADS Programme Steering Group. Section 5.1.2 of the report presents other findings.

All findings in this section have been unanimously agreed upon by the members of the TLAT.

Application Performance Results

The TLAT used both simulation results and analysis (presented in Appendices K and M) to determine the ability of the candidate links to meet the performance requirements associated with each application as specified in Section 3. The tables depict the results for each of the three traffic scenarios discussed in Section 4.

The results are presented using the following terms:

- Supported means that the performance requirements for the application were met.
- Inconclusive means that the uncertainties associated with the simulation results were too great to permit assessment.
- Not supported means that the candidate link does not meet one or more performance requirement for the application for the specified range.
- Not addressed means that the TLAT did not have time to address this issue. Not addressed does not infer that the requirement cannot be met.
- Not applicable means that the scenario does not include the application.

Results obtained exclusively through analysis are designated as such. The following acronyms are used in the tables:

SV: State Vector

TCP: Trajectory Change Point

RSC: Regional Signalling Channel

CAP: Controller Access Parameters

A-SMGCS: Advanced-Surface Movement Guidance and Control System

ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Application Performance Results - 2

Low Density Scenario - continued

	1090 Extended Squitter	UAT	VDL Mode 4
Additional Eurocontrol Criteria			
ATS Surveillance a/g			
TMA (SV and 4 TCP Update Rates to 60 nm)	Not applicable	Not applicable	Not applicable
En-Route (SV and 4 TCP Update Rates to 150 nm)	Not addressed	Not addressed	Not addressed
ATS Enhanced Surveillance a/g	Not applicable	Not applicable	Not applicable
TMA (SV and 4 TCP Update Rates to 60 nm)			
En-Route (SV and 4 TCP Update Rates to 150 nm)			
A-SMGCS	Not applicable	Not applicable	Not applicable
Taxi (0-5 nm)			
Approach (5-10 nm)			
Autonomous air to air operations – long range (SV and 4 TCP to 150 nm)	Unlikely to be met to 150 nm; may be possible to <120 (by analysis)	Supported	SV updates supported TCP change is likely to be met (by analysis); Acquisition was not addressed

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The results are presented using the following terms:

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ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Application Performance Results - 3

Core Europe 2015

	1090 Extended Squitter	UAT	VDL Mode 4
SF21 Performance Criteria			
Aid to Visual Acquisition (SV Update Rates to 10 nm)	Supported (by analysis)	Supported (by analysis)	Not supported except in Approach and Climb-out areas (by analysis)
Conflict and Collision Avoidance (SV Update Rates to 20 nm)	Supported	Supported	For ranges above 3nm, supported within RSC and supported outside RSC when below 10000ft
Separation Assurance and Sequencing (SV and 1 TCP Update Rates to 40 nm)	Inconclusive	Supported	SV Updates are supported; Proposed TCP scheme not evaluated
Flight path deconfliction planning (SV and 2 TCP Update Rates to 90 nm)	Not supported	Requirement is met only up to 70 nm	Inconclusive
Airport Surface	Not addressed	Not addressed	Not addressed
Simultaneous approaches (SV Update Rates based upon physical runway separation)	Supported (by analysis)	Supported (by analysis)	3sec SV update req. met (by analysis)

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The results are presented using the following terms:

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- Not supported means that the candidate link does not meet one or more performance requirement for the application for the specified range.
- Not addressed means that the TLAT did not have time to address this issue. Not addressed does not infer that the requirement cannot be met.
- Not applicable means that the scenario does not include the application.

Results obtained exclusively through analysis are designated as such. The following acronyms are used in the tables:

SV: State Vector

TCP: Trajectory Change Point

RSC: Regional Signalling Channel

CAP: Controller Access Parameters

A-SMGCS: Advanced-Surface Movement Guidance and Control System

ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Application Performance Results - 4

Core Europe 2015 - continued

	1090 Extended Squitter	UAT	VDL Mode 4
Additional Eurocontrol Criteria			
ATS Surveillance a/g			
TMA (SV and 4 TCP Update Rates to 60 nm)	Met with a 6-sector antenna	Likely to be met (by analysis)	Not supported with one Ground Station
En-Route (SV and 4 TCP Update Rates to 150 nm)	Met up to 100 nm with 6-sector antenna	Not addressed	SV Update Requirement met up to 70 nm with one omnidirectional antenna inside the RSC. TCP update method provided in Appendix E but not evaluated
ATS Enhanced Surveillance a/g	Not addressed for the transmission of CAP information	All parameters were addressed	Not addressed for the transmission of CAP and TCP information
TMA (SV and 4 TCP Update Rates to 60 nm)	Met with a 6-sector antenna	Likely to be met (by analysis)	Not supported with one Ground Station
En-Route (SV and 4 TCP Update Rates to 150 nm)	Met up to 100 nm	Not addressed	SV Update Requirement met up to 70 nm with one omnidirectional antenna inside the RSC
A-SMGCS			
Taxi (0-5 nm)	Not addressed	Not addressed	Not addressed
Approach (5-10 nm)	Not addressed	Not addressed	Not addressed
Autonomous air to air operations – long range (SV and 4 TCP to 150 nm)	Not supported	Not supported	Not supported

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The results are presented using the following terms:

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- Not supported means that the candidate link does not meet one or more performance requirement for the application for the specified range.
- Not addressed means that the TLAT did not have time to address this issue. Not addressed does not infer that the requirement cannot be met.
- Not applicable means that the scenario does not include the application.

Results obtained exclusively through analysis are designated as such. The following acronyms are used in the tables:

SV: State Vector

TCP: Trajectory Change Point

RSC: Regional Signalling Channel

CAP: Controller Access Parameters

A-SMGCS: Advanced-Surface Movement Guidance and Control System

ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Application Performance Results - 5

Los Angeles Basin 2020

	1090 Extended Squitter	UAT	VDL Mode 4
SF21 Performance Criteria			
Aid to visual Acquisition (SV Update Rates to 10 nm)	Supported (by analysis)	Supported (by analysis)	Not supported except in Approach and Climbout areas (by analysis)
Conflict and Collision Avoidance (SV Update Rates to 20 nm)	Supported	Supported	Supported beyond 3 nm
Separation Assurance and Sequencing (SV and 1 TCP Update Rates to 40 nm)	Unlikely to be met	Supported	SV Updates are supported; Proposed TCP scheme not evaluated
Flight path de-confliction planning (SV and two TCP Update Rates to 90 nm)	Not supported	Supported	Inconclusive
Airport Surface	Not addressed	Not addressed	Not addressed
Simultaneous approaches (SV Update Rates based upon physical runway separation)	Supported (by analysis)	Supported (by analysis)	3 sec SV update requirement met (by analysis)

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The results are presented using the following terms:

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- Inconclusive means that the uncertainties associated with the simulation results were too great to permit assessment.
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- Not addressed means that the TLAT did not have time to address this issue. Not addressed does not infer that the requirement cannot be met.
- Not applicable means that the scenario does not include the application.

Results obtained exclusively through analysis are designated as such. The following acronyms are used in the tables:

SV: State Vector

TCP: Trajectory Change Point

RSC: Regional Signalling Channel

CAP: Controller Access Parameters

A-SMGCS: Advanced-Surface Movement Guidance and Control System

ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Application Performance Results - 6

Los Angeles Basin 2020 - continued

	1090 Extended Squitter	UAT	VDL Mode 4
Additional Eurocontrol Criteria			
ATS Surveillance a/g			
TMA (SV and 4 TCP Update Rates to 60 nm)	Not addressed	Likely to be met (by analysis)	Not supported with one Ground Station (by analysis)
En-Route (SV and 4 TCP Update Rates to 150 nm)	Not addressed	Not addressed	At least as good as Core Europe 2015 because of the higher transmission rates used (by analysis)
ATS Enhanced Surveillance a/g			
TMA (SV and 4 TCP Update Rates to 60 nm)	Not addressed	Likely to be met (by analysis)	Not supported with one Ground Station (by analysis)
En-Route (SV and 4 TCP Update Rates to 150 nm)	Not addressed	Not addressed	At least as good as Core Europe 2015 because of the higher transmission rates used (by analysis)
A-SMGCS			
Taxi (0-5 nm)	Not Addressed	Not addressed	Not Addressed
Approach (5-10 nm)	Not Addressed	Not addressed	Not Addressed
Autonomous air to air operations – long range (SV and 4 TCP Update Rates to 150 nm)	Not supported	Not supported	Not supported

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The results are presented using the following terms:

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- Not addressed means that the TLAT did not have time to address this issue. Not addressed does not infer that the requirement cannot be met.
- Not applicable means that the scenario does not include the application.

Results obtained exclusively through analysis are designated as such. The following acronyms are used in the tables:

SV: State Vector

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A-SMGCS: Advanced-Surface Movement Guidance and Control System

ATS: Air Traffic Services

a/g: air-to-ground

TMA: Terminal Maneuvering Area

Further Findings - 1

- TIS-B
- FIS-B
- Time until Implementation
  - Standards
  - Availability of Spectrum
  - Risk and Complexity

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For **TIS-B**, the TLAT has considered the capability of the candidate links to support the service, but in terms of simulations it was not taken into account as the 100% ADS-B equipage scenario is considered more loaded than a mixed ADS-B TIS-B scenario. All link candidates have the capability to uplink TIS-B information.

FIS-B was evaluated by simulation using the future LA Basin scenario (2020). The following apply to FIS-B capacity for each link relative to the TLAT evaluation rate:

a) UAT was the only link shown to have FIS uplink capacity substantially greater than the TLAT evaluation rate. The total capacity of the protected uplink slots had over 80 times the TLAT evaluation rate.

b) VDL Mode 4 met the TLAT evaluation rate.

c) 1090 MHz Extended Squitter was shown to deliver about one third of the TLAT evaluation rate at the maximum range.

There are several items to consider when assessing the **time until implementation**—availability of standards, availability of spectrum, and complexity. Regarding standards:

a)**1090 MHz Extended Squitter**: The system described in Appendix F contains features not standardised in the current MOPS (RTCA DO-260/ED-102). RTCA DO-260A currently in progress is expected to include these features. SARPs for Extended Squitter are in place; SARPs harmonised to DO-260A await completion of DO-260A. Complementary AEEC characteristics are expected to be completed by the end of 2001. The TLAT is unaware of any standards activity for 1090 MHz ES ground stations.

b)**UAT**: RTCA MOPS activity has been initiated and is scheduled to be completed by February 2002. SARPs and AEEC characteristics have not been initiated. The FAA intends to request initiation of SARPs development. The TLAT is unaware of any standards activity for UAT ground stations.

c)**VDL Mode 4**: SARPs have been approved and will be published by November 2001. EUROCAE MOPS are scheduled to be approved and published by mid 2001. European Telecommunications Standardisation Institute (ETSI) standards for radio station approval for ground stations are expected mid 2001. Additional ETSI work is ongoing. AEEC activity has not been initiated as yet.

Further Findings - 2

- Time until Implementation - continued
  - Standards
  - Availability of Spectrum
  - Risk and Complexity

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Regarding availability of spectrum:

a)**1090 MHz Extended Squitter**: International spectrum allocation of the required 3 MHz channel exists. No further action is required.

b)**UAT**: Operating frequencies (supporting the required 3 MHz channel) must be identified. This will be done during the SARPs development process. International coordination of the UAT frequency is expected to take until 2006. After identification of a UAT frequency, DME channel(s) will need to be cleared.

c)Resolution of interference issues concerning **UAT** and **JTIDS/MIDS**, an important military tactical datalink, is critical to the deployment of UAT. The TLAT's evaluation of UAT has not taken into account the effects of JTIDS/MIDS systems. The UAT MOPS activity is considering this issue.

d)**VDL Mode 4**: VDL Mode 4 requires seven 25 KHz channels to operate in the high density scenarios evaluated by TLAT. The seven channels include: two Global Signalling Channels, two Regional Signalling Channels, two Local Signalling Channels, and one ground channel.

e)ICAO working groups are tasked to identify Global Signalling Channels. **VDL Mode** 4 operation in the VHF navigation band may require International Telecommunications Union coordination. The international co-ordination of the VDL Mode 4 Global Signalling Channels is expected to take until 2003.

The last aspect for time to implement relates to risk and complexity.

a)Implementation of ADS-B on any of the links—for performance consistent with the System Descriptions—will require new equipment installations.

b)A limited 1090 MHz Extended Squitter capability (supporting Aid to Visual Acquisition and Conflict Detection and Collision Avoidance applications) is available as an option now with new TCAS and transponder installations (installations since 1999), and could offer some near-term benefits.

c)Long-range, SARPs- and MOPS-compliant receivers are expected to be available within one year from the completion of DO-260A (receiver availability is estimated by 2003). These estimates apply to applications that require a maximum of 2 Trajectory Change Points (TCPs). The development and certification of avionics to support more than two TCPs applications may take longer.

d)Standards-compliant VDL Mode 4 avionics are expected to be available in the near future. The current standards address equipment of two receivers (while Appendix E proposes a four-receiver configuration).

e)UAT, as currently defined, has the simplest technical concept of the candidates. This simplicity suggests that the necessary validation testing and standards development may be accomplished relatively expeditiously. Presuming that JTIDS/MIDS interference issue is resolved, UAT avionics complying with Appendix D are expected to be available in 2003.

f)The TLAT is aware that Russia has published an order that determines October 1, 2005, as the date to start using ADS-B for air traffic monitoring in Russian airspace. Russia has indicated to ICAO that it plans to implement VDL Mode 4-based ADS-B.

Further Findings - 3

- Integration/Coexistence with Existing Systems
- Operational Safety Assessment
- Expandability
- Multi-link

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The TLAT agreed to the following additional observation concerning the ability of the candidate links to be integrated with and/or coexist with existing systems:

•Any operational frequency chosen for UAT will require coexistence with the JTIDS/MIDS military tactical data link. The TLAT's UAT results presume resolution of this important issue in a manner that does not add adverse interference to that used in the TLAT simulations.

The TLAT agreed to the following observation concerning the abilities of the candidate links to mitigate potentially catastrophic issues raised in the FAA's ADS-B Operational Safety Assessment:

•It is important for the ADS-B system to have a means for independent air-to-air range validation to reduce the risk of spoofing. Both UAT and VDL Mode 4 offer this capability by passive range monitoring. The 1090 MHz Extended Squitter ADS-B system as currently defined in DO-260 or Appendix F has no provision for air-to-air passive range monitoring (proposals to add this function to the system are under consideration for Draft DO-260A). Active air-to-air range monitoring can be employed by TCAS-equipped aircraft; however, the range of this active range monitoring is limited.

The TLAT agreed to the following observations concerning the expandability of the candidate links:

a)Future applications may require air-to-air two way data link. The combination of long range operation and the ability to provide two-way data link may make VDL Mode 4 attractive to support these future applications. UAT as currently defined does not support two way data link. TCAS-based installations could be modified to provide a two-way air-to-air data link capability for short- to medium-range applications.

b)All three links can be upgraded to support the broadcast of additional (to what is specified in RTCA DO-242) information, although VDL Mode 4 and UAT have more flexibility in this respect than does the 1090 MHz Extended Squitter.

c)In the high density scenarios considered, none of the three links appear to have excess air-to- air and air/ground capacity. The UAT System Description in Appendix D provides a uplink mechanism that is independent of the number of aircraft using the channel. In the case of VDL Mode 4, there is also a protected uplink mechanism; however, the capacity is less than that of UAT.

d)VDL Mode 4 has the capability to provide Global Navigation Satellite System (GNSS) augmentation services, and the channel loading from this application has been considered in the TLAT high density simulations. Although the ICAO GNSS panel is not currently considering VDL Mode 4 as a means to uplink GNSS augmentation, regional implementation of this capability is planned.

The TLAT considered general multi-link issues; this work is summarised in Appendix L. Multi-link discussions are ongoing within the FAA and Eurocontrol.

Areas for Potential Further Study

- Multipath
- Propagation in VDL Mode 4
- Range Limit of Core Europe Scenario
- Multi-link
- Co-site Interference
- Terrain Effects
- "Honeycomb" Channel Management Scheme for VDL Mode 4

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Multipath Appendix M.6 provides an analysis of multipath effects for air to air, air to ground, and airport surface operations using L-Band and VHF datalinks. This analysis shows that the potential of multipath for degrading L-Band long range air to air decoder performance. The TLAT simulations did not include multipath effects. Measurements are available from several sources, see Appendix N.1. The complexity of the RF environment particularly for airport surface operations suggests that further investigations are necessary.

Propagation in VDL Mode 4 The modelling of overlapping interfering signals (due to propagation delays) used in the TLAT VDL Mode 4 simulations was based on theoretical analysis. This model should be further refined and validated. Appendix N.2 indicates that the effect of overlaps due to propagation delay in the TLAT VDL Mode 4 simulation results was far smaller than other uncertainties.

Range Limit of Core Europe Scenario The Core Europe 2015 scenario used by the TLAT was specifically designed to measure performance in the scenario center (Brussels) and had a range of 300 nm. Appendix N.3 indicates that this scenario would have to be extended in order to measure performance in areas lying in the periphery and/or adjacent areas.

Multi-link The TLAT considered general multi-link issues, this work is summarized in Appendix L. Multi-link discussions are ongoing within the FAA and Eurocontrol.

Co-site interference Co-site interference is highly implementation dependent and will vary with each aircraft depending on its type, antenna location, and installation quality. The TLAT has not been able to assess the potential co-site issues relating to VDL Mode 4. Appendix N.5 indicates that VDL Mode 4 frequency planning criteria are being considered by the ICAO AMCP Working B. Co-site interference should therefore be further investigated when these criteria are in place.

Terrain Effects The TLAT 1090 simulations of the Los Angeles Basin 2020 scenario considered terrain effects. The results suggest that inclusion of the terrain had a significant effect on ADS-B performance depending on the aircraft altitude distribution. Appendix N.6 indicates that terrain effects need to be considered also for VDL Mode 4 evaluations.

"Honeycomb" Channel Management Scheme for VDL Mode 4 Appendix E, Attachment 3 describes an alternative scheme for VDL Mode 4 channel management based on centralised ground control of channel access. Appendix N.7 provides an initial analysis of this scheme, suggesting that further investigations will be needed to establish its feasibility and benefits.

What's Next for EUROCONTROL?

- Ongoing assessments
  - Elaboration of ADS-B/TIS-B technical requirements for ECAC
  - Operational and Implementation Case Studies
  - Safety and CBA Studies
- Complementary technical assessments
  - Exploration of Multi-Link
  - Link performance sensitivity to traffic load
  - TIS-B
- Continuing support and coordination with European ADS-B projects
- Agreement on ADS-B/TIS-B Implementation Strategy within Europe

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The Eurocontrol ADS Programme considers that the link decision process needs to take into account technical, operational, safety, and CBA assessments. With the TLAT report, the technical assessment reaches maturity but there are still ongoing studies on operational, safety and CBA issues which will be completed later this year.

The technical assessment suggests that each of the three links considered would meet some but not all of the currently defined potential requirements. Consequently and depending on the range of applications required the use of more than one link would have to be considered.

It should be noted that further evolution of ADS-B and TIS-B applications and requirements is possible. The ADS-B/TIS-B requirements for the European airspace are still under development, and the TLAT report points out a number of technical requirements requiring further evaluation.

Consequently the Eurocontrol ADS Programme will continue its assessment activities over the next year. Complementary technical assessment will be needed on

- The technical feasibility, costs,and also benefits of multi-link, especially as a long term measure to counteract the impact of increasing traffic density on the European surveillance system.
- Exploration of the sensitivity of ADS-B performance to the traffic load and system parameters to help define a transition plan to full ADS-B equipage with increasing traffic density
- TIS-B issues (ground infrastructure, performance requirements)

In parallel with the above activities, the Eurocontrol ADS programme will continue collaborating with the various ADS-B and TIS-B projects that are being funded by member states and the European Commission, promoting inter-project coordination, work sharing, and harmonisation of objectives.

Finally, a key objective for this year will be to arrive at an agreement with the Eurocontrol stakeholders on the ADS-B/TIS-B implementation strategy that should be applied in Europe in line with the overall Eurocontrol surveillance strategy for ECAC.

What's Next for the FAA?

- Safe Flight 21 Cost Benefit Assessment results due this month
- Multi-link avionics study still in process
- Comparative Safety Assessment due in September
- Safe Flight 21 operational evaluations being extended - Memphis in 2002
- Capstone - considering broader scope
- Other user initiatives with ADS-B applications
  - Operational Evolution Plan
  - AIR-21 cost sharing arrangements/demonstrations

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The TLAT has completed its Phase II work. There is tremendous value in the results, even though there is not a compelling "favorite." Each of the candidates has its advantages and disadvantages. The key to actual implementation lies in which applications of the technology are most desired.

Various studies will be completed over the next year. The Safe Flight 21 Cost Benefits Assessment will be available later this month. As a collateral activity, FAA has initiated a survey of avionics vendors to determine their views (and presumably those of their customers) regarding the various multi-link options and configurations. Particular emphasis will be placed on the cost vs. flexibility tradeoff. If the aviation community wishes to proceed with a multi-link solution, the community must determine the requirements for a multi-link solution. The FAA plans to complete a Comparative Safety Assessment of ADS-B to TCAS in September.

As mentioned before, Safe Flight 21 has also both shown the potential as well as documented the challenge in implementation of specific ADS-B enabled operations in the National Airspace System (NAS). The recent decision to defer Operational Evaluation-3 until next year underscores the challenges in certification and operational implementation. Initial successes with Capstone have led to discussions to expand the ADS-B coverage in Alaska. Capstone continues to gather data to validate the benefits of the ADS-B applications.

The NAS Operational Evolution Plan has proposed some specific ADS-B applications for focus and to characterize operations. Industry Day is planned for April 23. Additionally, the FAA received several proposals, stemming from the AIR-21 cost sharing demonstration program, that included ADS-B applications.

The factors discussed are not FAA unique. Each potential user of ADS-B has to make the business case to determine the "goodness" and timing of equipping with ADS-B. Real data is acquired only when a specific benefit is anticipated, driving specific users to equip. The FAA will continue to work with the user community through the Safe Flight 21 Steering Committee and other fora to achieve a link decision at the right time with an agreed upon implementation plan for both service providers and airspace users.