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THE APPROACH AND BASIS FOR THE FAA ADS-B LINK DECISION

Summary

This paper summarizes the approach taken by the FAA to assess alternative ADS-B link architectures and describes the basis used by the FAA for making a decision of the ADS-B link architecture to be used throughout the National Airspace System. The ADS-B link decision itself is described in a separate paper titled "Overview of the FAA ADS-B Link Decision" available from the FAA web site at: www.faa.gov/asd

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1. INTRODUCTION

The Federal Aviation Administration has been engaged in research and development of Automatic Dependent Surveillance – Broadcast (ADS-B) technologies and ADS-B enabled applications for the past 10 years. The development of technical standards for ADS-B link technologies began in the mid-1990s. More recent cooperative activities between the FAA and user organizations, including the Safe Flight 21 and Capstone initiatives, have demonstrated a user demand for ADS-B enabled services.

The maturity of the nearest-term ADS-B applications and the maturity of the ADS-B link technologies have now progressed to the point where avionics and airframe manufactures require direction from the FAA on which ADS-B link technology(ies) will be approved for operational use in the U.S. This need is being driven by both a perceived user demand for ADS-B and a need on the part of the manufacturers to make decisions on where to invest their resources. The choice of ADS-B link technology cannot be left to the marketplace to decide as this could be expected to lead to solutions that are not interoperable and would prevent the realization of the full benefits of ADS-B.

Over the past few years the FAA has been actively engaged in both technical and economic assessments of the alternative ADS-B link technologies, as further summarized in this paper. These assessments have been conducted in cooperation with the U.S. aviation industry and with international organizations, such as EUROCONTROL.

Sufficient results have been gathered from a combination of flight tests, technical simulations, cost-benefit analysis, and other studies to allow for a decision on the most appropriate ADS-B link architecture to satisfy the U.S. aviation needs, for least the near and mid-term (i.e., for the next decade) and to provide a flexible ADS-B architecture that will readily accommodate long-term needs. The ADS-B link decision for the U.S. must also account to the extent possible for the need for interoperability with the international aviation community. To this end the FAA has been actively engaged in coordination activities with EUROCONTROL on interoperability of our international fleets.

The FAA has received inputs indicating an ADS link decision is needed as a matter of urgency from both the user community, via the RTCA Free Flight Steering Committee, and from the manufacturing community, via the June and October 2001 ADS-B Link Decision Public Meetings sponsored by the FAA's office of System Architecture and Investment Analysis

2. BACKGROUND

The basic concept of ADS-B traces its origins back to at least the early 1970s. The earliest of the three candidate ADS-B link technologies currently being considered has its origins in the late 1980s.

- The candidate link technology with the longest history is Very High Frequency Digital Link (VDL) Mode 4 (VDL-M4) which traces is origins back to the very late 1980's with developments in Sweden. This VDL-M4 has substantially evolved from the original system demonstrated in the early 1990s, but retains support for a self-organizing channel access scheme. The initial version of VDL-M4 standards has been developed both within Europe (i.e., EUROCAE) and within the International Civil Aviation Organization (ICAO) [Reference: 1]. However, ICAO has assigned no global frequencies for use of VDL-M4 and currently any frequency assignments would need to be on local basis.

- The second candidate ADS-B link technology was developed in the early 1990s and builds upon Mode Select (Mode S) radar standards and technology. This system for 1090 MHz. Extended Squitter (1090ES) employs transmission characteristics and message formats that are already accepted for Mode S and TCAS II. The initial version of the 1090ES standards has been published within the U.S. by RTCA [Reference: 2], in Europe by EUROCAE and internationally by ICAO [Reference: 3]. 1090ES would operate on spectrum already authorized internationally for secondary surveillance radars.

- The third candidate ADS-B link technology is the Universal Access Transceiver (UAT), which was developed starting in the mid-1990s. UAT would operate at 978 MHz. within the U.S. Standards development is underway in the U.S. (RTCA) and the initial UAT standards are expected to be published in the second half of 2002. ICAO is considering whether to develop standards for UAT and a decision is expected during 2002. If ICAO decides to develop UAT standards, 3 to 5 years may be required before they are approved and published. The need for a global frequency assignment for UAT could be a significant factor in delaying approval of ICAO standards for UAT.

The FAA began sponsorship of the development and evaluation of the 1090ES link technology a decade ago. In the early 1990's significant technical tests were successfully conducted for surface and terminal use at Boston Logan International Airport and for low altitude helicopter operations and high altitude over-flights of the Gulf of Mexico [Reference: 5]. These initial test locations were selected as operations on the airport surface and over water were viewed to be two of the most difficult environments to achieve acceptable technical performance due to line-of-sight limitations and radio frequency multipath concerns. The focus of these early FAA sponsored tests was on air-to-ground surveillance. Also during the mid-1990s RTCA convened Task Force 3 from which the "Free Flight" concepts were developed [Reference: 6] that included ADS-B as an enabling technology.

During the early through mid-1990s the European focus was on tests with a VHF system that was the predecessor of the current VDL-M4. The European tests included air-to-air applications as well as air-to-ground applications.

RTCA in 1994 established Special Committee 186 (SC-186) to develop Minimum Aviation System Performance Standards (MASPS) for ADS-B and related applications. Subsequently SC-186 was tasked to develop Minimum Operational Performance Standards (MOPS) for the 1090ES ADS-B link and more recently for the development of MOPS for the UAT link. The ADS-B MASPS [Reference: 7] were published in 1998 [Reference: 7] and the 1090 MHz ADS-B MOPS [Reference: 2] were published in 2000.

3. ADS-B LINK ASSESSMENTS

The number and diversity of tests of the candidate ADS-B link technologies have increased over time and during the past three years both the U.S. and the Europeans have conducted evaluations, that to a varying extent involved each of the three candidate links. The FAA has worked closely with EUROCONTROL, under a memorandum of cooperation, to share information and to the coordinate the ADS-B evaluation activities being sponsored by the two organizations. The FAA has also worked with the German Deutsche Flugsicherung (DFS) for the evaluation of the 1090ES link technology.

The basis for the FAA link decision includes the results from the assessments of technical, economic and instructional factors. The following paragraphs provide a summary of the activities and results that were factors in the development of the recommended ADS-B link architecture.

3.1 TECHNICAL ASSESSMENT

As noted in section 2 above, a number of studies were conducted by the FAA and various European organizations prior to 1998. However, lacking a definitive set of technical or operational requirements these studies were not able to assess the acceptability of the services provided. With the publication of the ADS-B MASPS in 1998 there were at least an U.S. agreed to set of requirements against which candidate ADS-B links could be assessed. There is still no formal set of European requirements for ADS-B. However for purposes of conducting assessments, which EUROCONTROL either sponsored or co-sponsored along with the FAA, the RTCA ADS-B MASPS supplemented with a few additional potential European requirements were considered.

The FAA working with RTCA formed the ADS-B Link Evaluation Team (LET) in December 1998 (under the RTCA Free Flight Select Committee/ Safe Flight 21 Steering Committee). The report of this group was released in November 1999 [Reference: 15]. The link assessments that had begun under the LET were then advanced by the FAA/EUROCONTROL co-chaired Technical Link Assessment Team (TLAT). The focus of the TLAT was on assessing the technical performance of the three individual candidate ADS-B links. The TLAT issued their final report [Reference: 10] in March 2001. An overview of the methodology used by the TLAT for the link assessments is provided in Reference 11. Additional testing and modeling has been conducted both by the FAA and by EUROCONTROL since the TLAT produced their final report. The status of the FAA sponsored post-TLAT link assessment activities were reported at an ADS-B Link Decision public meeting held on October 19, 2001 [References: 12 and 13].

The FAA followed up the briefing materials presented at the October 19, 2001 public meeting with the release of "Summary of the Function and Technical Assessment of the ADS-B Link Architectures – Interim Report" [Reference 14].

The FAA in cooperation with the Cargo Airline Association conducted an initial ADS-B operational evaluation in 1999. The report of Phase I of this evaluation [Reference: 22] is focused primarily on the operational aspects of the ADS-B enabled applications there were being evaluated, but this report includes information of the configuration and characteristics of the 1090ES and UAT ADS-B links that were being used. Section 3.1 of the report provides a reference, in the form of an FTP web address, where the raw performance data collected during the evaluation is available for download.

The FAA has also sponsored the evaluation of ADS-B enabled services in Alaska under the Capstone program. This activity uses the UAT ADS-B link technology. The interim report [Reference: 24] provides details of the evaluation and initial results.

An overview of the ADS-B flight test activities in which the FAA has been involved was presented [Reference: 23] at the June 6, 2001 Link Decision Public Meeting.

EUROCONTROL has also continued to sponsor additional ADS-B link assessment activities. Their Post-TLAT focus has been on further VDL Mode 4 simulations, the development of new 1090ES and VDL Mode 4 simulation modeling tools, and a limited number of additional tests.

The additional Post-TLAT link-specific activities, which have been reviewed by the FAA during the course of the developing the recommended ADS-B link architecture, are summarized in the following paragraphs.

3.1.1 VDL MODE 4 ADDITIONAL ASSESSMENTS

EUROCONTROL has released a report [Reference: 16] on the VDL Mode 4 Trials conducted in 2000 showing relatively long reception ranges for one of the two VDL Mode 4 systems tested under a non-interference environment. EUROCONTROL has also enhanced their VDL-Mode 4 simulator (SPS) in the following areas:

- Protect the first four slots in each UTC second (these slots are used for uplink of differential GPS corrections, Directory of Service messages, and possibly TIS-B) from mobile station transmissions.
- Include the avionics antenna gain model developed by the TLAT
- Implement alternate top/bottom antenna transmissions.

The results reported by EUROCONTROL [References: 17 and 12] were a general decrease in the estimated VDL Mode 4 performance in terms of the effective range of the systems when used in a high traffic density environment as compared to the results previously reported to the TLAT. These updated results are now in close agreement with those previously reported by the FAA sponsored activity of John Hopkins University/Applied Physics Laboratory.

Subsequent to the TLAT, John Hopkins University/Applied Physics Laboratory (JHU/APL), under FAA sponsorship, has incorporated a small number of changes/enhancements to their VDL Mode 4 model to address specific issues raised by one vendor. These changes included a change to the receiver diversity model and additional assessment of an alternative 'honeycomb' channel management scheme. The first change had a minor effect of link performance while the alternative channel management scheme resulted in a decrease in performance. The overall impact on their performance of the VDL Mode 4 link with the changes incorporated was relatively minor and would not result in a change on the conclusions previously reported by JHU/APL to the TLAT on the VDL Mode 4 performance.

The effect of the changes made to the VDL Mode 4 simulations, especially for the EUROCONTROL case, is to indicate somewhat poorer performance than those directly indicated by the TLAT findings.

3.1.2 1090ES ADDITONAL ASSESSMENTS

Subsequently to the October 19, 2001 public meeting and the associated assessment report [Reference 15], the FAA in cooperation with EUROCONTROL, has sponsored additional simulations that focused on the performance of 1090ES in a high density core Europe scenario. The results of these additional FAA sponsored simulations, as well as the results of simulations conducted by EUROCONTROL, indicate that 1090ES will support the near and mid-term candidate applications of ADS-B at air-to-air ranges of at least 40 nautical miles [Reference 25] in high density airspace.

Some additional modeling activities are underway to increase the fidelity of the 1090ES simulations for the Los Angles 2020 scenario. Preliminary/partial results, not yet published, have been reviewed by the FAA, which would indicate the potential for improved performance, as compared to the TLAT findings, for the Los Angles 2020 scenario.

This additional work to date has focused on two general areas.

Improved reception techniques – The simulations performed and reported to the TLAT included a model for the 1090ES receiver that was developed based on JHU/APL bench testing of an UPSAT receiver. This was the same receiver used for the 1090ES evaluations in Los Angles in 1999 and Frankfurt in 2000. At the time of those evaluations and of the JHU/APL bench testing it was believed that this receiver had incorporated the enhanced reception techniques that had been developed by MIT Lincoln Laboratory [Reference: 4] and described in the 1090 MHz ADS-B RTCA MOPS [Reference: 2]. However, it was subsequently determined through additional bench testing at the FAA William J. Hughes Technical Center that this receiver had not fully implemented the enhanced decoding techniques. The performance of this receiver has now been compared against the two alternative multi-sample enhanced decoding techniques that are being described in the revision to the 1090 MHz ADS-B MOPS (i.e., DO-260A). The results from this post-TLAT work indicate that substantially better reception performance can be expected in high interference (i.e., high Mode A/C fruit) environments when the enhanced decoding techniques are fully implemented. The results of this work have been reported to RTCA SC-186 Working Group 3 in Reference 18. There has also been some additional work to optimize the performance of the two multi-sample enhanced decoding techniques and these changes are being incorporated in the revisions to the 1090 MHz ADS-B MOPS (draft DO-260A). Simulations of the enhanced multi-sample reception technique performance conducted by MIT Lincoln Laboratory also indicates a substantial improvement in performance as compared to the UPSAT receiver when used in a very high interference environment including both Mode A/C and Mode S related interference. The results from these bench tests and simulations have now been used by JHU/APL to update their 1090ES receiver model and this updated model has been used for the simulations of a core Europe 2010 scenario [Reference 25]. It is planned to also apply the updated 1090ES receiver model to the simulations for an updated LA2020 scenario.

A second area of investigations has been carried out by the John A. Volpe Transportation System Center under FAA sponsorship. Volpe had developed the basic 1090 MHz link modeling tools that were employed by JHU/APL to support the TLAT efforts. The initial results from the JHU/APL simulations were available only at the very end of the TLAT work program and subsequent work, especially by Volpe, has indicated several areas in which the models and scenarios needed improvement. Specifically the post-TLAT work performed by Volpe includes:

- Updating the ground SSR interrogators to reflect the types and locations that include the next generation radars (i.e., ASR-11 and ATCBI-6) now being procured by the FAA and expected to be fully deployed over the next several years.
- Relocating the aircraft that is receiving 1090ES to the ‘worst case’ geographic area (i.e., closer to LAX) and adjusting this aircraft’s altitude to 39,000 ft. as per the baseline TLAT scenario
- Using the local terrain model for the simulations (already a feature of the Volpe model that was not included in the results used by the TLAT).
- Adding the receiving aircraft antenna gain characteristics (JHU/APL previously had added this enhancement to the Volpe model that was used to support the TLAT).
- Run the simulations to determine the expected 1090 MHz fruit rates when using the TLAT LA2020 traffic scenario.

Results recently reported by Volpe to the FAA (not yet published) for the LA2020 scenario indicate substantially lower Mode A/C fruit rates (i.e., approximately one half) than predicted by the lower fidelity model/scenarios used by the TLAT as a basis for their findings for the future LA2020 environment. Since Mode A/C fruit is a significant factor in influencing the effective air-to-air range that can be provided by 1090ES, these preliminary results are encouraging as to the ability of the 1090ES to support air-to-air range requirements for all but the possible long-term requirements for a long-range (i.e., >40 nmi.) applications (e.g., flight path deconfliction) while over-flying a very high density terminal such as Los Angles or within core Europe. Further investigations are planned to have JHU/APL use the updated Volpe model and LA2020 scenario along with the enhanced 1090ES receiver model (as per DO-260A). Also the benefits on 1090 MHz interference levels that could be achieved through the introduction of TCAS hybrid surveillance may be explored in the future JHU/APL efforts.

Some analysis has been performed by MIT Lincoln Laboratory, with inputs from the FAA and Mitre/CAASD on the impact TIS-B, including a multi-link gateway service, will have on 1090ES performance. This analysis indicates there is not a significant capacity issue with providing TIS-B via the 1090ES link as long as the TIS-B service volume is properly defined. Both the 1090ES and the UAT simulation models will need to be updated to further validate the effects/performance of providing TIS-B via both ADS-B links.

3.1.3 UAT ADDITONAL ASSESSMENTS

JHU/APL developed the UAT simulation model that was used by the TLAT as the basis for their findings. Subsequent to the TLAT completing its work JHU/APL discovered an error in the UAT model, which has now been corrected. The results from the updated model indicate that the UAT link is expected to satisfy all of the requirements for ADS-B as defined by the TLAT for both the future U.S. and Core Europe high-density scenarios with the possible exception of the very longest range reception (i.e., > 120 nmi.) in Core Europe when subjected to worst case interference from a nearby DME.

Both the UAT and the 1090ES simulation models will need to be updated to further validate the effects/performance of providing TIS-B via both ADS-B links.

4. ECONOMIC ASSESSMENT

The economic factors associated with the introduction of ADS-B were a major focus of the FAA efforts during 2001. The FAA organized a series of three public meetings, announced in the Federal Register, to collect the ADS-B related costing data which could be used by the FAA for a Cost-Benefit Analysis (CBA). An earlier preliminary CBA had been performed for the Safe Flight 21 program and the additional efforts undertaken during the summer and fall of 2001 was to update this earlier work to substantially increase the fidelity of the estimates for ADS-B related costs and benefits. Through these public meetings the FAA, DoD, avionics manufacturers, and the airspace users reached consensus on a set of baseline avionics configurations and a baseline set of generic airframe types that were to be used for the costing exercises. The FAA used vendor surveys as well as one-on-one meetings to collect the detailed costing data. Many of the major U.S. avionics manufacturers participated in this effort. The costing analysis considered not just avionics costs, but other factors such as the installation and certification costs. Also the costs for other associated aircraft systems, such as cockpit displays and GPS avionics, were considered. The results form these efforts were briefed

[Reference: 19] at the third and final public meeting held on October 19, 2001. Subsequent to the October 19th public meeting there were issues raised by one the VDL Mode 4 vendors and the FAA had an exchange with that vendor. Incorporation of the additional costing information provided by that vendor did not significantly change the results of the CBA as reported at the October 19th public meeting.

The U.S. Department of Defense has also conducted a study of ADS-B equipage costs for the DoD aircraft fleet. Their result as reported in at the Oct. 19th public meeting [Reference: 20] indicate the option for 1090ES transmit only capability is far less expensive that the other alternatives based in part on their architectural assumptions, which differed from those used by the FAA. Subsequent to the October 19th Public Meeting the FAA received a report of the DoD cost analysis [Reference: 21] and held additional discussions with representatives from DoD where additional information was provided by DoD. The additional information provided by DoD continues to indicate a significant cost advantage for a 1090ES transmit-only configuration for their aircraft fleet based on their architectural assumptions.

5. FACTORS BEHIND THE RECOMMENDED ADS-B LINK ARCHITECTURE

The recommended ADS-B link architecture includes a combination of 1090ES and UAT equipage across the U.S. aircraft fleet. There were a number of factors considered by the FAA's offices of System Architecture and System Analysis in recommending this architecture for the ADS-B links. The following paragraphs provide background on additional factors that were considered and for which the community should be aware of when reviewing the specifics of the ADS-B link decision. This information is intended to serve as a supplement to the information provided in the ADS-B link decision paper itself and it not intended to be a comprehensive discussion all of the details related to the link decision.

5.1 POTENTIAL AIRSPACE RULES

The FAA's use of the term "Airspace Rules" or statements implying ADS-B equipage requirements within the link decision documentation does not imply an intent on the part of the FAA to initiate any specific rulemaking that would require users to equip with ADS-B. Rather, for long-term planning purposes it could be envisioned that a point in time may be reached when the majority of airspace users, both in the high altitude airspace and in the high-density terminal airspace, have already voluntarily equipped with ADS-B. In this case where partial fleet equipage has already been achieved certain benefits will be possible from pair-wise operations and from situational awareness enabled by ADS-B supplemented by traffic information broadcasts from the ground. However, other potential benefits may not be possible unless full equipage by the airspace users is achieved. Airspace rulemaking would be considered only when these additional potential benefits are perceived by the user community to be significant enough to warrant airspace rules requiring ADS-B equipage. Thus, any future ADS-B related rulemaking is viewed as being user driven. Any such future airspace rules are assumed to be focused on a baseline requirement for an ADS-B transmission capability in order to operate in the airspace that is the subject to the rulemaking. Any requirements for ADS-B reception, application processing and cockpit display capabilities would only be linked to participating in specific types of operations where such ADS-B enabled applications would be considered as a necessary onboard capability.

5.2 AIRCRAFT ADS-B EQUIPAGE

5.2.1 LOW/MID GENERAL AVIATION EQUIPAGE

The FAA in reviewing the ADS-B applications of most interest to the various segments of the U.S. aviation user community noted the low and mid-level General Aviation users tend to be most interested in obtaining Flight Information Services (FIS including graphical weather) and Traffic Information Services. The FAA technical analysis, summarized in Reference 13, indicates that UAT is the most capable link for providing the FIS services and UAT is also expected to the least expensive solution [Reference: 19] for this category of user. Also this user category does not generally operate internationally, therefore the lack of international approval for UAT would not be a significant negative factor. Further, the majority of operations for this category of user/aircraft are expected to not include routine operations along side the air carrier class of users (i.e., not frequently flying into or out of major terminals on approaches or departures used by the air carriers). Since the vast majority of operations by this user/aircraft category involve close proximity with predominately other general aviation users the UAT link will offer the opportunity for direct air-to-air interoperability among the members of this user category. Anticipate airspace rules that would require ADS-B transmit equipage would not be applicable to the majority of airspace where this user category operates. Only a 40% to 70% equipage level is envisioned in the long-term for this category of user [Reference: 19]. Given incomplete ADS-B equipage for this user category is expected, a ground infrastructure providing an uplink TIS-Broadcast service will be needed for the pilot to have a complete situational awareness. Thus, even if all ADS-B equipped aircraft operating in such airspace were to be equipped with the same type of ADS link, a complete situational awareness would only be possible when within coverage of an ADS-B ground infrastructure that is providing a TIS-B service.

5.2.2 HIGH GA/CORPORATE/AIR TAXI EQUIPAGE

The high-end GA/Corporate/Air Taxi users frequently operate in high altitude enroute airspace where other airspace users may include domestic and international air carriers and military. This user category also frequently operates in major terminal areas and on approach and departure patterns where air carriers also operate. In these respects this user category resembles the air carriers in terms of the applicable role for ADS-B. This user category may also operate outside of U.S. airspace. For aircraft capable of operating in the high altitude enroute airspace where future ADS-B rulemaking may apply, the 1090ES ADS-B link provides the greatest opportunity to achieve interoperability among the domestic, international and military airspace users. 1090ES would be at a modest cost disadvantage [Reference: 19] for the high-end GA/Corporate/Air Taxi category of users as compared to UAT equipage. 1090ES was selected as the baseline ADS-B link for this user category mainly as a result of the desire to achieve direct interoperability in the high altitude airspace and to allow for access to airspace outside of the U.S. This user category is expected to include some, perhaps many, users that also operate in airspace where the predominate traffic is general aviation (i.e., UAT equipped if ADS-B equipped at all) and in which the ground infrastructure does not support the ADS-B multilink gateway capability as a means of providing interoperability between 1090ES and UAT. Such users are encouraged to equip with a dual link (i.e., 1090ES and UAT) capability. However, no rulemaking is anticipated that would require such an equipage configuration.

5.2.3 AIR TRANSPORT EQUIPAGE

The air transport category of users/aircraft routinely operates in high altitude enroute airspace where other airspace users may include domestic and international air carriers, high-end GA/corporate/air taxi, and military. This user category also routinely operates in major terminal areas and on approach and departure patterns where predominately air carriers operate. Also a significant portion of the air transport fleet is used for international operations. 1090ES was selected as the baseline ADS-B link for this user category as it is the only alternative that offers the opportunity for achieving near-term interoperability among the airspace users. Specifically, the lack of international spectrum authorization for both UAT and VDL Mode 4 and the lack of ICAO standards for UAT effectively preclude these alternative links from being viable near-term global ADS-B solutions for this category of users. However, in the longer-term if the international standards and spectrum issues are overcome, these links could play a role in a global ADS-B solution. Cost estimates [Reference: 19] indicate that 1090ES would not be at a cost disadvantage to the alternative link technologies (i.e., similar in cost to UAT and less expensive than VDL Mode 4). While UAT would be allowed as a second ADS-B link within the U.S. for the air transport category, the provision of 1090ES as an internationally approved common link provides the means to provide direct aircraft-to-aircraft interoperability without the necessity of a ground infrastructure in the high altitude U.S. enroute airspace. In the high-density terminal airspace where mixed 1090ES and UAT equipage is anticipated, the predominate traffic on the approach and departure patterns used the air transport category will also be capable of high altitude operations and are expected to be equipped with 1090ES. For those aircraft equipped with UAT and operating in the high-density terminal airspace, the ground multilink gateway services is expected to provide the interoperability between the 1090ES and UAT equipped users. It is recognized that 1090ES has certain air-to-air range limitations when operating in a high interference environment. As reported in Section 3.1.2 above, certain pervious technical assessments have raised concerns over the ability to 1090ES to support the potential requirements for longer-range (>40 nmi.) air-to-air applications in the high density U.S. airspace (i.e., Los Angles and potentially the U.S. Northeast corridor). Unlike the other ADS-B link alternatives 1090ES must share the same radio frequency channel with TCAS and with secondary surveillance radar systems. Therefore, as noted above, additional modeling efforts are underway to increase the fidelity of the simulations to more accurately reflect the radio frequency environment. The current engineering judgment of the FAA office of System Architecture and Investment Analysis is that 1090ES will likely support, at least through the mid-term, ADS-B applications that do not require air-to-air ranges exceeding 40 nmi. when used in the highest density U.S. airspace and will provide longer ranges out to 90 nmi. in lower traffic density airspace.

There are long-term questions both about the need for longer-range applications in high traffic density airspace as well as the ability of 1090ES to support such applications. Given these questions remaining about the needed long-term ADS-B capabilities, the avionics and airframe manufactures are encouraged to implement an airborne ADS-B architecture that will readily accommodate a second ADS-B link in addition to 1090ES.

Also certain air carriers may elect to equip with a dual 1090ES and UAT capability in the near-term (i.e., before a national ground ADS-B infrastructure is implemented) as a means of achieving interoperability with general aviation users equipped with only UAT.

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