Overview of Assessment Results

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Overview

- Description of the baseline ADS-B link architecture requirements
- Summary of the results from the assessment of alternative airborne ADS-B equipage scenarios to support the baseline requirements
  - same 3 single link and 4 multi-link fleet-wide equipage scenarios as used for the Cost-Benefit Analysis
  - when used within the context of an overall ADS-B system architecture (i.e. with complementary airborne and ground equipage)
- More details will be provided in a soon-to-be-released report providing a summary of the functional and technical assessments of the ADS-B link architecture alternatives

Assumptions

- While the forthcoming summary report will also address the 13 individual aircraft equipage configurations from the June 25-26 Workshop, the results briefed today are for the 7 fleet equipage scenarios
- ADS-B ground stations will be capable of receiving and transmitting on all ADS-B links associated with that scenario
- In the long-term it will be necessary for at least some classes of users to be able to achieve interoperability for air-to-air ADS-B applications independent of the ground infrastructure
- The ADS-B MASPS requirements for such factors as range, message content, and update rates are used as the criteria to judge the ability of a given link configuration to satisfy the application/operational requirements

Assumptions

- Single link avionics configurations assumed were generally consistent with the TLAT configurations. Link characteristics were based on the MOPS/SARPs (current drafts where applicable)
- The TLAT results, plus results from subsequent technical evaluations, were considered in determining the likelihood of a given avionics configuration to satisfy the requirements

ADS-B Link Assessment Overview

- RTCA ADS-B MASPS (DO-242) generally served as the requirements basis for assessing the capability of any candidate ADS-B link architecture to satisfy the long-term needs for ADS-B enabled services
- 13 broad requirements were used as:
  - a means of assessing the alternative ADS-B link configurations against specific known operational, technical, and transition requirements
  - a means of identifying discriminators between the candidate ADS-B link configurations
- Each alternative equipage scenario was assessed against each requirement

Assessment Results

- Assessment results are indicated on the following slides as:
  - Ö Configuration satisfies requirements
  - **X** Configuration does not satisfy requirements
  - **C** Configuration satisfies requirements only under certain conditions
  - **?** Unknown if configuration satisfies requirements
- Notes provided for explanation of assessment for cases other than Ö

REQUIREMENT 1

- The ADS-B architecture must be able to support a baseline set of applications that include:
  - short range situational awareness and see-and-avoid (near-term through long-term)
  - the ADS-B enabled applications as defined in the FAA's Operational Evolution Plan (OEP) (mid-term through long-term)
  - applications identified by the Safe Flight 21 program (selected pockets in the near-term and national in the long-term)

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT	UAT
Low GA				UAT	1090	1090ES Tx	1090ES Rx
	√	√	C	√	√	√	√

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Notes for Scenario C

VDL Mode 4 MOPS/SARPs does not provide a state vector update rate high enough to support the tactical applications of terminal approach and departure spacing in low visibility, defined by SF21 when used at air-to-air ranges of less then 3 nmi. Thus VDL-M4 could partially support such baseline application requirements. This configuration would only be acceptable on the condition these limitations can be accommodated.

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REQUIREMENT 2

- The ADS-B architecture must support the near and mid-term ADS-B MASPS applications with reliable air-to-air reception for ranges within 20 nmi., and other long-term applications for reception ranges within 40 nmi.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	C	√	C	√	C	C	C

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Notes for Scenario A

The 20 nmi. air-to-air reception requirement for near and mid-term applications are expected to be satisfied with the 1090ES system. In the longer term the 40 nmi. air-to-air reception requirement is expected to be satisfied in all but potentially the highest traffic density environments (e.g., LA or NE corridor). Enhancements to the first generation simulation model (the results of which were reviewed by the TLAT) are needed to better estimate the performance of 1090 MHz ES in the highest traffic density future U.S. environments.

Notes for Scenario C

The VDL-M4 system could generally support the 20 nmi. air-to-air range requirement for the near/mid-term application and 40 nmi. for long-term applications. With the TLAT configuration the rate at which certain information (e.g., intent) is transmitted is not consistent with the ADS-B MASPS requirements.

Notes for Scenario E

The concerns for Scenarios A and C also apply to this case.

Notes for Scenarios F and G

The concerns express for Scenario A apply for this scenario for the case of the 1090ES path

REQUIREMENT 3

- The ADS-B architecture must support the ADS-B MASPS long-term flight path de-confliction application and possibly other strategic applications with reliable ADS-B reception at air-to-air ranges of at least 90 nmi. (in the forward direction) in oceanic and en-route airspace where “free flight” operations are authorized.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA				UAT	1090	UAT 1090ES Tx	UAT 1090ES Rx
Low GA							
	C	√	C	√	C	C	C

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Notes for Scenario A

The flight path de-confliction application, as defined by the ADS-B MASPS (DO-242) applies in low density en route and oceanic airspace. The findings of the TLAT also considered this application in the context of a LA2020 high density environment. Both limited flight measurements and analysis for a low traffic density environment indicate that 1090 MHz ES may be able to satisfy the 90 mile range ADS-B MASPs requirement. The current simulations indicate that it is unlikely that 1090 MHz ES would be able to support this application in the highest interference environments, such as LA, at the full 90 nmi. range.

Notes for Scenario C

Limiting consideration to just the use in low density airspace, the nominal characteristics/performance for the VDL-M4 system as defined in the MOPS/SARPs (and the TLAT configuration) would support the 90 nmi. air-to-air range requirement, but the TLAT configuration would not support the update rate requirements. This is a result of the defined transmission rate of the intent information not being sufficient to satisfy the ADS-B MASPS requirements for the de-confliction application.

Notes for Scenario E

The concerns for Scenarios A and C also apply to this case.

Notes for Scenarios F and G

The concerns express for Scenario A apply for this scenario for the case of the 1090ES path

REQUIREMENT 4

- The ADS-B architecture must support near-term and mid-term single link equipage supporting early operational use with associated benefits
  - air-to-ground in local pockets for terminal and/or surface applications where ADS-B ground stations and ATC ground automation upgrades have been implemented
  - pair-wise air-to-air applications for high altitude en route/offshore airspace and terminal applications in the local pockets where the ADS-B enabled procedures are authorized.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	X	√	√	√	√

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Notes for Scenario C

Near-term, and perhaps mid-term, use of VDL-M4 in the U.S. appears unlikely due to the lack of available VHF channels that could be assigned for exclusive use by VDL-M4.

REQUIREMENT 5

- The ADS-B architecture must support TIS-B delivered over the ADS-B ground-to-air link(s) in order to accommodate a mixed equipage environment of ADS-B and non-ADS-B equipped aircraft

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	√	√	√	√	√

REQUIREMENT 6

- The overall ADS-B requirements, especially in the long-term, may be satisfied by either a single ADS-B link or by the combined capabilities of multiple ADS-B links as long as such a multi-link solution is integral to the ADS-B architecture.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	C	√	X	√	C	C	C

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Notes for Scenario A

Same concerns as previously described above for requirements 2 & 3 apply. These relate to the ability of 1090ES to satisfy the long term requirements for ADS-B at the maximum required air-to-air ranges especially if a applied in high density airspace (beyond that required by the current ADS-B MASPS).

Notes for Scenario C

As configured by the VDL M4 TLAT Subject Matter Experts, the system does not fully support the requirements for long-term ADS-B applications requiring intent information, particularly in terms of the required update rates.

Notes for Scenario E

In general the same issues as for Requirements 1 and 2, scenarios A and C apply. Note there is a potential that an optimally configured 1090ES plus VDL-M4 combination (not constrained by the TLAT configurations) could perhaps satisfy the long-term requirements for those users so equipped. However, defining and assessing such a configuration was beyond the scope of the efforts to date.

Notes for Scenarios F and G

In general the same issues as for Scenario A above. These relate to configurations where only a 1090ES air-to-air path is provided. In this case the ability of 1090ES to satisfy the long term requirements for ADS-B at the maximum required air-to-air ranges especially if applied in high density airspace (beyond that required by the current ADS-B MASPS).

REQUIREMENT 7

- The long-term ADS-B ground infrastructure and associated system architecture must, to the maximum extent practical, accommodate foreign aircraft equipped with one or multiple ICAO specified ADS-B link(s) operating on ICAO authorized frequencies.
  - support the operational benefits to the extent they can be enabled by the specific ADS-B link(s) and U.S. compatible applications for which the aircraft is equipped.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	C	?	C	C	C	C	C

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Notes for Scenario A

Since 1090 MHz ES is one of the two ICAO approved ADS-B links, any NAS ground infrastructure supporting 1090 MHz ES would accommodate foreign aircraft equipped for this ADS-B link. Accommodation of aircraft equipped with VDL-M4 only, the other ICAO ADS-B link, would not be provided.

Notes for Scenario B

RTCA MOPS for UAT will be completed in 2002. However, the role of UAT is currently under review within ICAO, and a decision on the international role of UAT is expected during 2002 at the earliest. Lacking an ICAO decision to develop standards for UAT, a UAT single link decision in the U.S. would not directly support foreign aircraft equipped with either of the ICAO already approved ADS-B solutions. Thus for the moment this requirement is not satisfied, but this could change if ICAO ultimately decides to move forward with SARPs for UAT and approves an operating frequency.

Notes for Scenario C

Since VDL-M4 is one of the two ICAO approved ADS-B links, any NAS ground infrastructure supporting VDL-M4 would accommodate foreign aircraft equipped for this ADS-B link. Accommodation of aircraft equipped with 1090ES only, the other ICAO ADS-B link, would not be provided.

Notes for Scenarios D

Although foreign aircraft equipped with the ICAO approved 1090ES would be accommodated, aircraft equipped with VDL-M4 only, the other ICAO ADS-B link, would not be provided.

Notes for Scenario E

Although both of the currently approved ICAO ADS-B link are accommodated, since ICAO is currently considering UAT and if UAT ICAO standards are forthcoming then this scenario would not accommodate aircraft equipped with only UAT.

Notes for Scenarios F and G

Neither of these scenarios would accommodate foreign aircraft equipped with only VDL-M4. Also Low/Mid GA equipage would not support fully 2-way 1090ES capability.

REQUIREMENT 8

- The ADS-B architecture must require all ADS-B equipped aircraft to provide:
  - ADS-B transmissions of sufficient power level to support the reception range requirements for air-to-air, air-to-ground and airport surface applications as defined by the ADS-B MASPS (DO-242)
  - ADS-B transmissions at update rates sufficient to support the reception at the rates and probabilities required by the ADS-B MASPS (DO-242)
  - ADS-B transmissions containing at least the minimum information set required by the ADS-B MASPS (DO-242) for that aircraft equipage category

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	X	√	√	√	√

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Notes for Scenario C

VDL-M4 configuration defined by the TLAT, does not provide sufficient rates of transmission to satisfy the requirements of the ADS-B MASPS for the applications currently under consideration. Specifically, certain of the short-range tactical applications are not supported due to insufficient state vector update rates. Also certain of the longer-range applications require intent information that is not provided with a sufficient update rate.

REQUIREMENT 9

- The ADS-B architecture must include airborne reception capabilities consistent with the requirements associated with ADS-B enabled applications applicable to that aircraft equipage category.
  - supporting the requirements (range, update rate, content) as specified for all supported applications as per the applicable RTCA MASPS and/or MOPS

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	C	√	√	√	√

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Notes for Scenario C

The VDL-M4 could satisfy the reception requirements on the condition that the VHF channel loading be kept to a moderate level and the airborne installation includes the capability to simultaneously receive on all channels serving the airspace. However, the concerns noted for requirement 8, scenario C would prevent the reception at an adequate update rate to satisfy the ADS-B MASPS requirements for certain applications (i.e., using the TLAT configuration).

REQUIREMENT 10

- The ADS-B architecture must provide the capacity to support FIS-B services over the ADS-B ground-to-air link. Due to current FIS-B policy and existing contracts it is unlikely that FIS-B services could be offered via the ADS-B link in the near-term except in the context of limited trials.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	C	√	√	√	√	C	√

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Notes for Scenario A

1090 MHz ES will have a limited capacity to support FIS-B services. It may be able to support a basic set of FIS-B services but probably not the more real-time or high update rate services. In the highest interference environments (e.g. LA) and in the long-term, the capacity limitations may result in a reduced service volume or reduced update rates for the FIS-B services. Also the Class A0 and A1 1090ES receivers as defined by the DO-260 may not have sufficient sensitivity to provide adequate reception range to permit continuos FIS-B coverage.

Notes for Scenario F

Same issues as described above for scenario A for those aircraft equipped with only 1090ES reception capability (High GA and Air Carrier).

REQUIREMENT 11

- The ADS-B link(s) must be functionally consistent with the near thru long term evolution of the NAS architecture.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	?	√	?	√	√

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Notes for Scenarios C and E

It is currently unclear if VDL-M4 would fit into the evolution of the NAS surveillance architecture. The requirements for the VDL-M4 systems management including the associated ground network and management requirements are not clear.

REQUIREMENT 12

- Viable aircraft ADS-B configurations must be consistent with an ADS-B architecture that supports a cost effective means for the introduction of ADS-B capability into all user classes. The following criteria is used to assess each alternative against this requirement.
  - An alternative is considered viable if the installed system costs do not exceed +30% of the cost of the least expensive alternative for each aircraft category.
  - An alternative is considered as not being viable (from a cost effective standpoint) only if the estimated installed system costs exceeded +60% of the estimated costs for the least expensive alternative for 2 or more civil aircraft categories.
  - Otherwise the alternative is considered to be conditionally viable (i.e., might be viable for only certain aircraft categories).

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See details of cost deltas (on the next slide) vs. the above assessment criteria defined for this requirement

REQUIREMENT 12 - continued

		ADS-R Airborne Link Equipage Scenarios (Change from Lowest Cost Configuration)						
		A	B	C	D	E	F	G
Equipage	Air Carrier	1090 ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
	High GA						UAT 1090ES Tx	UAT 1090ES Rx
	Low GA				UAT	1090ES		
User	Group	A	B	C	D	E	F	G
Air Carrier	Forward Fit	LC	+1 %	+22 %	+8 %	+41 %	+5 %	+5 %
	Modern/ Integ	+1 %	LC	+25 %	+7 %	+60 %	+5 %	+5 %
	Non-Classic	+1 %	LC	+11 %	+4 %	+33 %	+3 %	+3 %
	Classic	+2 %	LC	+62 %	+12 %	+138 %	+9 %	+9 %
General Aviation	High/ Advanced Avionics	+6 %	LC	+25 %	+31 %	+82 %	+24 %	+22 %
	Low-Mid/ Basic Avionics	+21 %	LC	+59 %	LC	+21 %	+46 %	+42 %
Overall Scenario Cost Rating		√	√	C	C	X	C	C

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Overall assessment results for requirement 12 shown on the bottom of the above table.

REQUIREMENT 13

- There must be industry inputs indicating that the ADS-B link technology(ies)/configuration is technically practical with no greater than moderate technical risk.

User	ADS-B Airborne Link Equipage Scenarios						
	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT 1090ES Tx	UAT 1090ES Rx
Low GA				UAT	1090		
	√	√	C	√	C	√	√

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Notes for Scenarios C and E

The technical risks associated with a fully MOPS/SARPs compliant and certifiable VDL-M4 airborne installation are considered moderate (as compared to low for the other ADS-B link alternatives). This could be considered acceptable. However, when considered in the context of the overall system, the VDL-M4 can be considered to have acceptable technical risk on the condition that an acceptable system management scheme, involving both the aircraft and the VDL-M4 ground infrastructure, could be fully defined and validated via modeling.

Summary of the Assessment Results

ADS-B Airborne Link Equipage Scenarios

User	A	B	C	D	E	F	G
Air Carrier	1090ES	UAT	VDL4	1090ES UAT	1090ES VDL4	1090ES UAT Tx	1090ES UAT Rx
High GA						UAT	UAT
Low GA				UAT	1090	1090ES Tx	1090ES Rx
Link Regts							
1. Support for Baseline Applications...	√	√	C	√	√	√	√
2. Support Air-to-Air Reception...	C	√	C	√	C	C	C
3. Support Flight Path Deconfliction...	C	√	C	√	C	C	C
4. Support Near/Mid-Term Single-Link Equip...	√	√	X	√	√	√	√
5. Support TIS-B...	√	√	√	√	√	√	√
6. Support NAS-wide Multi-Link...	C	√	X	√	C	C	C
7. Accommodate Foreign Aircraft...	C	?	C	C	C	C	C
8. Support ADS-B Transmissions...	√	√	X	√	√	√	√
9. Support Airborne Reception...	√	√	C	√	√	√	√
10. Support FIS-B...	C	√	√	√	√	C	√
11. Consistent with NAS Architecture...	√	√	?	√	?	√	√
12. Supports Cost-Effective Implement...	√	√	C	C	X	C	C
13. Configuration is Technically Practical...	√	√	C	√	C	√	√

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Above a summary of the results reported on the previous slides.

SUMMARY

- **Sufficient data exists to allow for a realistic assessment of the ADS-B link alternatives**
- **The forthcoming report will provide additional details, including assessment results on the individual ADS-B link configurations**
- **The report on the assessment results will be available shortly for download from the FAA William J. Hughes Technical Center's web site under the FAA-Industry ADS-B Forum page:**

http://adsb.tc.faa.gov/ADS-B/186-subf.htm