Automatic Dependent Surveillance Broadcast

OPERATIONAL SAFETY ASSESSMENT REPORT

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Prepared by ADS-B OSA Team
Report Coordinator – Steve Paasch,
Certification Services, Inc.

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Reviewed by Scott VanBuren
FAA, Chief System Safety Engineer
Co-chair, System Safety Working Group (SSWG)

___SOF IN ASD-100_____________________

Approved by
Mike Harrison
FAA, Director, NAS Architecture & System Engineering
Chair, System Engineering Council (SEC)

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1. INTRODUCTION AND PURPOSE

This report documents the operational safety assessment (OSA) results from the Automatic Dependent Surveillance Broadcast (ADS-B) Safety Team. The results of the team efforts are candidate operational safety requirements for both the ADS-B ground and vehicle systems as well as candidate operational safety requirements for operational procedures using ADS-B. It should be noted by the reader that this is NOT a risk assessment of the ADS-B system. The OSA is a method of developing safety requirements for a system using safety engineering techniques. Since risk is not evaluated in this process, neither the authors nor the readers can make conclusions, one way or another, regarding the safety of ADS-B. The reader can conclude that hazards associated with ADS-B have been identified, and that the requirements, if implemented, can mitigate those hazards. Further risk assessments should be performed to verify that the requirements in this report mitigate the risk from the hazards identified in this report.

NOTE: The analysis was done on the surveillance functional level across a range of operational contexts and applications to identify, classify, and provide mitigating requirements for the hazards associated with failures [loss or malfunction] of surveillance supported by ADS-B. This means that worst case scenarios were utilized to account for the range of operational contexts. It should be noted that this may tend to overstate the requirements for discrete changes to operations that are in less safety critical services (e.g., operator facility tracking of operator's aircraft for business purposes and not ATM, or enhanced visual acquisition only in VMC). However, until these discrete changes are explicitly identified and defined, and appropriately segregated from the general operational environment, a worst case approach was deemed most appropriate at this stage in ADS-B operational usage development.

In conjunction with ADS-B, the team also surveyed Traffic Information System Broadcast (TIS-B) usage per a request by the FAA's Aircraft Certification Service (AIR). This report also documents candidate operational safety requirements for TIS-B ground and vehicle systems as well as candidate operational safety requirements for operational procedures using TIS-B. The survey of potential ADS-B usage included the possibility that airport facility surface vehicles as well as aircraft might be equipped with ADS-B for air traffic control (ATC) tracking of all ground traffic in ramp, taxiway, and runway areas. The term "vehicle" is therefore used in this report to mean aircraft as well as airport surface vehicles.

A synopsis of potential ADS-B usage includes the provision of surveillance data to airborne and surface-maneuvering aircraft, and to surface vehicle operators, controllers and aviation operations facilities on the ground. This information is expected to be used to provide surveillance services for a wide range of airborne and surface maneuvering, flight following and control requirements across all operating contexts. It could greatly extend and perhaps replace current radar surveillance in some airspaces. ADS-B alone, or used in combination with TIS-B and cockpit display of traffic information (CDTI), may be used to provide improved terminal operations in low visibility, including low visibility approach operations so that the flight crew will be better able to identify the aircraft to follow and accomplish visual flight rule (VFR) approaches at lower minima, thus maintaining VFR throughput levels over a wider range of conditions. The crew will also be able to maintain better spacing during VFR and instrument flight rule (IFR) approaches. ADS-B will be used to enhance surface surveillance at ASDE equipped airports or provide surface surveillance at airports not equipped with ASDE, and provide for cooperative separation, and enhanced traffic situational awareness for maneuvering and station keeping. **Appendices A** and **B** provide detailed reports on potential ADS-B and TIS-B usage.

The purpose of this report is to convey candidate operational safety requirements for consideration by the FAA and public committees working in conjunction with the FAA to develop detailed specifications and requirements for the design, development, procurement, and operational use of vehicle and ATC surveillance systems using ADS-B and TIS-B, as well as serve as input for the considerations of definition of Required Surveillance Characteristics. (Requirements are not provided for aircraft operator facilities, as such requirements would be either subordinate to ATC requirements, or related to business performance considerations which are out of the scope of this report.) The report is structured as follows:

Section 1 provides an introduction, as well as the report's purpose and structure.

Section 2 provides a list of references used in the report.

Section 3 provides definitions of acronyms and less commonly used terms.

Section 4 describes the methodology by which the candidate operational safety requirements were derived.

Section 5 sets forth the allocated candidate operational safety requirements for vehicles (air and ground), ground systems, and operational procedures. This section provides a condensed summary of key requirement assumptions and conditions, as well as the details of each specific candidate requirement.

Section 6 is a listing of unallocated initial candidate requirements related to lower severity hazards, such as minor hazards, from the hazard tracking database. This section is simply an archive of unconsolidated, non-finalized, initial requirements candidates. The purpose of listing these in this section is to document them for future reference as risk assessments are made, or if information captured in the OSED is modified such that higher severity levels are identified for these hazards.

A set of appendices is provided to document the in-progress materials developed during the team's efforts and used to eventually derive the candidate operational safety requirements.

2. BIBLIOGRAPHY AND REFERENCES

a. RTCA/EUROCAE Special Committee (SC) 189/Working Group (WG) 53 position paper P-PUB-22, Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by Data Communications, Revisions G through M.

b. AC 23.1309-1C, Equipment, Systems, and Installations in Part 23 Airplanes.

c. AC 25.1309-1B, System Design and Analysis, ARAC draft.

d. MIL-STD-882D, Department of Defense, Standard Practice for System Safety.

e. RTCA document DO-242, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B).

f. RTCA Joint Government/Industry Roadmap for Free Flight Enhancements.

g. FAA NAS CONOPS 2005, NAS Architecture, Version 4.

h. FAA ADS-B Mission Need Statement #326.

i. FAA ADS-B Plan.

j. FAA Safe Flight 21 Functional Specification, and Surveillance Vision Plan.

k. ICAO Manual of ATS Data Link Applications.

l. RTCA document DO-178B, "Software Considerations in Airborne Systems and Equipment Certification", December 1, 1992.

m. Society of Automotive Engineers (SAE), Aerospace Recommended Practice (ARP) 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment", December 1996.

n. SAE ARP 4754, "Certification Considerations for Highly-Integrated or Complex Aircraft Systems", November 1996.

o. FAA, System Safety Handbook: Practices and Guidelines for Conducting System Safety Engineering and Management.

p. ICAO Doc 4444, Annex 11, Appendix 5, Aeronautical Data Quality Requirements.

3. DEFINITIONS AND ACRONYMS

Acronyms used in this document are defined in section 3.1. Definitions of several terms used in this document are provided in section 3.2.

3.1 ACRONYMS

ADS-B	Automatic Dependent Surveillance Broadcast
ASOR	Allocation of Safety Objectives and Requirements
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CDTI	Cockpit Display of Traffic Information
CNS	Communication, Navigation, and Surveillance
CNS/ATM	Communication, Navigation, and Surveillance/Air Traffic Management
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LVC	Low Visual Cue
NAS	National Airspace System
OHA	Operational Hazard Assessment
OSA	Operational Safety Assessment
OSED	Operational Services and Environment Description
TIS-B	Traffic Information System Broadcast
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

3.2 DEFINITIONS

Allocation of Safety Objectives and Requirements (ASOR): that portion of an operational safety assessment (OSA) in which safety objectives and requirements resulting from an operational hazard assessment (OHA) are allocated to components of the communication, navigation, surveillance/air traffic management (CNS/ATM) system and to the organizations developing the components.

Operational Hazard Assessment (OHA): an assessment of air traffic services (ATS) provided in a specific operational environment, in order to identify the hazards associated with the ATS, determine hazard effects, and determine the severity of the effects.

Operational Safety Assessment OSA): an assessment of ATS provided in a specific operational environment, the identification of safety objectives and requirements for the systems and procedures supporting the ATS, and an allocation of those safety objectives and requirements to components of the CNS/ATM system and to the organizations developing the components. A complete OSA is made up of an OHA and an ASOR.

Operational Services and Environment Description (OSED): a description of the ATS supported by communications, navigation, or surveillance and their intended operational environments, and including the operational performance expectations, functions, and selected technologies of the related CNS/ATM system.

4. METHODOLOGY

RTCA SC-189, working in joint committee with EUROCAE WG-53, are in the process of developing guidance material for conducting operational safety assessments, as well as performance and interoperability assessments, for elements of the CNS/ATM system. Although the committee work was still in progress at the time the ADS-B Safety Team was conducting its work, the general process concepts for conducting an operational safety assessment were captured in the joint committee's position paper, **Reference a**. The ADS-B Safety Team utilized the **Reference a** process concepts as general guidelines, while supplementing the process with guidance from **References b**, **c**, and **d**. From the references, the Safety Team first developed OSEDs. Using the OSEDs as input, the Safety Team then developed an OSA in two parts: first, an OHA, and second, using the OHA and OSEDs, ASORs for more severe hazards. The requirements determined from the ASORs were then consolidated and captured in this report. The details of the processes are provided below.

This material extends the scope of the RTCA/SC-189 method to Required Surveillance Characteristics, where characteristics may be taken to mean capabilities or performance parameters. We assert that the RTCA/SC-189 method is equally appropriate to derive safety requirements for any component of the required total system characteristics, including communication, navigation, surveillance, and vehicle traffic control. In deriving the surveillance characteristics for a particular service or set of services, we compiled the related set of environment characteristics that include communication, navigation, and vehicle traffic control functional characteristics. These characteristics as well as related procedures for use may require changes or assurance in the operational approval activities for an ADS-B supported service.

The ADS-B Safety Team began their effort with a survey of potential ADS-B and TIS-B operational uses and environments, as well as with information from the Ohio Valley Project and the Capstone effort in Alaska. The first task in performing the OSA was to develop an OSED depicting the services to be provided or supplemented by ADS-B and TIS-B, and the operational environments in which those services were to be provided. The OSED provides the input into the OSA process from which an OHA can be developed. Two OSEDs were developed utilizing **References e** through **k**. The first OSED captured general usage information, and the second OSED concentrated on Safe Flight 21 usage information. The two OSEDs are complimentary to each other. The OHA was developed from a synthesis of the information in both, but with emphasis on Safe Flight 21 concepts, as these appeared to be more immediate and capture much of the general usage information from other sources. The general OSED is provided in **Appendix A**, and the OSED focusing on Safe Flight 21 is provided in **Appendix B**.

An OSA consists of two processes, an OHA and an ASOR. An OHA is an identification of hazards associated with the loss or malfunction of, procedural errors in the use of, or external events relating to the system undergoing analysis, in the context of the service being provided and the characteristics of the environment in which the system is used. In addition, the OHA is an analysis of the effects of the identified hazards, an identification of the severity of each hazard based on the hazard's effects, an identification of a safety objective or objectives for the hazard commensurate with its severity, and identification of initial candidate operational safety requirements for meeting the safety objectives. The ASOR results in the agreed allocation of safety objectives and requirements to components of the CNS/ATM system (including procedures), such as ATC ground components and aircraft components, to be utilized as requirements by the respective organizations providing or developing those components or procedures. The ASOR may also allocate procedural requirements for use by the operators, including controllers and flight crew.

Using information from the OSED as input, an OHA was developed. Hazards related to ADS-B and TIS-B operational usage were identified and analyzed for their effects. From their effects, the hazards were classified as to their severity in accordance with **Table 4-1**. Current procedural practices were noted as well. From all of the above information, safety objectives in the form of candidate hazard probability requirements were identified in accordance with **Table 4-2**, where risk levels are defined in **Table 4-3** and probability terms are defined in **Table 4-4**, and initial candidate operational safety requirements were determined. The source for these tables is 14 CFR 25.1309. The OHA was performed on two levels: at the combined air-ground system level, and at lower system or component levels. The OHA information was captured in a hazard tracking database utilizing the Access database program. Reports from the OHA database are provided in **Appendix C**. (In general, the OSA leads to an update to the baseline OSED that provides for the supporting airspace, operations descriptive, and functional characteristics update required to support the ADS-B supported service. However, the OSEDs, as coming from information from other programs, were not iterated to add material derived in the OSA. It is hoped that consideration of the candidate requirements in this report will result in a review to see if changes to this information are required.)

Hazard Severity:	**Hazard effects:**
Catastrophic	Result in multiple fatalities usually with loss of the vehicle.
Hazardous	Reduce the capability of the system or the operator ability to cope with adverse conditions to the extent that there would be – (1) Large reduction in safety margin or functional capability. (2) Crew physical distress or excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely. (3) Serious or fatal injury to small number of occupants of aircraft (except operators).
Major	Reduce the capability of the system or the operators to cope with adverse operating conditions to the extent that there would be – (1) Significant reduction in safety margin or functional capability. (2) Significant increase in operator workload. (3) Conditions impairing operator efficiency or creating significant discomfort. (4) Physical distress to occupants of aircraft (except operators) including injuries.
Minor	Do not significantly reduce system safety. Actions required by operators are well within their capabilities. Effects include – (1) Slight reduction in safety margin or functional capabilities. (2) Slight increase in workload such as routine flight plan changes. (3) Some physical discomfort to occupants of aircraft (except operators).
No Safety Effect	Have no effect on safety.

Table 4-1: Hazard Severity Classifications

Severity / Likelihood	No Safety Effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Probable A					
Remote B					
Extremely Remote C					
Extremely Improbable D					

- High Risk
- Medium Risk
- Low Risk

Table 4-2: Safety Objective Assessment Matrix

High	High risk - Unacceptable level of risk. Tracking in Hazard Tracking System is required until the risk accepted at the appropriate level of management.
Med	Medium risk - Acceptable with management review. Tracking in Hazard Tracking System is required until further controls are added and the risk accepted.
Low	Low risk - Acceptable without review. No further tracking of the hazard is required.

Table 4-3: Risk Level Definitions

Probable		**Qualitative**: Anticipated to occur one or more times during the entire system/operational life of an item. **Quantitative**: Probability of occurrence per operational hour is greater than or equal to 1×10^{-5}
Remote		**Qualitative**: Unlikely to occur to each item during its total life. May occur several time in the life of an entire system or fleet. **Quantitative**: Probability of occurrence per operational hour is less than or equal to 1×10^{-5} , but greater than 1×10^{-7}
Extremely Remote		**Qualitative**: Not anticipated to occur to each item during its total life. May occur a few times in the life of an entire system or fleet. **Quantitative**: Probability of occurrence per operational hour is less than or equal to 1×10^{-7} but greater than 1×10^{-9}
Extremely Improbable		**Qualitative**: So unlikely that it is not anticipated to occur during the entire operational life of an entire system or fleet. **Quantitative**: Probability of occurrence per operational hour is less than or equal to 1×10^{-9}

Table 4-4: Probability Terms Definitions

Next, using information from the OHA as input, several ASORs were developed, focusing on the more severe hazards. In the ASOR effort, the initial candidate operational safety requirements identified by the OHA are formalized. Other requirements were also determined during the ASOR effort. For the ASORs, fault tree analyses were performed for some of the more severe hazards identified in the OHA. The fault tree information and the information from the OHA and OSEDs were used to develop requirements and safety objectives. In the OHA, hazard severity was classified without full account of procedural mitigation. However, potential procedural mitigation was identified in the OHA. The fault trees and resulting allocations took into account the potential procedural mitigation, which was then captured in candidate procedural requirements. In some cases, the addition of procedural requirements allowed for a less conservative requirement for physical system failures than would be acceptable without the procedural requirement. In other words, hazard management strategy could be "budgeted" between the procedures and the physical system. Fault trees for the more severe hazards are provided in **Appendix D**.

Lastly, the candidate operational safety requirements from the ASORs were consolidated to eliminate duplications or incompatibilities, and captured in this report.

5. CANDIDATE OPERATIONAL SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ADS-B, TIS-B, and procedures utilizing these systems. Sections 5.1 through 5.9, respectively, capture candidate requirements for:

- vehicle ADS-B systems;
- vehicle ADS-B operator procedures;
- ATC ADS-B systems;
- ATC ADS-B operator procedures;
- vehicle TIS-B systems;
- vehicle TIS-B operator procedures;
- ATC TIS-B systems;
- ATC TIS-B operator procedures; and
- General ADS-B and TIS-B requirements.

Some of the candidate operational safety requirements are dependent on others. After the statement of the candidate operational safety requirement, those requirements upon which it is dependent are shown in square brackets as follows: "[**Dependent on:**]." In this case, the identified candidate requirement should not be considered valid unless the requirements identified in the brackets are also implemented.

Due to consolidating requirements from the ASORs, the requirement numbering in this report body may not match the requirement numbering in the ASORs. Therefore, each requirement in sections 5.1 through 5.8 are cross-referenced to the ASOR reports in **Appendix D.** (Requirements in section 5.9, as general, are not cross-referenced). The cross referencing is indicated inside curly braces as follows: "{*ASOR cross ref:* }." Also, as the process of developing this report included reviews and refinements of the ASOR requirements, the requirements wording in section 5.1 through 5.9 may not exactly match the requirements wording in the ASORs.

In the candidate operational safety requirements provided in sections 5.1 through 5.9 the word "shall" is used. It should be noted that although "shall" is used, these are candidate requirements, and the program managing authority is responsible for deciding whether to use these requirements or not. The use of "shall" in this context, is not intended to indicate a mandatory requirement. The use of "shall" is only used to remain consistent with best system engineering practice.

5.1 ADS-B CANDIDATE VEHICLE SYSTEM SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for airborne and surface-maneuvering aircraft ADS-B systems, and surface vehicle ADS-B systems:

a. Transmittal of inaccurate or false ADS-B information from a vehicle, without annunciation of failure, shall be remote (as defined in table 4-4). [**Dependent on: 5.1.b, 5.1.m-u, 5.2.a, 5.4.a, 5.4.b**] {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-1*}

b. (This requirement is applicable only if ADS-B is used for surface surveillance). The ADS-B system accuracy shall be within the requirements for runway and taxi areas widths in AC 150/5300-13. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-3*}(Note: This may mean that aircraft taking advantage of surface movement in LVC environments may require augmentation equipage to gain the required accuracy.)

c. Vehicle navigation data integrity shall be checked of prior to ADS-B system initiation. System initiation is defined as the startup sequence for any individual ADS-B unit. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-4*}

d. A velocity vector data integrity comparison function in the vehicle shall be based on independent sources. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-5*}

e. The ADS-B system shall include a limiting function , to limit position "jumping" to at most 4.5 seconds (based upon current radar update rate). This function should be based on an independent speed check or independent navigation source in the vehicle. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-6*}

f. On system initiation, the ADS-B system shall require the vehicle crew to confirm or enter a new call sign before it will operate. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-8*}

g. Altitude data integrity shall be a checked, using independent sources. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-9*} (Note: redundant pressure altitude sources with a checking function, or a checking function between AGL altitude from GPS and one pressure altitude source.)

h. For aircraft, an assessment shall be performed in accordance with regulation and guidance material applicable to the aircraft type, and considering the other requirements of this section, to identify required development assurance levels for the aircraft ADS-B systems. For surface vehicles, a risk assessment shall be performed in accordance with **Reference o**, with consideration of the other requirements in this section, to identify required development assurance levels for ATC systems and surface vehicle ADS-B systems. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-10*}

i. Display of inaccurate or false ADS-B data on a single pilot's (or surface vehicle operator's) display equipment, shall be remote. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-12*}

j. For use in indicating the position of fixed objects or obstructions in the NAS, the ADS-B display shall indicate the nature, location (relative position and actual lat/long), name, MSL (Mean Sea Level) and AGL (Above Ground Level) altitude of the object. {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-V-2*}

k. For use of ADS-B in indicating the position of fixed objects or obstructions in the NAS, the aircraft displays shall include the ability to overlay the ADS-B information on a moving map display consistent with aeronautical chart requirements. {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-V-3*}

l. For use of ADS-B in indicating the position of fixed objects or obstructions in the NAS, the system data containing the “known object" information shall comply with existing requirements in the 14 CFR as they apply to aeronautical charts (see **Reference p**). {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-V-4*}

m. The ADS-B system shall cross check position data with vehicle velocity data and if the comparison indicates an error with the position data, the system shall indicate an error to all the operators. {*ASOR cross ref: ADS-B ASOR Hazard 104, req. 104-V-6*}

n. The ADS-B avionics shall , cross check independent navigation sources. {*ASOR cross ref: ADS-B ASOR Hazard 104, req. 104-V-7*}

o. The ADS-B system shall incorporate ADS-B targets and the local ADS-B information on, and be referenced to a moving map system.i {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-9*}

p. The ADS-B display shall be located within the vehicle or facility to optimize visibility and interpretation and to prevent spatial disorientation during critical maneuvers. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-10*}

q. The ADS-B system shall employ FAA display symbology standards when defining target symbology. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-11*}

r. The ADS-B altitude shall use both pressure altitude (MSL) and ground (AGL) referenced altitude. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-12*}

s. Both altitude types (MSL and AGL) shall be displayed, however the AGL altitude may be selectable for de-cluttering. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-13*}

t. Both altitude types (MSL and AGL) shall be clearly distinguishable from each other. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-14*}

u. The ADS-B system shall not adversely increase the flight crew or ATC workload levels in comparison to existing systems/operations. {*ASOR cross ref: ADS-B ASOR Hazard 109, req. 109-V-15*} (Note (SOW statement): The impact to crew and ATC workload shall be evaluated in simulation considering the re-allocation of rules, roles, and responsibilities that are proposed in RTCA DO-242.)

v. Vehicle position shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates (based upon current radar update rate). {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-13*}

5.2 ADS-B CANDIDATE VEHICLE OPERATOR PROCEDURAL SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for airborne and surface-maneuvering aircraft ADS-B operator procedures, and surface vehicle ADS-B operator procedures:

a. Vehicle operator shall obtain ATC clearance upon area/sector entry/exit and update controlling ATC at regular intervals regarding position, altitude, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of ADS-B. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-2*}

b. There shall be a procedure in the vehicle checklist for entering correct identification for flight information. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-7*}

c. ADS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional pilot skill or strength. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-V-11*}

5.3 ADS-B CANDIDATE ATC SYSTEM SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ATC ADS-B ground systems:

a. Display of inaccurate or false ADS-B data on an ATC operator's display equipment, without annunciation of failure, shall be remote. [**Dependent on: 5.1.b, 5.1.m, 5.1.o-u, 5.2.a, 5.4.a, 5.4.b**] {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-1*}

b. A risk assessment shall be performed in accordance with **Reference o**, with consideration of the other requirements of this section, to identify required development assurance levels for acquired and developed ADS-B ground systems. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-5*}

c. Transmittal of inaccurate or false ADS-B information from a system used to locate "known objects" and obstruction positions, without annunciation of failure, shall be remote. [**Dependent on: 5.1.j, 5.1.l, 5.3.d-f**] {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-A-1*}

d. Airports/runways/taxiways shall be marked, located, and displayed in the ADS-B system. {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-A-2*}

e. Obstacles requiring lighting in accordance with existing 14 CFR shall be marked, located, and displayed in the ADS-B system. {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-A-3*}

f. The ATC display shall include the ability to overlay the ADS-B information onto a map display covering the airport operations and terminal areas consistent with terminal area charts. {*ASOR cross ref: ADS-B ASOR Hazard 102, req. 102-A-5*}

g. Vehicle positions shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates (based upon current radar update rate). {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-6*}

5.4 ADS-B CANDIDATE ATC OPERATOR PROCEDURAL SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ATC ADS-B procedures:

a. ATC shall contact the next area/segment control for positive handoff when a vehicle leaves their respective control area/segment. Receiving and controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications while the vehicle is in the receiving/controlling ATC area/segment. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-2*}

b. Airports using ADS-B without a second independent means of ground surveillance shall implement a "one in-one out" procedure to clear runways, ramps, and taxi-ways of vehicles prior to allowing the landing or taxiing of an aircraft, during IMC or low visibility VMC. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-3*}

c. Tracking (of past position) on the ATC display shall be ON. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-4*}

d. ADS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional operator skill or strength. {*ASOR cross ref: ADS-B ASOR Hazard 500, req. 500-A-6*}

5.5 TIS-B CANDIDATE VEHICLE SYSTEM SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for airborne and surface-maneuvering aircraft TIS-B systems, and surface vehicle TIS-B systems:

a. Display of inaccurate or false TIS-B data on a single pilot's (or surface vehicle operator's) traffic information display equipment, without annunciation of failure, shall be remote. [**Dependent on: 5.6.a, 5.8.a**] {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-1*}

b. The TIS-B system shall have a limiting function, to limit position "jumping" to at most 4.5 seconds (based upon current radar update rate). {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-3*}

c. For aircraft, an assessment shall be performed in accordance with regulation and guidance material applicable to the aircraft type, and considering the other requirements of this section, to identify required development assurance levels for the aircraft TIS-B systems. For surface vehicles, a risk assessment shall be performed in accordance with **Reference o**, with consideration of the other requirements of this section, to identify required development assurance levels for surface vehicle TIS-B systems. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-4*}

d. Failures and malfunctions of the TIS-B system shall be detected and annunciated to the ATC. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-6*}

e. Vehicle positions shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates (based upon current radar update rate). {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-7*}

5.6 TIS-B CANDIDATE VEHICLE OPERATOR PROCEDURAL SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for airborne and surface-maneuvering aircraft TIS-B operator procedures, and surface vehicle TIS-B operator procedures:

a. Vehicle operator shall obtain ATC clearance upon area/sector entry/exit and update controlling ATC at regular intervals regarding position, altitude, speed, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of TIS-B and ADS-B. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-2*}

b. TIS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional pilot skill or strength. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-V-5*}

5.7 TIS-B CANDIDATE ATC SYSTEM SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ATC TIS-B ground systems:

a. Transmittal of inaccurate or false TIS-B information from ATC systems, without annunciation of failure, shall be remote. [**Dependent on: 5.6.a, 5.8.a**] {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-1*}

b. The system shall display only the most accurate data for each target. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-4*} (Note: The end ATC system should employ a checking function that compares ADS-B and TIS-B locations for each target.)

c. A risk assessment shall be performed in accordance with **Reference o**, with consideration of the other requirements of this section, to identify required development assurance levels for acquired and developed TIS-B ground systems. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-5*}

d. Failures and malfunctions of the TIS-B system shall be detected and annunciated to the ATC. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-7*}

e. Vehicle positions shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates (based upon current radar update rate). {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-8*}

5.8 TIS-B CANDIDATE ATC OPERATOR PROCEDURAL SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ATC TIS-B operator procedures:

a. ATC shall contact the next area/segment control for positive handoff when a vehicle leaves their respective control area/segment. Receiving and controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications while the vehicle is in the receiving/controlling ATC area/segment. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-2*}

b. Target "ground track" function on the ATC display shall be ON. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-3*}

c. TIS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional operator skill or strength. {*ASOR cross ref: TIS-B ASOR Hazard 505, req. 505-A-6*}

5.9 GENERAL ADS-B AND TIS-B SAFETY REQUIREMENTS

This section provides candidate operational safety requirements for ATC TIS-B operator procedures:

a. Collision between vehicles or between a vehicle and an obstruction resulting from undetected false or innacurate information from ADS-B or TIS-B as it relates to ADS-B shall be extremely improbable (as defined in Table 4-4). (Note (SOW statement): it should be shown by verification methods described in the FAA Systems Engineering Manual.

6 UNALLOCATED ADS-B AND TIS-B SAFETY REQUIREMENTS

This section provides candidate operational safety requirements and statements of work related to less severe hazards, such as minor hazards. These requirements have not been allocated, nor finalized, and are documented only for future reference as risk assessments are made, or if information captured in the OSED is modified such that higher severity levels are identified for these hazards.

From hazard record 100:

- When under secondary radar coverage, the Aircraft ID of the target shall be displayed next to the target symbol on the ATC display.
- The ADS-B system shall require the crew/operator to either enter or confirm the vehicle's ID before initialization of ADS-B for that vehicle.
- The manufacturers shall develop initial qualification and recurrent training standards for operators of the ADS-B system.
- Procedures shall require the ATC to resolve duplicate targets.
- Procedures using ADS-B shall include positive measures to ensure correct airport service vehicle identification

- ADS-B displays shall allow ATC to highlight individual targets for correct sequencing.

- Procedures shall include the provision for reduction of service vehicle traffic during low visibility conditions.

- If CDTI is to be used for airport surface surveillance and navigation in low VCE's then all vehicles (air and ground) shall be equipped with ADS-B and have a unique identification.

From hazard record 101:

- The ADS-B system shall use alternate and independent sources for velocity information for each airborne target vehicle.

- The ADS-B system shall display track information for each target such that the operators will be able to determine the past path of the target.

- The ADS-B system shall display information indicating whether the airborne target is climbing or descending.

- ASDE-X shall be compatible ADS-B.

- ATC automation shall compare velocity information from the A/C with the algorithm that computes ground velocity from the present and past position returns. The ADS-B shall not transmit information that disagrees with the integrity indicator by a TBD amount and shall employ functional and data integrity tests on startup and periodically during operation.

- The ADS-B display shall indicate A/C altitude.

From hazard record 103:

- The ADS-B system shall compare intent and position information. If the airborne target position information is outside a 4 mile limit, the system shall notify the operator.

- If ADS-B vehicle intent is going to be used for ground clearances then ADS-B shall have specific routes on the ground or be able to assign that route to ADS-B aircraft and detect when an aircraft deviates from that route by amounts specified in AC 150/5300-13 (table 4-1).

From hazard record 106:

- The ADS-B system shall employ data checking algorithms for information that is deemed critical - i.e. could lead to catastrophic or hazardous conditions.

- The ADS-B system shall detect loss of signal and/or function.

- The ADS-B system shall be compatible with other on-board electronics such that it does not interfere with critical systems nor is susceptible to interference by other on-board systems and conform with FAA Electromagnetic Effects requirements.

- The ADS-B system shall be compatible with the expected EM environment throughout the system envelope.

- The ADS-B system shall be compatible with operations in the expected weather environment in accordance with the system certification.

- The ADS-B system shall be compatible with ground RF emitters.

- It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than probable for this hazard.

From hazard record 108:

- The ADS-B system on the ground shall have alternative, independent and/or redundant means for the display of the ADS-B information.

- The ADS-B display shall be compatible with day and night illumination within both air and ground vehicles as well as ATC facilities.

- The ADS-B display shall be capable of displaying various ranges (radials from the center of the target) as appropriate to the application.

- The CDT shall have a selectable "off" mode.

From hazard record 110:

- The ADS-B fusion system shall minimize (less than 3%) "ghost" targets including those due to reflections and different update rates of the various sensors.

- The ADS-B fusion function algorithms shall be designed to present the most accurate altitude, velocity and position data on the display.

- The ATC system shall have a means of detecting corrupted target data and displaying a warning to the ATC.

- The ATC end system shall have means to monitor and alert for corrupted TIS and TIS-B data.

- The ADS-B system shall be compatible with other integrated systems such as ASDE-3, ASDE-X, ASR-9 & 11, etc.

From hazard record 502:

- The occurrence of this hazard should be remote (or improbable).
- Procedural requirements shall be retained for flights in non-radar airspace.
- The ADS-B avionics shall warn the crew if the ADS-B set ceases to transmit.

From hazard record 503:

- Procedural requirements shall be retained for flights in non-radar airspace.

From hazard record 504:

- Maintain current radar displays as alternate to TIS-B.
- Assure that ADS-B is independent of secondary surveillance function such that loss of secondary surveillance function does not result in loss of ADS-B information to ATC.
- Loss of the TIS-B function should not result in loss of the ADS-B function on board the aircraft.

From hazard record 506:

- Current radar displays shall be retained as alternate to TIS-B.
- Assure that ADS-B is independent of secondary surveillance function such that loss of secondary surveillance function does not result in loss of ADS-B information to ATC.
- A procedure shall be required for ATC to notify flight crews of misleading TIS-B information.
- Limiting system shall not shut the system down, but rather, flag the potential erroneous data.

From hazard record 600:

- Pilot training and procedures shall include proper use of CDTI.
- ATC procedures shall include mixed equipage scenarios.

From hazard record 601:

- Discrepancy between radar and ADS-B on existence of target shall be detected. ATS display shall include warning to ATS that a specified target may be erroneous.

From hazard record 604:

- All CDTI controls shall be located within the 10th percentile adult US civilian female grip reach length.

- Pilots shall be trained to incorporate CDTI into visual instrument and OTW scan so that OTW scan remains primary.

- The ADS-B system developers shall demonstrate compliance with Human factors criteria contained in MIL-STD-1472 and the FAA's AMS. These requirements will be validated and verified in accordance with the FAA system engineering manual and system engineering management plan.

- The CDTI display shall include provisions for declaring the displays are in accordance with MIL-STD-1472.

From hazard record 606:

- ATS training should include scenarios simulating loss of ADS-B data for one or all aircraft in a series of aircraft closely spaced on visual approach.

From hazard record 609:

- ADS-B and / or CDTI equipage shall be displayed to the controller automatically as a controller-selected option.

From hazard record 610:

- The ADS-B display shall be able to be decluttered to the extent that ownership, nearby vehicles, taxiways, and runways are easily distinguishable and identifiable.

- Clearances and confirmations shall be required at all runway intersections.

- Pilot training shall be provided for ADS-B operation in heavy traffic airport surface areas.

- Requirement for screen resolution TBD

- Requirement for selectable option to zoom in and out TBD

From hazard record 614:

- Training for pilots using ADS-B on airport movement area shall include provisions for one pilot maintaining OTW surveillance and coordinating movement with ground crew.

- Procedures shall include provisions for reporting surface objects to ATC.

- The effect of this hazard shall be examined in a simulator to validate the concern.

From hazard record 615:

- ADS-B avionics shall have sufficient resolution to provide accurate representation of all airport surface areas intended for use by ADS-B equipped aircraft.

- Procedures shall require that airport maps for use with ADS-B CDTI shall be current with respect to NOAA airport charts.

- Critical reference points are those obstacles that require marking in accordance with the FARs. The airports, runaways, taxiways, and critical reference points shall be displayed on the ADS-B display with an accuracy that is within those specified in AC 150/5300-14 table 4-1. The obstacles must be verified to be within 10 meters of the displayed position.

From hazard record 616:

- Procedures shall include provisions for clearing frequencies for ATC instructions, including restrictions on message contents and duration (radio protocol).

- Operational test of the ADS-B system shall measure any change in frequency occupancy.

From hazard record 700:

- The ADS-B data shall be encoded/encrypted so that the probability of successful spoofing is extremely improbable.

- The ADS-B system shall employ a unique identifier for each legitimate unit produced.

- The ADS-B system shall check each message for the presence of the unique identifier and provide a warning to the operator if the identifier is not present.

- ADS-B shall consider frequency hopping and spread spectrum techniques to protect against spoofing.

APPENDIX A: OPERATIONAL SERVICES AND ENVIRONMENT DESCRIPTION - GENERAL

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST

OPERATIONAL SERVICES AND ENVIRONMENT

INTRODUCTION

This document outlines the operational services that Automatic Dependent Surveillance-Broadcast (ADS-B) will provide. It characterizes the operation of ADS-B services and their environment regardless of the specific technologies that will be utilized to implement them.

DEFINITION

ADS-B is the function on an aircraft or surface vehicle that automatically broadcasts aircraft or surface vehicle horizontal and vertical position, velocity, intent, and other information.[1]

BASIS

This operational services and environment description is based on the RTCA *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, and *Joint Government/Industry Roadmap for Free Flight Enhancements*, the FAA *NAS CONOPS 2005*, *NAS Architecture,* Version 4, the FAA *ADS-B Mission Need Statement #326*, *ADS-B Plan*, FAA *Safe Flight 21 Functional Specification, and Surveillance Vision Plan*, the *ICAO Manual of ATS Data Link Applications*, and other applicable documents.

[1] "ADS-B is a function on an aircraft or a surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is *automatic* because no external stimulus is required to elicit a transmission; it is *dependent* because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users are receiving its broadcast; any user, either aircraft or ground-based, within range of this broadcast, may choose to receive and process ADS-B surveillance information." (*Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, RTCA, Document No. RTCA/DO-242, February 19, 1998; 2)

PURPOSE OF ADS-B

The primary purpose of ADS-B is to provide pilots, air traffic controllers, airport services vehicle drivers and traffic managers with information on the positions and movements of aircraft and vehicles. They need this information to act to maintain required separation, and to comply with other maneuvering safety requirements. ADS-B is intended to enhance the:

- Maintenance of required safe separation distances between aircraft in flight
- Capabilities of aircraft and air traffic control operators to prevent incursions of aircraft or surface vehicles into restricted airspace, airport surface areas or hazardous weather
- Collision avoidance capabilities of aircraft in flight, and of aircraft and airport service vehicles on the ground.

Used with other enhancements planned for aeronautical navigation, communications and air traffic control, ADS-B data may also:

- Enable reductions in the separation required between aircraft while maintaining or improving safety margins
- Provide options for more direct routing of flights, increase airspace capacity, increase airport throughput, and potentially reduce delays, resulting in savings of time and money.

ADS-B data may be used for guiding aircraft and airport service vehicles on the airport surface when visibility is restricted. It may be used for flight following and traffic flow management, for locating aircraft for search and rescue, directing search and rescue operations and tracking their progress.

This document outlines in-flight and airport surface operations using ADS-B data, the ADS-B operational environment, and the potential impact of ADS-B on aeronautical operations.

SCOPE

ADS-B implementation and the services that its implementation will provide extend to aeronautical applications of ADS-B through the phases of NAS modernization outlined by the *NAS Architecture*, Version 4. Initially, these services will support operational enhancement applications for Safe Flight 21(SF21).[2]

[2] The Safe Flight 21 Applications of ADS-B Operational Service table on page **Error! Bookmark not defined.** identifies ADS-B operational services that will support SF 21 enhancements identified in the draft *Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999. It also identifies technologies in addition to ADS-B that will implement the SF 21 enhancements supported by ADS-B operational services.

OPERATIONS

ADS-B data will be used for airborne and surface surveillance of aircraft and ground vehicles. Currently, surveillance of airborne traffic involves direct visual observation by flight crews of other aircraft, use of radar and beacon-based systems, and communications of proximity information from surface air traffic control (ATC) facilities. ATC surveillance depends primarily on processed radar and beacon-returns of airborne traffic displayed to air traffic controllers, and visual or limited radar observation of traffic and verbal reports from aircraft and ground vehicle operators on the airport surface.

SURVEILLANCE OF AIRCRAFT IN FLIGHT

Unlike radar-based surveillance systems, ADS-B will automatically broadcast position and velocity information, aircraft identification, intent, and other information. It will broadcast this information to aircraft and surface vehicles equipped with ADS-B receivers, to air traffic control facilities, to airline operators, and to others within range. Operators on the flight deck will use this information to help maintain safe separation from other aircraft. Air traffic control facilities will use this information as radar information is used today, to assist in separating aircraft from other aircraft, terrain, hazardous weather, and restricted airspace

The primary purpose of ADS-B for surveillance of aircraft in flight is to provide and acquire surveillance data that will:

- Improve safety and efficiency by enabling the approval of safer and more efficient procedures and operations for separation, station keeping and maneuvering
- Enhance air-traffic control operations in areas where radar coverage does not exist today
- Enhance the capabilities for avoidance of collisions between aircraft and, when associated with other systems, between aircraft, terrain and other surface structure.

ADS-B will also be used to enhance hazardous weather avoidance capabilities, and to prevent incursions of unauthorized flight into special use or restricted airspace. The latter functions would involve use of ADS-B information by surface facilities to direct aircraft movements.

Separation

ADS-B data will be input to both airborne and ground based automation functions for separation assurance.[3] Specific separation requirements, or minima, vary with airspace class, flight level, and other characteristics of the aeronautical environment. In general, however, separation is the requirement for "the spacing of aircraft to achieve their safe

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[3] The International Civil Aviation Organization (ICAO) refers to the airborne separation segment as Airborne Separation Assurance System (ASAS). (SICASP/6-WP/44 Section 6.3.6).

and orderly movement of flight and while landing and taking off." Separation minima are established as the "minimum longitudinal, lateral, or vertical distances by which aircraft are spaced through the application of air traffic control procedures."[4]

ADS data are expected to enable higher capability surveillance services compared to today's radar-based surveillance. ADS data will enable reduced horizontal and vertical separation in oceanic and in domestic airspace, because it will provide surveillance services where none are now available and provide for greater and more accurate coverage where those services are currently available.

Air Traffic Services (ATS) Separation

ATS separation involves the use of ADS-B data by ground ATC to direct aircraft maneuvers to maintain safe separation of aircraft in flight. This will involve the fusion of ADS information with radar and other ATC data, resulting in extended and more accurate coverage. The resulting enhanced surveillance capability of ATC operations will enable separation minima reductions and more flexible routings throughout domestic and oceanic airspace.

Non-Radar Airspace Separation Services

Surface-based surveillance is not available in oceanic airspace, and ATC currently depends on flight plans and verbal communications to locate aircraft and track their movements in oceanic and other non-radar airspace. Safe separation involves requirements for greater distances between aircraft than where surface-based surveillance is available, e.g., in the enroute positive-control context. Addressable ADS (ADS-A) will provide surveillance information for oceanic separation by ATS. In the future, ADS-B will also provide surveillance information for cooperative separation by aircraft flying in oceanic and other non-radar airspace.

ADS-B will enable the extension of instrument flight rules (IFR) separation services to non-radar areas of domestic airspace, including low-altitude airspace, remote airspace (e.g., mountainous areas), and coastal waters. The extent to and manner in which ADS-B data will support visual and instrument operations in such airspace remain to be defined. Options will include extension of surface-based ATS to this airspace using ADS-B surveillance data, or application of technologies and procedures for airborne cooperative separation with ADS-B surveillance data support for situational awareness.

Cooperative Separation Management

Data provided by ADS-B will be applied in all operational contexts to assist in aircraft-to-aircraft cooperative separation procedures for maintaining fixed or variable lateral, horizontal and vertical distances between aircraft. The result will be improved safety and throughput in all flight regimes. For example, ADS-B data will be processed by automation tools to assist pilots in maintaining the desired minimum spacing during in-trail approaches. A more advanced application would involve using ADS-B data to maintain separation during closely spaced parallel approaches.

[4] *Controller-Pilot Glossary*

Other Separation Operations

Other ADS-B enhancements of separation services will include improved conformance monitoring, closer separation simultaneous and other approach procedures with improved sequencing and improved conflict management and airspace deconfliction.

Maneuvering

Use of ADS-B data for airborne surveillance will enhance flight crews' traffic situational awareness capabilities, such as those required for "see and avoid," to maneuver aircraft among and around other traffic.

Aircraft and ATC will use ADS-B information on the locations, headings and speeds of aircraft in contiguous airspace to support visual acquisition as part of normal see and avoid operations. For example, in the approach context a pilot would use ADS-B information to distinguish arriving aircraft and other traffic in relation to the airport and approach paths. Alternatively, ADS-B information could be used for passing maneuvers or station-keeping. For a passing maneuver, a pilot will be authorized by the controller to increase altitude once the distance and relative speed of the lead aircraft is obtained from its ADS-B.

ADS-B data processed by applicable automation will also guide control inputs for in-trail and parallel climb, descent, passing and other heading and course change maneuvers.

Station-Keeping

ADS-B will provide data for station keeping in all operational contexts to maintain a fixed or variable distance between aircraft. For instance, displayed ADS-B data "can assist flight crews in the final approach. For example, an opportunity for station keeping occurs with aircraft cleared to fly an (Flight Management System) FMS 4D profile to the final approach fix. Another aircraft can perform ADS-B station keeping to follow the lead aircraft using a Cockpit Display of Traffic Information (CDTI) that provides needed cues and situational data on the lead and other proximate aircraft. In this scenario, station keeping allows a lesser equipped aircraft to fly the same approach as the FMS-equipped aircraft. The in-trail aircraft will maintain minimum separation standards, including wake vortex limits, with respect to the lead aircraft." ATC will monitor the actions using ADS-B surveillance information that is more accurate than information presently provided by current radar and beacon returns.[5]

Conflict Management

Aircraft and ATC will use ADS-B data to project flight paths in order to detect potential conflicts between aircraft in flight and between traffic maneuvering on the surface before collisions become imminent. This function will be especially important in airspace designated for Free Flight. In Free Flight, ATC clearances would not be required for aircraft to change their headings, altitudes and airspeeds. Intentions would be communicated to other aircraft sufficiently in advance for the coordination of changes to maintain required separation and avoid conflicts.

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[5] RTCA/DO-242; 47-48

Airborne Incursion Avoidance

ATC will use ADS-B surveillance data to track aircraft or surface vehicle movements and detect pending incursions. ATC will then issue guidance for navigating to avoid incursions based on this information. Specific airspace avoidance zones will include special use airspace, restricted airspace, hazardous weather locations, and other operational control zones such as noise sensitive areas.

Preventing Flight into Terrain, Structures and Flying Objects

ADS-B transmitters might also be placed on temporary or unmapped fixed obstructions such as cranes, temporary antennas, etc. to broadcast their positions and heights, serving as warnings to prevent aircraft from colliding with them. Since ADS-B will broadcast aircraft surveillance data to ground ATC facilities, controllers can also use this information to detect potential controlled and uncontrolled flights into temporary or unmapped structures and to direct heading or altitude changes.

ADS-B transmitters can also be placed on flying objects, such as balloons, unmanned vehicles, and space flight vehicles that may be obstructions to aviation.

Collision Avoidance

Collision avoidance is defined as the commission or omission of specific actions with the intent of evading an impending impact. Surveillance data provided by ADS-B will be useful information for collision avoidance in a range of operating contexts, including domestic enroute, terminal and remote airspace, and oceanic airspace.

ADS-B data will be used to supplement, enhance or replace surveillance data used by present collision avoidance systems, i.e., the Traffic Alert and Collision Avoidance System (TCAS). Initially, use of ADS-B data will reduce TCAS interrogation rates through "hybrid surveillance." ADS-B data will also be used to enable extension of collision avoidance to below 1,000 ft AGL. In the future, a collision avoidance system with further enhancements might be based entirely on the use of ADS-B data, with no need for active interrogations.

Also, ADS-B data "… used within the collision avoidance logic (will) reduce the number of unnecessary alerts and improve the Resolution Advisory maneuver selection process, for example, by eliminating alerts for aircraft which will pass with large lateral separation and by enabling more accurate trajectory prediction."[6]

SURVEILLANCE OF SURFACE OPERATIONS

Aircraft surface operations involve taxiing between runways, along taxiways, and to and from gates or stands and aprons, or corresponding floatplane operations and, to some extent, rotorcraft operations. These operations are controlled by the tower, where one exists.

Surface operations also involve movements of all other traffic on the airport surface.

[6] DO-242; 1.3.2; 20

Surface operations supported by ADS-B data will include managing surface traffic and preventing aircraft and services vehicle incursions into dangerous or otherwise prohibited areas.

Traffic Management

ADS-B data will identify and provide position and movement information for aircraft and airport service vehicles maneuvering on taxiways and runways. It will provide this information to the aircraft and airport service vehicles and to airport traffic control and management facilities personnel. The goal is for ADS-B to support surface movement twenty-four hours a day in all weather conditions, including low and zero visibility conditions.

Location, position and distance from other aircraft and surface vehicles are crucial safety considerations for surface operations. In the aircraft and on surface vehicles, surveillance data provided by ADS-B will be input to a CDTI and a moving map display for taxi guidance and surface station keeping. Information provided by ADS-B on traffic movements will be integrated with a moving map display to show obstructed and cleared travel paths. For surface station keeping, an in-trail aircraft would monitor the position and speed of the lead aircraft, detect changes, and change its own speed to maintain safe separation.

Traffic position data provided by ADS-B will also enable automatic operation of airport lighting in response to aircraft proximity.

Surface Incursion and Collision Avoidance

ADS-B will provide information on the locations and movements of aircraft and surface vehicles to enable surface movement controllers to issue directions, warnings and alerts. The intent would be to prevent incursions into runways and taxiways, lighting control areas (areas where lighting is under ATS control), weight-limited or wingspan-limited areas, and other operational control zones such as noise sensitive areas. The intent would also be to prevent collisions between aircraft, between surface vehicles, and between aircraft and surface vehicles.

ADS-B data will also be used in incursion alert, warning and alarm systems on board aircraft and in control facilities to detect or deter runway incursions. For example, aircraft on approach using an automated system with ADS-B data inputs might be warned of traffic incursions onto landing runway in sufficient time to request clearance for or to take effective avoidance actions. Alternatively, controllers may detect pending incursions and conflicts in time to redirect the incurring traffic.

ADS-B OPERATIONAL ENVIRONMENT

In the near term, the ADS-B operational environment will be characterized by aeronautical operations enhancements and applications that use ADS-B data during the Safe Flight 21 (SF21) program. These enhancements and applications are delineated in the draft *Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999 and the *Safe Flight 21 Functional Specification*, September 7, 1999. The enhancements are:

- Improved Terminal Operations in Low Visibility
- Enhanced See and Avoid
- Enhanced En Route Air-To-Air Operations
- Improved Surface Surveillance & Navigation for the Pilot
- Enhanced Surface Surveillance for the Controller
- ADS-B Surveillance in Non-Radar Airspace
- ADS-B Surveillance in Radar Airspace.

In the longer term, the ADS-B operational environment will be characterized by diverse levels of traffic and multiple airspace contexts. In domestic airspace, operations will include surveillance for enroute, terminal, and airport surface. Addressable ADS is currently being implemented to provide ATS surveillance for oceanic airspace. ADS-B will be implemented for oceanic airspace in the future for cooperative separation and for collision avoidance in the conduct of in-trail climbs, descents, passing and other maneuvers.

POTENTIAL IMPACT

ADS-B will provide surveillance data to airborne and surface-maneuvering aircraft, and to surface vehicle operators, controllers and aviation operations facilities on the ground. This information can be used to provide surveillance services for a wide range of airborne and surface maneuvering, flight following and control requirements across all operating contexts. It could greatly extend and perhaps conceivably replace current ATS surveillance in a number of areas.

As delineated in the *NAS Architecture*, Version 4, the FAA plans to modernize the surveillance system hardware and software infrastructure with common operating systems and services. Once the infrastructure is modernized, new flight data management and surveillance data processing systems will use data from ADS broadcasts. The new systems will support conflict detection and resolution, sequencing to terminals, and optimal descent profiles. Modernization of surveillance data acquisition and processing capabilities with ADS-B will lead to more flexible airspace sectors with more dynamic boundaries than at present.

The availability of ADS-B data is also a central element in the extension of flexible routing options. These include a Free Flight environment in which separation would be managed cooperatively between pilots and controllers in the enroute, remote, and oceanic environments and for selected terminal operations.

ADS-B data and associated map displays in airport service vehicles in addition to Air Traffic Control Tower (ATCT) systems upgrades outlined in the *ATS CONOPS-2005* and *NAS Architecture* Version 4 will enable greater overall control of airport surface vehicle movements. In the time frame envisioned in the *ATS CONOPS-2005*, movement of aircraft on the airport surface might be pre-planned, integrated with flight information profiles, and monitored and adjusted with the use of ADS-B data. Future ADS-B position and movement data will provide universal dependent surveillance of surface vehicle movements for separation assurance at equipped airports.

The ultimate operational impact of ADS-B and other planned air traffic service enhancements that will use ADS-B surveillance data could be air-to-air based separation management and cooperative procedures. This would enable progress toward the Free Flight environment. This progress might be accompanied by more efficient terminal and airport operations, enhanced by the use of ADS-B data to optimize flow management and throughput. The employment of ADS-B data for sequencing and surface separation management might help avoid the potential congestion that might be otherwise expected from increasing capacity demands on airport surface facilities in a Free Flight environment. It would also result in commensurate improvements in safety.

APPENDIX B: OPERATIONAL SERVICES AND ENVIRONMENT DESCRIPTION - SAFE FLIGHT 21

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B)

SAFE FLIGHT 21 OPERATIONAL ENVIRONMENT

24 April 2000

Prepared for Mr. Robert D. Balderston U.S. Department of Transportation Federal Aviation Administration 800 Independence Avenue, Rm. 725 Washington, DC 2059	Prepared by Dr. Alexander D. Blumenstiel U.S. Department of Transportation John A. Volpe National Transportation Systems Center 55 Broadway, Cambridge, MA 02142

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1. INTRODUCTION

This document is a preliminary analysis toward characterizing the Safe Flight 21 (SF21) environment for aeronautical operations that will use Automatic Dependent Surveillance-Broadcast (ADS-B) data. Its purpose is to provide an initial basis of considerations for discussion preparatory to developing an operational environment definition (OED) for ADS-B as the foundation of an operational safety assessment conducted to develop safety objectives. The OED is basic to the process of developing safety objectives, because the content and environment of ADS-B operations will both engender and mitigate safety hazards.

ADS-B is the function on an aircraft or surface vehicle that automatically broadcasts aircraft or surface vehicle horizontal and vertical position, velocity, intent, and other information.[7] This information will enhance a number of aeronautical operations. For example, among other applications, use of ADS-B data for maneuvering, station keeping, collision avoidance and traffic management will improve terminal operations in low visibility. Use of ADS-B data will improve surface surveillance and navigation for the pilot, enhancing maneuvering, station keeping and collision avoidance in the airport movement area. ADS-B data will enable the expansion of surveillance coverage to en-route non-radar airspace. This will enable cooperative separation, conflict management, and airborne incursion avoidance in that airspace.

Aeronautical services and operations that will use ADS-B data are established in the FAA *National Airspace System Architecture*, Version 4, the *Air Traffic Services NAS Concept of Operations 2005*, FAA *Surveillance Vision Plan*, RTCA *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, FAA *ADS-B Mission Need Statement #326*, the *ADS-B Plan*, *ICAO Manual of ATS Data Link Applications*, and by other design, plan and specification documents that define the NAS architecture and its services and systems.

SF21 enhancements and applications are delineated in the *NAS Architecture*, the *Joint Government/Industry Roadmap for Free Flight Enhancements*, *Safe Flight 21 Functional Specification*, *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, and other documents issued by FAA, RTCA and other government and industry organizations. These enhancements and applications define the SF21 operational environment for ADS-B in the near term. In the future, the operational environment for use of ADS-B data may expand with additional services that further enhance aviation safety and efficiency. This future environment may be characterized by a diversity of aeronautical applications and contexts, incorporating and extending beyond SF21 applications.

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[7]"ADS-B is a function on an aircraft or a surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal and vertical velocity) and other information. ADS-B is *automatic* because no external stimulus is required to elicit a transmission; it is *dependent* because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users. The aircraft or vehicle originating the broadcast may or may not have knowledge of which users are receiving its broadcast; any user, either aircraft or ground-based, within range of this broadcast, may choose to receive and process ADS-B surveillance information." (*Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, RTCA, Document No. RTCA/DO-242, February 19, 1998; 2)

The following sections of this document characterize aeronautical operations that will use ADS-B data and define the environment for these operations in terms of SF21 enhancements and applications that will use ADS-B data. Since experience with employment of ADS-B data will likely generate new applications in the future, the last section reviews some potential implications of ADS-B for aeronautical operations in the longer term.

2. ADS-B DATA APPLICATIONS

The primary purpose of ADS-B is to provide pilots, air traffic controllers, airport services vehicle drivers and traffic managers with information on the positions and movements of aircraft and vehicles. They need this information to act to maintain required separation, and to comply with other maneuvering safety requirements. ADS-B data will be used to:

- Maintain required safe separation distances between aircraft in flight
- Prevent incursions of aircraft or surface vehicles into restricted airspace, airport surface areas or hazardous weather
- Avoid collisions between aircraft in flight, and of aircraft and airport service vehicles on the ground.

Used with other advancements in aeronautical navigation, communications and air traffic control services, ADS-B data may also:

- Enable reductions in the separation required between aircraft while maintaining or improving safety margins
- Enhance terrain avoidance capabilities
- Provide options for more direct routing of flights, increase airspace capacity, increase airport throughput, and potentially reduce delays, resulting in savings of time and money.

ADS-B data may be used for guiding aircraft and airport service vehicles on the airport surface when visibility is restricted. It may be used for flight following and traffic flow management, for locating aircraft for search and rescue, directing search and rescue operations and tracking their progress.

ADS-B data will be used for airborne and surface surveillance of aircraft and ground vehicles. Currently, surveillance of airborne traffic involves direct visual observation by flight crews of other aircraft, use of radar and beacon-based systems, and communications of proximity information from surface air traffic control (ATC) facilities. ATC surveillance depends primarily on processed radar and beacon-returns of airborne traffic displayed to air traffic controllers, and visual or limited radar observation of traffic and verbal reports from aircraft and ground vehicle operators on the airport surface.

3. ADS-B OPERATIONAL SERVICES

ADS-B data will support the following operational services:

- ♦ Surveillance of Aircraft in Flight
  - ATS Separation
  - Non-Radar Airspace Separation Services
  - Cooperative Separation Management
  - Maneuvering
  - Station Keeping
  - Conflict Management
  - Preventing Flight into Terrain, Structures and Flying Objects
  - Airborne Incursion Avoidance
  - Collision Avoidance
- ♦ Surveillance of Surface Operations
  - Surface Traffic Management
  - Surface Incursion Avoidance[8]

3.1 SURVEILLANCE OF AIRCRAFT IN FLIGHT

Unlike radar-based surveillance systems, ADS-B will automatically broadcast position and velocity information, aircraft identification, intent, and other information. It will broadcast this information to aircraft and surface vehicles equipped with ADS-B receivers, to air traffic control facilities, to airline operators, and to others within range. Operators on the flight deck will use this information to help maintain safe separation from other aircraft. Air traffic control facilities will use this information as radar information is used today, to assist in separating aircraft from other aircraft, terrain, hazardous weather, and restricted airspace.

The primary purpose of ADS-B for surveillance of aircraft in flight is to provide and acquire surveillance data that will:

- ♦ Improve safety and efficiency by enabling the approval of safer and more efficient procedures and operations for separation, station keeping and maneuvering
- ♦ Enhance air-traffic control operations in areas where radar coverage does not exist today
- ♦ Enhance the capabilities for avoidance of collisions between aircraft and, when associated with other ATS and other systems, between aircraft, terrain and other surface structure, and between aircraft and other flying objects.

ADS-B will also be used to enhance hazardous weather avoidance capabilities, and to prevent incursions of unauthorized flight into special use or restricted airspace. The latter functions would involve use of ADS-B information by surface facilities to direct aircraft movements.

[8] This includes runway incursions.

3.1.1 Separation

ADS-B data will be input to both airborne and ground based automation functions for separation assurance.[9] Specific separation requirements, or minima, vary with airspace class, flight level, and other characteristics of the aeronautical environment. In general, however, separation is the requirement for "the spacing of aircraft to achieve their safe and orderly movement of flight (en route) and while landing and taking off." Separation minima are established as the "minimum longitudinal, lateral, or vertical distances by which aircraft are spaced through the application of air traffic control procedures."[10]
ADS data are expected to enable higher capability surveillance services compared to today's radar-based surveillance. ADS data will enable reduced horizontal and vertical separation in oceanic and in domestic airspace, because it will provide surveillance services where none are now available and provide for greater and more accurate coverage where those services are currently available.

3.1.1.1 Air Traffic Services (ATS) Separation

ATS separation involves the use of ADS-B data by ground ATC to direct aircraft maneuvers to maintain safe separation of aircraft in flight. This will involve the fusion of ADS information with radar and other ATC data, resulting in extended and more accurate coverage. The resulting enhanced surveillance capability of ATC operations will enable separation minima reductions and more flexible routings throughout domestic and oceanic airspace.

3.1.1.2 Non-Radar Airspace Separation Services

Surface-based surveillance is not available in oceanic airspace, and ATC currently depends on flight plans and verbal communications to locate aircraft and track their movements in oceanic and other non-radar airspace. Safe separation involves requirements for greater distances between aircraft than where surface-based surveillance is available, e.g., in the enroute positive-control context. Addressable ADS (ADS-A) will provide surveillance information for oceanic separation by ATS. In the future, ADS-B will also provide surveillance information for cooperative separation by aircraft flying in oceanic and other non-radar airspace.
ADS-B will enable the extension of instrument flight rules (IFR) separation services to non-radar areas of domestic airspace, including low-altitude airspace, remote airspace (e.g., mountainous areas), and coastal waters. The extent to and manner in which ADS-B data will support visual and instrument operations in such airspace remain to be defined. Options will include extension of surface-based ATS to this airspace using ADS-B surveillance data, or application of technologies and procedures for airborne cooperative separation with ADS-B surveillance data support for situational awareness.

3.1.1.3 Cooperative Separation Management

Data provided by ADS-B will be applied in all operational contexts to assist in aircraft-to-aircraft cooperative separation procedures for maintaining fixed or variable lateral,

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[9] The International Civil Aviation Organization (ICAO) refers to the airborne separation segment as Airborne Separation Assurance System (ASAS). (SICASP/6-WP/44 Section 6.3.6).
[10] *Controller-Pilot Glossary*

horizontal and vertical distances between aircraft. The result will be improved safety and throughput in all flight regimes. For example, ADS-B data will be processed by automation tools to assist pilots in maintaining the desired minimum spacing during in-trail approaches. A more advanced application would involve using ADS-B data to maintain separation during closely spaced parallel approaches.

3.1.1.4 Other Separation Operations

Other ADS-B enhancements of separation services will include improved conformance monitoring, closer separation simultaneous and other approach procedures with improved sequencing and improved conflict management and airspace deconfliction.

3.1.2 Maneuvering

Use of ADS-B data for airborne surveillance will enhance flight crews' traffic situational awareness capabilities, such as those required for "see and avoid," to maneuver aircraft among and around other traffic.

Aircraft and ATC will use ADS-B information on the locations, headings and speeds of aircraft in contiguous airspace to support visual acquisition as part of normal see and avoid operations. For example, in the approach context a pilot would use ADS-B information to distinguish arriving aircraft and other traffic in relation to the airport and approach paths. Alternatively, ADS-B information could be used for passing maneuvers or station-keeping. For a passing maneuver, a pilot will be authorized by the controller to increase altitude once the distance and relative speed of the lead aircraft is obtained from its ADS-B.

ADS-B data processed by applicable automation will also guide control inputs for in-trail and parallel climb, descent, passing and other heading and course change maneuvers.

3.1.3 Station-Keeping

ADS-B will provide data for station keeping in all operational contexts to maintain a fixed or variable distance between aircraft. For instance, displayed ADS-B data "can assist flight crews in the final approach. For example, an opportunity for station keeping occurs with aircraft cleared to fly an (Flight Management System) FMS 4D profile to the final approach fix. Another aircraft can perform ADS-B station keeping to follow the lead aircraft using a Cockpit Display of Traffic Information (CDTI) that provides needed cues and situational data on the lead and other proximate aircraft. In this scenario, station keeping allows a lesser equipped aircraft to fly the same approach as the FMS-equipped aircraft. The in-trail aircraft will maintain minimum separation standards, including wake vortex limits, with respect to the lead aircraft." ATC will monitor the actions using ADS-B surveillance information that is more accurate than information presently provided by current radar and beacon returns.[11]

3.1.4 Conflict Management

Aircraft and ATC will use ADS-B data to project flight paths in order to detect potential conflicts between aircraft in flight and between traffic maneuvering on the surface before collisions become imminent. This function will be especially important in airspace

[11] RTCA/DO-242; 47-48

designated for Free Flight. In Free Flight, ATC clearances would not be required for aircraft to change their headings, altitudes and airspeeds. Intentions would be communicated to other aircraft sufficiently in advance for the coordination of changes to maintain required separation and avoid conflicts.

3.1.5 Airborne Incursion Avoidance

ATC will use ADS-B surveillance data to track aircraft movements and detect pending incursions. ADS-B will extend current ATC capabilities to non-radar airspace for guiding aircraft to avoid incursions. Airspace avoidance zones include special use airspace, restricted airspace, hazardous weather, and operational control zones such as noise sensitive areas.

3.1.6 Preventing Flight into Terrain, Structures and Collisions of Aircraft with Other Flying Objects

ADS-B transmitters might also be placed on temporary or unmapped fixed obstructions such as cranes, temporary antennas, etc. to broadcast their positions and heights, serving as warnings to prevent aircraft from colliding with them. Since ADS-B will broadcast aircraft surveillance data to ground ATC facilities, controllers can also use this information to detect potential controlled and uncontrolled flights into temporary or unmapped structures and to direct heading or altitude changes.

ADS-B transmitters can also be placed on flying objects, such as balloons, unmanned vehicles, and space flight vehicles that may be obstructions to aviation.

3.1.7 Avoidance of Collisions between Aircraft

Collision avoidance is defined as the commission or omission of specific actions with the intent of evading an impending impact. Surveillance data provided by ADS-B will be useful information for avoidance of collisions between aircraft in a range of operating contexts, including domestic enroute, terminal and remote airspace, and oceanic airspace.

ADS-B data will be used to supplement, enhance or replace surveillance data used by present collision avoidance systems, i.e., the Traffic Alert and Collision Avoidance System (TCAS). Initially, use of ADS-B data will reduce TCAS interrogation rates through “hybrid surveillance.” ADS-B data will also be used to enable extension of collision avoidance to below 1,000 ft AGL. In the future, a collision avoidance system with further enhancements might be based entirely on the use of ADS-B data, with no need for active interrogations.

Also, ADS-B data will be “used within the collision avoidance logic (to) reduce the number of unnecessary alerts and improve the Resolution Advisory maneuver selection process, for example, by eliminating alerts for aircraft which will pass with large lateral separation and by enabling more accurate trajectory prediction.”[12]

[12] DO-242; 1.3.2; 20

3.2 SURVEILLANCE OF SURFACE OPERATIONS

Aircraft surface operations involve taxiing between runways, along taxiways, and to and from gates or stands and aprons, or corresponding floatplane operations and, to some extent, rotorcraft operations. These operations are controlled by the tower, where one exists.

Surface operations also involve movements of all other traffic on the airport surface. Surface operations supported by ADS-B data will include managing surface traffic and preventing aircraft and services vehicle incursions into dangerous or otherwise prohibited areas, such as active runways.

3.2.1 Traffic Management

ADS-B data will identify and provide position and movement information for aircraft and airport service vehicles maneuvering on taxiways and runways. It will provide this information to the aircraft and airport service vehicles and to airport traffic control and management facilities personnel. The goal is for ADS-B to support surface movement twenty-four hours a day in all weather conditions, including low and zero visibility conditions.

Location, position and distance from other aircraft and surface vehicles are crucial safety considerations for surface operations.   In the aircraft and on surface vehicles, surveillance data provided by ADS-B will be input to a CDTI and a moving map display for taxi guidance and surface station keeping. Information provided by ADS-B on traffic movements will be integrated with a moving map display to show obstructed and cleared travel paths. For surface station keeping, an in-trail aircraft would monitor the position and speed of the lead aircraft, detect changes, and change its own speed to maintain safe separation.

Traffic position data provided by ADS-B will also enable automatic operation of airport lighting in response to aircraft proximity.

3.2.2 Surface Incursion and Collision Avoidance

ADS-B will provide information on the locations and movements of aircraft and surface vehicles to enable surface movement controllers to issue directions, warnings and alerts. The intent would be to prevent incursions into runways and taxiways, lighting control areas (areas where lighting is under ATS control), weight-limited or wingspan-limited areas, and other operational control zones such as noise sensitive areas. The intent would also be to prevent collisions between aircraft, between surface vehicles, and between aircraft and surface vehicles.

ADS-B data will also be used in incursion alert, warning and alarm systems on board aircraft and in control facilities to detect or deter runway incursions. For example, aircraft on approach using an automated system with ADS-B data inputs might be warned of traffic incursions onto landing runway in sufficient time to request clearance for or to take effective avoidance actions. Alternatively, controllers may detect pending incursions and conflicts in time to redirect the incurring traffic.

4. SF21 OPERATIONAL ENVIRONMENT

The SF21 operational environment is defined by communications, navigation and surveillance (CNS) applications that will enhance aeronautical operations. Seven of the nine planned enhancements will be accomplished either primarily or substantially by the use of ADS-B data. These seven enhancements can be considered to be enabled by ADS-B data and to define the SF21 operational environment for ADS-B. They are:

1. Improved Terminal Operations in Low Visibility
2. Enhanced See and Avoid
3. Enhanced En Route Air-To-Air Operations
4. Improved Surface Surveillance and Navigation for the Pilot
5. Enhanced Surface Surveillance for the Controller
6. ADS-B Surveillance in Non-Radar Airspace
7. ADS-B Surveillance in Radar Airspace.

The ADS-B SF21 OED will characterize airspace, traffic, and functional characteristics of aeronautical operations that involve the use of ADS-B data in this operational environment. The operational safety assessment (OSA) based on the OED will identify, rate the severity, and identify mitigations for hazards from and to operations that use ADS-B data in the SF21 environment defined by these enhancements.[13]

4.1 IMPROVED TERMINAL OPERATIONS IN LOW VISIBILITY

The SF21operational environment is defined for ADS-B in part by improved terminal operations in low visibility. Operations in this environment involve "use of automatic dependent surveillance broadcast (ADS-B), cockpit display of traffic information (CDTI) and traffic information services broadcast (TIS-B) during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish visual flight rule (VFR) approaches at lower minimums, thus maintaining VFR throughput longer. The crew will also be able to maintain better spacing during VFR and instrument flight rule (IFR) approaches."[14]

Terminal operations in low visibility that will use ADS-B data will involve:

[13] Technology, systems and facilities that will implement SF21 applications include the Global Positioning System (GPS), the Wide Area Augmentation System (WAAS), the Local Area Augmentation System (LAAS), area navigation equipment (RNAV), Cockpit Display of Traffic Information (CDTI), Station Keeping Aid and Display Generator, Traffic Information System-Broadcast (TIS-B) Processor, Transmitter and Receiver, TIS-B/ADS-B Correlated, Data Link Processor, Enhanced See and Avoid (ESA) Display and Alert Generator, ATC System Data Link Processor, Airport Surface Detection Equipment (ASDE), Overlay Map, Airport Map Data, Controller Airport Surface Display, ATC Automation Alerts, Weather Information Systems, Non-Radar Automation Facility, ATC Automation Facility, En Route and Terminal Radar, Fusion Processor, Air Route Traffic Control Center (ARTCC), and Air Traffic Control Tower (ATCT)/ Terminal Radar Approach Control (TRACON.

[14] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999. Pilot workload using CDTI for VFR at minimums may be a human factors safety issue.

- Enhanced visual approaches without positive identification procedures using ADS-B only. These approaches may involve aircraft use of ADS-B data for maneuvering, station keeping and collision avoidance.
- Enhanced visual approaches with positive identification procedures using ADS-B only. These approaches may involve aircraft use of ADS-B data for maneuvering and station keeping, and ATC use of ADS-B data for preventing flight into terrain, structures or flying objects.
- Enhanced visual approaches with positive ID procedures using ADS-B and TIS-B. This approach may involve the use of ADS-B data for ATS separation, simultaneous and other approach procedures with improved sequencing, and station keeping.
- Final approach spacing for visual approach. This operation may also involve the use of ADS-B data for ATS separation, simultaneous and other approach procedures with improved sequencing, and by the aircraft for maneuvering and station keeping.
- Final approach spacing for instrument approach. This operation may involve the use of ADS-B data for ATS separation, simultaneous and other approach procedures with improved sequencing, and by the aircraft for station keeping and collision avoidance.
- Enhanced parallel approaches in VMC/MVMC. These approaches may involve the use of ADS-B data for ATS and cooperative separation and for conformance monitoring and improved sequencing, and for maneuvering.

Table 1 summarizes the operational environment characterized by SF21 applications that will use ADS-B data for improved terminal operations in low visibility.

Table 1. Improved Terminal Operations In Low Visibility							
	Operations Using ADS-B Data						
	Surveillance of Aircraft in Flight						
	Separation					***Preventing Flight into Terrain, Structures and Flying Objects***	
SF 21 Applications[15]	***ATS***	***Cooperative***	***Other***	***Maneuvering***	***Station Keeping***		***Collision Avoidance***
3.1.1 Enhanced Visual Approaches (w/o Positive ID procedures using ADS-B only)				♦	♦	♦	
3.1.2 Enhanced Visual Approaches (w/ Positive ID procedures using ADS-B only)				♦	♦	♦	
3.1.3 Enhanced visual Approaches (w/ Positive ID procedures using ADS-B and TIS-B)	♦		♦	♦	♦		
3.2.1 Final Approach Spacing (for visual approach)	♦		♦	♦	♦		
3.2.2 Final Approach Spacing (for instrument approach)			♦		♦		♦
3.3 Enhanced Parallel Approaches in VMC/MVMC	♦	♦	♦	♦			

4.2 ENHANCED SEE AND AVOID

The ADS-B operational environment is defined by enhanced see and avoid operations. These operations involve the provision of "traffic information, electronically, to the cockpit using ADS-B, CDTI, and TIS-B. This will enable the pilot to maintain situational awareness of surrounding traffic."[16]

[15]Enhancement applications and their numerical designations are cited from *SF 21 Applications: Target Fiscal Years and Importance*, 15 December 1999.

[16] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

Enhanced see and avoid operations will use ADS-B data:

- To enhance visual acquisitions of other traffic for see-and-avoid (using ADS-B only and using ADS-B and TIS-B). "If traffic is sighted, the pilot must first assess the threat posed by nearby aircraft then, if necessary maneuver to avoid the other aircraft."[17] Enhanced visual acquisitions of other traffic for see-and-avoid involves the use of ADS-B data for maneuvering, and collision avoidance.
- For Conflict Situational Awareness. "This application builds on the safety benefits of using CDTI for traffic situation awareness by alerting pilots to potential conflicts with other aircraft, thereby facilitating timely action (if necessary) to prevent or end the conflict, enabling the pilot to take action to avoid the other aircraft if necessary."[18] Conflict situational awareness involves the use of ADS-B data for conflict management and collision avoidance.
- For Conflict Resolution. "This application expedites recovery from conflict events by advising maneuvers to resolve the conflict."[19] It involves the use of ADS-B data for conflict management.

Table 2 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for enhanced see and avoid.

Table 2. Enhanced See and Avoid

SF21 Applications	Operations Using ADS-B Data		
	Surveillance of Aircraft in Flight		
	Maneuvering	*Conflict Management*	*Collision Avoidance*
4.1.1 Enhanced Visual Acquisition of Other Traffic for See-and-Avoid (using ADS-B only)	♦		♦
4.1.2 Enhanced visual Acquisition of Other Traffic for See-and-Avoid (using ADS-B and TIS-B)	♦		♦
4.2.1 Conflict Situational Awareness		♦	♦
4.2.2 Conflict Resolution		♦	

4.3 ENHANCED EN ROUTE AIR-TO-AIR OPERATIONS

The ADS-B operational environment is defined by enhanced en route air-to-air operations. Operations in this environment involve the use of "CDTI and ADS-B to allow the delegation of the separation authority to the cockpit, resulting in increased efficiency. ADS-B and CDTI may also enhance safety in radar and non-radar airspace by

[17] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[18] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[19] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

assisting the pilot in maintaining situational awareness and visually acquiring proximate traffic and enhancing visual separation."[20]

Enhanced en route air-to-air operations will use ADS-B data to "extend pilot situational awareness of traffic that is beyond visual range by including distant traffic and airspace boundaries on the cockpit multi-function display."[21] This information will be applied:

- For closer climb and descent in non-radar airspace. Closer climb and descent in non-radar airspace will involve the use of ADS-B data for cooperative separation, maneuvering, and station keeping.[22]
- To extend see-and-avoid in non-radar airspace for special VFR. This application will also involve the use of ADS-B data for cooperative separation, maneuvering and station keeping.
- For extended see-and-avoid in non-radar airspace (for IFR). This application will involve the use of ADS-B data for cooperative separation, station keeping and conflict management.

Table 3 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for enhanced en route air-to-air operations.

Table 3. Enhanced En Route Air-to-Air Operations

	Operations Using ADS-B Data			
	Surveillance of Aircraft in Flight			
SF21 Applications	*Cooperative Separation*	*Maneuvering*	*Station Keeping*	*Conflict Management*
5.1 Closer climb and Descent in Non-Radar Airspace	♦	♦	♦	
5.2.1 Extended See-and-Avoid in Non-Radar Airspace (for special VFR)	♦	♦	♦	
5.2.2 Extended See-and-Avoid in Non-Radar Airspace (for IFR)	♦		♦	♦

4.4 IMPROVED SURFACE SURVEILLANCE AND NAVIGATION FOR THE PILOT

The ADS-B operational environment will be defined by applications that will improve surface surveillance and navigation for the pilot. These applications will enable "the pilot in the cockpit and the operators of equipped vehicles on the airport surface … to 'see' all the other traffic on a display with a moving map, resulting in safer and more efficient surface operations. Also, aircraft will be able to taxi using augmented global positioning

[20] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[21] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[22] "The current separation for climbs and descents range from 10 NMI to 10 minutes depending how far aircraft are from fixes or whether they are using DME. With ADS-B these procedures could be tightened up allowing the aircraft to reach their desired altitude faster and minimize fuel burn." (*Safe Flight 21 Functional Specification*; 87)

system (GPS) navigation and maps and in extremely low visibility conditions using local area augmentation system (LAAS)”[23]

Applications for improved surface surveillance for the pilot that will involve the use of ADS-B data are:

- ♦ Runway and final approach occupancy awareness using ADS-B only, and using ADS-B and TIS-B. These applications will provide pilots on final approach and on the runway with awareness of other aircraft that are on or approaching the runway,” and awareness of vehicles and obstructions.[24] ADS-B data will be used for maneuvering, station keeping, collision avoidance, surface traffic management, and surface incursion avoidance.
- ♦ Airport surface situational awareness and enhanced IMC airport surface operations (CAT3-B). ADS-B data will be used for maneuvering, station keeping, collision avoidance and surface traffic management.

Table 4 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for improved surface surveillance and navigation for the pilot.

Table 4. Improved Surface Surveillance and Navigation for the Pilot

	Operations Using ADS-B Data					
	Surveillance of Aircraft in Flight				**Surveillance of Surface Operations**	
SF21 Applications	***Maneuvering***	***Station Keeping***	***Preventing Flight into Terrain, Structures and Flying Objects***	***Collision Avoidance***	***Traffic Management***	***Surface Incursion Avoidance***
6.1.1 Runway and Final Approach Occupancy Awareness (using ADS-B only)	♦	♦	♦	♦	♦	♦
6.1.2 Runway and Final Approach Occupancy Awareness (using ADS-B and TIS-B)	♦	♦		♦	♦	
6.2 Airport Surface Situational Awareness	♦	♦		♦	♦	
6.3 Enhanced IMC Airport Surface Operations (CAT3-B	♦	♦		♦	♦	

4.5 ENHANCED SURFACE SURVEILLANCE FOR THE CONTROLLER

The ADS-B operational environment will be defined by applications that will improve surface surveillance and navigation for the controller. These applications will involve

[23] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999. ADS-B data will support incursion and collision avoidance, not navigation for surface maneuvers.

[24] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

equipping "aircraft and ground vehicles in the airport movement area with ADS-B using augmented GPS derived positions. For those locations with airport surface detection equipment (ASDE), this will provide the position, identification, and speed of all equipped aircraft. The local and ground controllers in the tower would then monitor the positions and speeds of all traffic" [25]

Applications for improved surface surveillance for controllers are:

- ♦ Enhanced presentation of surface targets to the controller. "Ground automation would receive GPS derived positions from equipped aircraft and ground vehicles on the airport movement area. For those locations with ASDE this will provide the position, identification, and speed of all equipped aircraft and fill gaps in ASDE coverage. The local and ground controllers in the tower would then monitor the position and speeds of all the traffic." [26] Operations using ADS-B data will include surface traffic management and surface incursion avoidance.
- ♦ Surveillance coverage at airports without ASDE. This application would involve the use of ADS-B data and multilateration of radar to provide coverage similar to ASDE at airports without ASDE. Operations using these data would include surface traffic management, including surface collision avoidance, and surface incursion avoidance.

Table 5 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for improved surface surveillance and navigation for the controller.

Table 5. Improved Surface Surveillance and Navigation for the Controller

	Operations Using ADS-B Data		
	Surveillance of Surface Operations		
SF 21 Applications	***Collision Avoidance***	***Traffic Management***	***Surface Incursion Avoidance***
7.1 Enhanced Presentation of Surface Targets to the Controller	♦	♦	♦
7.2 Surveillance Coverage at Airports without ASDE		♦	♦

4.6 ADS-B SURVEILLANCE IN NON-RADAR AIRSPACE

The ADS-B operational environment will be defined by applications that use ADS-B data "to provide additional surveillance coverage and fill gaps in radar coverage." [27] "In essence, information that will enhance a controller's and/or pilot's awareness of the identity, position, speed and heading of aircraft not under radar surveillance is distributed

[25] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[26] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[27] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

to pilots, non-radar control facilities and to ATC automation."[28] This application of ADS-B data includes:

- Expanded surveillance coverage in en route non-radar airspace, and expanded surveillance coverage in terminal areas without radar. "There are large portions of non-radar airspace in the lower altitudes of the domestic route environment as well as in remote areas inside and outside the US. ADS-B could provide a cost effective alternative for extending surveillance coverage in this airspace."[29] In terminal areas without radar coverage, ADS-B data will enable operators to apply radar-like separation procedures on approach or departure and to "monitor the progress and conformance of aircraft on non-radar procedural approaches."[30]

  Operations using ADS-B data for expanded surveillance in non-radar airspace and terminal areas without radar will include non-radar, cooperative and other separation, conflict management, airborne collision avoidance and prevention of flight into terrain, structures and flying objects.
- Expanded visual acquisition for tower controllers. ADS-B data will enable the display of aircraft positions and trajectories for traffic that is beyond visual range on tower displays. This will assist tower-pilot and tower-center coordination for VFR, SVFR and night operations "by showing the over-all multiple-aircraft pattern of operations in the airspace…."[31] Enhanced operations will include non-radar separation, airborne incursion avoidance, prevention of flight into terrain, structures and flying objects, and collision avoidance assistance from controllers.

Table 6 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for surveillance in non-radar airspace.

[28] *Safe Flight 21 Functional Specification*, 7 September 1999; 135.

[29] *Safe Flight 21 Functional Specification*, 7 September 1999; 137.

[30] *Safe Flight 21 Functional Specification*, 7 September 1999; 137.

[31] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

Table 6. ADS-B Surveillance in Non-Radar Airspace							
	Operations Using ADS-B Data						
	Surveillance of Aircraft in Flight						
	Separation						
SF21 Applications	***ATS***	***Non-Radar***	***Cooperative***	***Other***	***Conflict Management***	***Airborne Incursion Avoidance***	***Preventing Flight into Terrain, Structures and Flying Objects***
8.1 Expanded Surveillance Coverage in En Route Non-Radar Airspace [Note possible phases: enhanced flight following / improved S&R / verify position for procedural separation / reduced proc. sep. / radar-like sep.]		♦	♦	♦	♦	♦	♦
8.2 Expanded Surveillance Coverage in Terminal Areas without Radar		♦	♦	♦	♦	♦	♦
8.3 Expanded Visual Acquisition for Tower Controllers		♦				♦	♦

4.7 ADS-B SURVEILLANCE IN RADAR AIRSPACE

Applications that will "integrate ADS-B data with radar and conflict alert to determine if separation standards can be reduced" will also define the ADS-B operating environment. "Ultimately, ADS-B will be integrated with advanced decision support automation."[32] "ADS-B and beacon radar reports will be processed and the data will be integrated to improve accuracy and update rate compared to beacon radar. In addition, when ADS-B data and radar data exists on the same target, this information will be used to automatically calibrate the radar thus reducing radar bias errors and ADS-B/Radar registration errors. This will also improve the radar tracking accuracy on radar only targets. Finally, when there is multiple radar coverage on a single target without ADS-B capability, this multi-radar information will be fused to improve the surveillance of that target."[33]

Use of ADS-B data for surveillance in radar airspace will:

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[32] *Draft Safe Flight 21 Operational Enhancement Applications Concept of Operations and Concept of Use*, 1 December 1999.

[33] *Safe Flight 21 Functional Specification*, 7 September 1999; 135.

- Enhance enroute surveillance for current separation standards. This will facilitate ATS and other separation, conflict management and airspace incursion avoidance.
- Enhance terminal surveillance for current separation standards. This will also facilitate ATS and other separation, conflict management and airborne incursion avoidance operations, and the prevention of flight into terrain, structures and other flying objects.
- Enable reduced separation standards. Reduced separation standards will impact ATS and other separation by air traffic control.

Table 7 summarizes the operational environment characterized by SF21 applications that will involve the use of ADS-B data for surveillance in radar airspace.

Table 7. ADS-B Surveillance in Radar Airspace

	Operations Using ADS-B Data				
	Surveillance of Aircraft in Flight				
	Separation				
SF21 Applications[34]	*ATS*	*Other*	*Conflict Management*	*Airborne Incursion Avoidance*	*Preventing Flight into Terrain, Structures and Flying Objects*
9.1 ADS-B Enhancement of En Route Surveillance (for current separation standards)	♦	♦	♦	♦	
9.2 ADS-B Enhancement of Terminal Surveillance (for current separation standards)	♦	♦	♦	♦	♦
9.3 ADS-B Reduced Standards	♦	♦			

5. IMPACT

ADS-B will provide surveillance data to airborne and surface-maneuvering aircraft, and to surface vehicle operators, controllers and aviation operations facilities on the ground. This information can be used to provide surveillance services for a wide range of airborne and surface maneuvering, flight following and control requirements across all operating contexts. It could greatly extend and perhaps conceivably replace current ATS surveillance in a number of areas.

As delineated in the *NAS Architecture*, Version 4, the FAA plans to modernize the surveillance system hardware and software infrastructure with common operating systems and services. Once the infrastructure is modernized, new flight data management and surveillance data processing systems will use data from ADS broadcasts. The new systems will support conflict detection and resolution, sequencing to terminals, and optimal descent profiles. Modernization of surveillance data acquisition and processing capabilities with ADS-B is intended to lead to more flexible airspace sectors with more dynamic boundaries than at present. SF21 is the initial environment for aeronautical operations enhanced by the use of ADS-B data.

[34] Enhancement applications and their numerical designations are cited from *SF21 Applications: Target Fiscal Years and Importance*, 15 December 1999.

The availability of ADS-B data is also a central element in the extension of flexible routing options. These include a Free Flight environment in which separation would be managed cooperatively between pilots and controllers in the enroute, remote, and oceanic environments and for selected terminal operations.

ADS-B data and associated map displays in airport service vehicles in addition to Air Traffic Control Tower (ATCT) systems upgrades outlined in the *ATS CONOPS-2005* and *NAS Architecture* Version 4 will enable greater overall control of airport surface vehicle movements. In the time frame envisioned in the *ATS CONOPS-2005*, movement of aircraft on the airport surface might be pre-planned, integrated with flight information profiles, and monitored and adjusted with the use of ADS-B data. Future ADS-B position and movement data will provide universal dependent surveillance of surface vehicle movements for separation assurance at equipped airports.

The ultimate operational impact of ADS-B and other planned air traffic service enhancements that will use ADS-B surveillance data is air-to-air based separation management and cooperative procedures, enabling progress toward the Free Flight environment beyond SF21. This progress might be accompanied by more efficient terminal and airport operations, enhanced by the use of ADS-B data to optimize flow management and throughput. The employment of ADS-B data for sequencing and surface separation management might help avoid the potential congestion that might be otherwise expected from increasing capacity demands on airport surface facilities in a Free Flight environment. It would also result in commensurate improvements in safety.

APPENDIX C: OPERATIONAL HAZARD ASSESSMENT

HAZ: 100	PROGRAM: ADS-B	Capability:	ALL Surveillance
TITLE: Corruption of Identity of vehicles (air or ground)information into local ADS-B		DomainName:	Aircraft
		SubSystemName:	CNS Avionics
FUNCTION NAME:	Other Information	Service	ATC Advisory

DESCRIPTION This function is the input, retention, and output of information required for some or all ADS-B operations. The function of Vehicle identification information is to inform other operators using the ADS-B system of the identify of the local ADS-B unit or vehicle. This function's output is an input to the local ADS-B unit. Once processed in the local ADS-B unit it is output as a broadcast signal to the rest of the participants in the ADS-B system. This permits other ADS-B operators to direct communication to the local ADS-B vehicle as needed.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Loss of IDENTITY information from the ADS-B network for a single vehicle.

False or duplicate IDENTITY information passed onto the ADS-B network.

HAZARD CAUSE: Software anomalies in ADS-B data processing
Human error in entering the data.
Functional faults with the data entry subsystems.

EXISTING CONTROLS Existing RADAR coverage. ADS-B in most cases is intended as a supplement to Secondary Radar. Identification through the transponders while under Radar coverage.

Communication. Voice communication permits the controllers and pilots to determine via radio communication the identity of targets.

HAZARD EFFECT: In the case of a loss of IDENTITY, the ATC's workload would increase as she directed traffic around the unknown aircraft.

If the IDENTITY passed was false information it is possible that ATC would attempt communication with the vehicle using the incorrect IDENTITY. One outcome is that the ATC would not receive a response and continue to attempt to make contact with the unknown target. ATC would still direct other aircraft around the target.

Duplicate of AC ID will be resolved by the ATC. This will result in a slight increase in workload as the ATC resolves the situation.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. When under secondary radar coverage, the Aircraft ID of the target shall be displayed next to the target symbol on the ATC display.

2. The ADS-B system shall require the crew/operator to either enter or confirm the vehicle's ID before initialization of ADS-B for that vehicle.

3. The manufacturers shall develop initial qualification and recurrent training standards for operators of the ADS-B system.

4. Procedures shall require the ATC to resolve duplicate targets.

5. Procedures using ADS-B shall include positive measures to ensure correct airport service vehicle identification

6. ADS-B displays shall allow ATC to highlight individual targets for correct sequencing.

7. Procedures shall include the provision for reduction of service vehicle traffic during low visibility conditions.

8. If CDTI is to be used for airport surface surveillance and navigation in low VCE's the all vehicles (air and ground) shall be equipped with ADS-B and have a unique identification.

THRESHOLD: Probable

OBJECTIVE: Remote

HAZ:	101	PROGRAM:	ADS-B	Capability:	ALL Surveillance

TITLE: Corruption of air vehicle velocity and ROC information into local ADS-B.

DomainName: Aircraft

SubSystemName: CNS Avionics

FUNCTION NAME: Other Information

Service: ATC Advisory

DESCRIPTION: This function is the input of vehicle velocity and rate of climb (ROC) information into the local ADS-B processing function in the local ADS-B unit. Once processed in the local ADS-B unit the information is output as a broadcast signal to the rest of the participants in the ADS-B system. The purpose is to provide local ADS-B unit/vehicle velocity and ROC information to other operators in the ADS-B system. This information is used to provide the local vehicle vertical velocity state information to the other operators in the ADS-B system. This information is also used by the other operators to predict future vehicle positions and closure rates with other participants or known objects such as airports, runways, airways, approaches, and obstacles in the ADS-B system.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: False velocity information for a single remote air vehicle. It is assumed the vehicle position is accurate.

HAZARD CAUSE:

Functional faults in aircraft air data sensors or system. (for example, ice accretion on the pitot tubes).

Functional faults in the ADS-B local unit.

Software anomalies in the Air data system or ADS-B processing.

Non ADS-B equipped aircraft.

EXISTING CONTROLS:

Mode A/C/S, radar, TCAS, TIS-B, air-ground communications.

Micro EARTS uses past position to display vertical velocity.

HAZARD EFFECT:

ATC and other pilots using the ADS-B system would not know the aircraft's correct velocity.

In the case of a loss of information ATC could contact the vehicle operators for the information, increasing frequency congestion and workload.

In the case of incorrect velocity, it is possible that the information could lead to ATC increased workload.

The worst case is the increase workload during the resolution of the conflict.

Potential Severity: Minor

RQMTS & RECOMMENDATIONS:

1. The ADS-B system shall use alternate and independent sources for velocity information for each airborne target vehicle.

2. The ADS-B system shall display track information for each target such that the operators will be able to determine the past path of the target.

3. The ADS-B system shall display information indicating whether the airborne target is climbing or descending.

4. ASDE-X shall be compatible ADS-B.

5. ATC automation shall compare velocity information from the A/C with the algorithm that computes ground velocity from the present and past position returns. The ADS-B shall not transmit information that disagrees with the integrity indicator by a TBD amount and shall employ functional and data integrity tests on startup and periodically during operation.

6. The ADS-B display shall indicate A/C altitude.

THRESHOLD: probable

OBJECTIVE: remote

HAZ:	102	PROGRAM:	ADS-B	Capability:	Surveillance: All
TITLE:	Corruption of "known object" position data into local ADS-B subsystem.			DomainName:	All ATC
				SubSystemName:	CNS Avionics
FUNCTION NAME:	Other Information			Service	ATC Advisory

DESCRIPTION: This function is the input, retention, and output of locations of known objects or entities in the NAS. Known objects in this context include airspace, airways, airports and runways, taxiways, and significant obstacles to flight. Known object position information is used in conjunction with vehicle state vector information to predict if an air vehicle is at risk of collision with the object; or is used to determine if the air and ground vehicles under surveillance are in the correct relative position in relation to the known objects. Airway/runway position: This information is used to determine vehicle position relative to the airway, approach path, runways, and taxiways. Airspace locations and type. This information is used to determine vehicle relative locations in relation to airspace types, including special use airspace and class A through G airspace.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS:

Loss of "known object" position data.

Incorrect or false position displayed.

HAZARD CAUSE:

Data entered into the system incorrectly.

Software anomalies in the ADS-B system.

Functional faults in the objects ADS-B transmission.

EXISTING CONTROLS:

Mode A/C/S radar, TCAS, ASDE-X if properly used with a "differences comparator" that cross-checks inputs from multiple sources.

Use of published approaches, lighting, aeronautical charts, GCAWS

HAZARD EFFECT:

ATC and pilots using the ADS-B system would not see the objects correct location on the ADS-B display.

When in visual contact (under VMC conditions) with a physical object, an error will be apparent to the air crew and ATC.

If operating in low visual cue environments (VCE), and using ADS-B for separation there is the potential that a controller or aircrew could see a false target or not see a real target. Published approach procedures to assure adequate clearance. Such a situation would significantly increase workload as the operators attempt to resolve the situation.

Potential Severity: Major

RQMTS & RECOM-MENDATIONS:

1. Airports/runways/taxiways shall be marked, located, displayed in the ADS-B system.

2 Obstacles requiring lighting in accordance with existing FARs shall be marked, located, displayed in the ADS-B system.

3. The ADS-B display shall indicate the nature, location (relative and actual lat/long), name, MSL and AGL altitude of the object.

4. The A/C displays should include ability to overlay the ADS-B info on a moving map display consistent with other charts.

5. The ATC display shall include the ability to overlay the ADS-B onto a map display covering the airport ops and terminal areas consistent with terminal area charts.

6. The system data containing "known object" information shall comply with existing validation, verification, qualification, and current requirements in the FAR as they apply to aeronautical charts.

7. The ADS-B system shall employ data integrity checks. An alternative and independent measure of known position data shall be used to check the integrity of the ADS-B data.

THRESHOLD: Remote

OBJECTIVE: Extremely Remote

HAZ: 103 PROGRAM: ADS-B Capability: Surveillance: All

TITLE: Corruption of "vehicle intent" information into local ADS-B. DomainName: Aircraft, ground vehicle

SubSystemName: CNS Avionics

FUNCTION NAME: Other Information

Service ATC Advisory

DESCRIPTION "Vehicle intent" information is used to assist and enhance the understanding of target vehicle operators future intentions by controllers and pilots participating in the ADS-B system. This information is used by the controllers and participating pilots to plan their future actions appropriately to maintain separation and traffic flow management.

WORST CASE: Low VCE in the Airport Movement Area (AMA) Low UCE in non-radar environment

HAZARD CONDITIONS: Loss of "vehicle intent" information to other participants in the ADS-B system.

False or incorrect "vehicle intent" information to other participants in the ADS-B system.

HAZARD CAUSE: Human error inputting the data into the ADS-B system.

Functional faults with ADS-B equipment.

Software anomalies in the ADS-B processing.

EXISTING CONTROLS Comm verification by ATC.

HAZARD EFFECT: Loss of the information would result in negligible safety effects.

False information has the potential to cause ATC's and other operators in the system to make incorrect decisions in planning future course based on the false information. This has the potential to cause a minor increase in workload, since the vehicles actual position and velocity will still be known.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: 1. The ADS-B system shall compare intent and position information. If the airborne target position information is outside a 4 mile limit, the system shall notify the operator.

2. If ADS-B vehicle intent is going to be used for ground clearances then ADS-B shall have specific routes on the ground or be able to assign that route to ADS-B aircraft and detect when an aircraft deviates from that route by amounts specified in AC 150/5300-13 (table 4-1).

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 104 PROGRAM: ADS-B Capability: Surveillance: All

TITLE: Corruption of vehicle navigation solution as input to the local ADS-B unit.

DomainName: Aircraft, ground vehicle

SubSystemName: CNS Avionics, airport ground

FUNCTION NAME: Navigation

Service ATC Separation Assurance

DESCRIPTION The navigation solution tells the vehicle where it is using an earth centered system such as a UTM or LAT/LONG coordinates. This function's output is an input to the local ADS-B unit and includes position, heading, and ground velocity. Once processed in the local ADS-B unit it is output as a broadcast signal to the rest of the participants in the ADS-B system.

WORST CASE: No Radar coverage and Low visual cue environement (IMC and/or night)

HAZARD CONDITIONS: Loss of vehicle (air and ground) location information.

False or incorrect vehicle location information.

HAZARD CAUSE: Functional faults in the navigation system.

Software anomalies in the navigation or ADS-B software.

Jamming of Nav signal

Inaccurate location determination (low performance)

aircraft are depicted on the CDTI as the same size regarless of actual size.

EXISTING CONTROLS radar, TCAS, GCAWS, multiple Nav systems

HAZARD EFFECT: ATC's, pilots, and other operators will be unable to accurately determine the vehicles relative location using ADS-B.

In the worst case condition, ATC may issue inappropriate clearances based on false information leading to the potential for a collision. This is considered potentially catastrophic.

Potential Severity: Catastrophic

RQMTS & RECOM-MENDATIONS: Note: Many navigation systems employ an uncertainty or error sphere that indicates the accuracy of the system. ADS-B could use this information to display the accuracy of the target system.

1. ADS-B system shall cross check position data with vehicle velocity data and if the comparison indicates an error in the position data, the system shall indicate a possible error to all the operators.

2. The ADS-B airborne avionics shall employ redundancy cross checking for navigation sources.

3. Procedures for use of the ADS-B in high density gate, alley, or ramp areas shall include provisions for alternative means of aircrat sepatation.

4. It must be verified by test or assessment, that the likelihood of this hazard resulting in a catastrophic mishap is extremely improbable.

THRESHOLD: Extremely Improbable

OBJECTIVE:

HAZ: 106	PROGRAM: ADS-B	Capability:	Surveillance: All
TITLE: Loss of local ADS-B data/signal broadcast		DomainName:	National Airspace System
		SubSystemName:	CNS Avionics
FUNCTION NAME:	Other Information	Service	ATC Advisory

DESCRIPTION The broadcast function transmits the local ADS-B information to the other participants in the ADS-B system via RF transmission.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Loss of ADS-B signal.

HAZARD CAUSE:
Low signal strength.
Software anomalies in ADS-B system.
Failure of ADS-B subsystem.
Functional faults in the ADS-B transmission.
EMI, Ice accumulation, physical antenna damage.

EXISTING CONTROLS
TCAS.
GPWS or EGPWS for known objects.
ATC communications for ground vehicles.
Radar
VFR procedures (non-radar procedures assumes low-density traffic).

HAZARD EFFECT: These causes can lead to the loss of the ADS-B signal. This will result in a slight increase in workload as the ATC takes procedural steps to compensate.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. The ADS-B system shall employ data checking algorithms for information that is deemed critical - I.e. could lead to catastrophic or hazardous conditions.

2. The ADS-B system shall detect loss of signal and/or function.

3. The ADS-B system shall be compatible with other on-board electronics such that it does not interfere with critical systems nor is susceptible to interference by other on-board systems and conform with FAA Electromagnetic Effects requirements.

4. The ADS-B system shall be compatible with the expected EM environment throughout the system envelope.

5. The ADS-B system shall be compatible with operations in the expected weather environment in accordance with the system certification.

6. The ADS-B system shall be compatible with ground RF emitters.

7. It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than probable.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 108	PROGRAM: ADS-B	Capability:	Surveillance: All
TITLE: Loss of ADS-B Information display to operators.		DomainName:	ALL
		SubSystemName:	All
FUNCTION NAME:	Display	Service	ATC Advisory

DESCRIPTION: The display function uses the ADS-B processing output as an input. The output of this function is the information displayed to the operator on a display screen that depicts the local vehicle's position relative to terrain, other ADS-B targets, and known objects/entities participating in the ADS-B system.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Loss of or obviously false information displayed to the operators.

The assumption is that the information into the display is correct and that corruption takes place within the display unit function, i.e., too bright, too dim, etc.

HAZARD CAUSE:
Functional failure of display.
Incorrect data encoding to display processor.
Functional failure of processor-display connection.
Software anomaly.
Environmental conditions.

EXISTING CONTROLS: TCAS, EGPWS, ATC communications, procedures, backup displays.

ADS-B systems and displays in other locations (I.e. If the ATC loses ADS-B the A/C will still have ADS-B available.

HAZARD EFFECT: Increased pilot and/or ATC workload.

Bright displays can cause a loss of night vision and a greater workload.

Loss of display or frozen display.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. The ADS-B system on the ground shall have alternative, independent and/or redundant means for the display of the ADS-B information.

2. The ADS-B display shall be compatible with day and night illumination within both air and ground vehicles as well as ATC facilities.

3. The ADS-B display shall be capable of displaying various ranges (radials from the center of the target) as appropriate to the application.

4. The CDT shall have a selectable "off" mode.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 109 | PROGRAM: ADS-B | Capability: Surveillance: ALL

TITLE: Operator error integrating ADS-B information and ATC communications related to ADS-B surveillance

DomainName: All

SubSystemName: All

FUNCTION NAME: Human

Service: ATC Advisory

DESCRIPTION: The crew's function in the ADS-B system is to integrate the information from the display function output with the current aircraft state vector, situation, procedures and regulations, and ATC directions. The output of this function is the human decision and control of the air vehicle.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Operator difficulty with interpreting and integrating ADS-B information regarding the real situation.

HAZARD CAUSE:
Display difficult to interpret (cluttered) e.g. Display location not optimum.
Display contrast not adequate considering worst case external lighting.
Human error in mis-hearing of comm information, no readback correction.
Inadequate pilot training.
Inadequate or unworkable procedures
TIS-B or TCAS do not agree with ADS-B information.
ADS-B information does not agree with ATC instructions.
ADS-B data displayed on CDTI.

EXISTING CONTROLS:
TCAS, EPGWS, ATC communications.
Radar, moving maps, FMS, Comm.

HAZARD EFFECT:
Reduced margin of safety leading to an increased crew or ATC workloads.

Confusion on the part of the operators can lead to significant increase in pilot and/or ATC workload.

Reduced margin of safety in ADS-B only environment.

Incorrect object Identified

Potential Severity: Major

RQMTS & RECOM-MENDATIONS:

1. The ADS-B system shall incorporate a moving map system in which the ADS-B targets and the local ADS-B information are displayed and referenced to the moving map coordinates.

2. The ADS-B display shall be located within the vehicle or facility to optimize visibility and interpretation and to prevent spatial disorientation during critical maneuvers.

3. For the ATC display the ADS-B horizontal position and velocity shall be referenced to the ground, i.e. ground speed and course.

4. The ADS-B system shall employ FAA display symbology standards when defining target symbology.

5. The ADS-B altitude shall use both pressure altitude (I.e MSL) and ground (I.e. AGL) references. Both shall be displayed, however the AGL altitude may be selectable for de-cluttering. Both altitude types must be clearly distinguishable from each other.

6. The FAA should evaluate in simulation the impact to crew and ATC workload with the re-allocation of rules and responsibilities that are proposed with ADS-B operation in MOPS DO-242.

7. Procedures shall require pilots to follow TCAS warnings.

THRESHOLD: remote

OBJECTIVE: extremely remote

HAZ: 110 PROGRAM: ADS-B

TITLE: Corruption of Sensor fusion function/data

FUNCTION NAME: Other Sensors

Capability: Surveillance: ALL

DomainName: All ATC

SubSystemName: Surveillance

Service ATC Separation Assurance

DESCRIPTION Sensors data will be fused (including ADS-B surveillance information) and displayed to the air traffic controller.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Radar coverage.

HAZARD CONDITIONS:
High density traffic.
Multiple targets.
Mixed equipage.
Loss or corruption of secondary surveillance radar data that is fused with ADS-B data.

HAZARD CAUSE:
Software anomalies in fusion algorithms.
Corrupted data in fusion logic.
Corrupted transmission of data into and/or out of fusion processor.
Faulty comparator logic.
Different data update rates could cause "ghost" targets.

EXISTING CONTROLS
ATC reversion to radar only.
TCAS, EGPWS
controller observation of disruption in display.
COMM

HAZARD EFFECT:
Faulty data is displayed and decisions are made using the faulty data.
Disrupted traffic flow.
Increased operator workload.
Increased position uncertainty below radar ceiling.

Potential Severity: Major

RQMTS & RECOM-MENDATIONS:

1. The ADS-B fusion system shall minimize (less than 3%) "ghost" targets including those due to reflections and different update rates of the various sensors.

2. The ADS-B fusion function algorithms shall be designed to present the most accurate altitude, velocity and position data on the display.

3. The ATC system shall have a means of detecting corrupted target data and diplaying a warning to the ATC.

4. The ATC end system shall have means to monitor and alert offor corrupted TIS and TIS-B data.

5. The ADS-B system shall be compatible with other integrated systems such as ASDE-3, ASDE-X, ASR-9 & 11, etc.

THRESHOLD: remote

OBJECTIVE: extremely remote

HAZ: 500 PROGRAM: ADS-B Capability: Surveillance in Non-radar

TITLE: Undetected misleading ADS-B information from a vehicle DomainName: All ATC

FUNCTION NAME: ADS-B Processing SubSystemName: CNS equipment and

Service ATC Separation Assurance

DESCRIPTION The function is to determine the position, altitude, and vectoring information for purposes of air and ground traffic surveillance and control.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including final approach spacing for instrument approach, station keeping, and collision avoidance, and enhanced visual approaches.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot, including airport surface situational awareness and enhanced IMC airport surface operations (CAT3-B), maneuvering, station keeping, collision avoidance and surface traffic management, runway and final approach occupancy awareness.

OSED 4.5 Enhanced Surface Surveillance for the Controller, including surveillance coverage at airports without ASDE for surface traffic management, including surface collision avoidance and surface incursion avoidance.

OSED 4.6 ADS-B Surveillance in Non-Radar Airspace, including expanded surveillance coverage in en route non-radar airspace, and expanded surveillance coverage in terminal areas without radar, including terminal area radar-like separation procedures on approach or departure, non-radar, cooperative and other separation, conflict management, and airborne collision avoidance and prevention of flight into terrain, structures and flying objects.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Undetected misleading aircraft ID, position, altitude, or vectoring ADS-B information from an vehicle.

HAZARD CAUSE: This hazardous condition could be caused by equipment failures in the transmitting vehicle or signal interference in the transmission media in combination with failures to detect the misleading information by other aircraft or ground equipment, as well as the transmitting vehicle.

--Failures of transmitting aircraft's ADS-B equipment. Failures in controller equipment, other surface vehicle equipment, or other aircraft equipment to detect misleading information from transmitting vehicle.
--Failures in transmitting aircraft's navigational equipment or other sensors and systems which provide information to the transmitting vehicle's ADS-B system.
--Failure to procedurally report transmitting vehicle's ID, speed, altitude, position, and intent from properly operating on-board navigational equipment and other on-board sensors and systems.

EXISTING CONTROLS Procedural based on communication, and on-board vehicle navigational, altitude, heading, and speed sensors, etc.
RADAR, TCAS, EPGWS, Visual Flight Rules, Instrument Flight Rules.

HAZARD EFFECT: ATC makes decisions based on erroneous position or altitude, and vector info, and may provide erroneous clearance/directions to the aircraft or other vehicle. In non-radar, low visual cue environments, this may result in a collision between vehicles, or clearance into a ground obstacle (CFIT.) Effect could include collision with structures, vehicles, or other aircraft during surface movement.

In a non-radar environment ATC will not know the target is there.

Potential Severity: Catastrophic

RQMTS & RECOM-MENDATIONS: Remarks:

This hazard would be most severe when extending radar-like positive ATC into non-radar environments or to non-radar covered aircraft in low visual cue environments.
Candidate requirements:

1. If ADS -B is to be used for airport surveillance and ground movement, then the accuracy of the targets and objects on the display must be within the requirements for runway and taxi areas widths in AC

150/5300-13 (table 4-1). This may mean that aircraft taking advantage of surface movement in LVC environments may require WAAS or LAAS equipage to gain the required accuracy.

2. Check of NAV data integrity.

3. Velocity vector data integrity comparison function based on 2 independent sources (e.g., GPS derived velocity vector checked against airspeed, heading, and rate of climb indicators.

4. Tracking on ATC display should be ON.

5. Limiting function in ADSB system, to limit position "jumping" within 4.5 seconds. Should be based on independent speed check or independent NAV source.
6. Procedure in checklist for entering correct ID for flight.

7. On system initiation, system requires crew to confirm or enter new call sign before it will operate.

8. Check of altitude data integrity, using either alternate and independent pressure altitude sources with a checking function, or checking function between AGL altitude from GPS and one pressure altitude source.

THRESHOLD: extremely improbable

OBJECTIVE:

HAZ: 501 PROGRAM: ADS-B Capability: Surveillance in Non-radar

TITLE: Detected misleading ADS-B information from a vehicle. DomainName: Aircraft

SubSystemName: Aircraft Systems

FUNCTION NAME:

Service ATC Advisory

DESCRIPTION The function is to determine the position, altitude, and vectoring information for purposes of air and ground traffic surveillance and control.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including final approach spacing for instrument approach, station keeping, and collision avoidance, and enhanced visual approaches.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot, including airport surface situational awareness and enhanced IMC airport surface operations (CAT3-B), maneuvering, station keeping, collision avoidance and surface traffic management, runway and final approach occupancy awareness.

OSED 4.5 Enhanced Surface Surveillance for the Controller, including surveillance coverage at airports without ASDE for surface traffic management, including surface collision avoidance and surface incursion avoidance.

OSED 4.6 ADS-B Surveillance in Non-Radar Airspace, including expanded surveillance coverage in en route non-radar airspace, and expanded surveillance coverage in terminal areas without radar, including terminal area radar-like separation procedures on approach or departure, non-radar, cooperative and other separation, conflict management, and airborne collision avoidance and prevention of flight into terrain, structures and flying objects.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Detected misleading aircraft ID, position, altitude, or vectoring ADS-B information from a vehicle.

This hazard would be most severe when extending radar-like positive ATC into non-radar environments or to non-radar covered aircraft in low visual cue environments.

HAZARD CAUSE: Failures in transmitting aircraft's ADS-B equipment, or failures in sensor inputs to ADS-B, or signal interference in transmission media.

EXISTING CONTROLS Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc.

HAZARD EFFECT: The false ADS-B info is detected. Result is a minor increase in workload ATC and crew to compensate.

Potential Severity: Minor

RQMTS & RECOMMENDATIONS:

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 502	PROGRAM:	ADS-B	Capability:	ALL Surveillance	
TITLE: Undetected loss of ADS-B information from a vehicle.				DomainName:	All ATC
			SubSystemName:	National Airspace System	
FUNCTION NAME:			Service	ATC Advisory	

DESCRIPTION The function is to determine the position, altitude, and vectoring information for purposes of air and ground traffic surveillance and control.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including final approach spacing for instrument approach, station keeping, and collision avoidance, and enhanced visual approaches.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot, including airport surface situational awareness and enhanced IMC airport surface operations (CAT3-B), maneuvering, station keeping, collision avoidance and surface traffic management, runway and final approach occupancy awareness.

OSED 4.5 Enhanced Surface Surveillance for the Controller, including surveillance coverage at airports without ASDE for surface traffic management, including surface collision avoidance and surface incursion avoidance.

OSED 4.6 ADS-B Surveillance in Non-Radar Airspace, including expanded surveillance coverage in en route non-radar airspace, and expanded surveillance coverage in terminal areas without radar, including terminal area radar-like separation procedures on approach or departure, non-radar, cooperative and other separation, conflict management, and airborne collision avoidance and prevention of flight into terrain, structures and flying objects.

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Undetected loss of aircraft ID, position, altitude, or vectoring ADS-B information from an aircraft in low visual cue environment.

HAZARD CAUSE: This hazardous condition could be caused by equipment failures in the transmitting aircraft in combination with failures to detect the misleading information by other aircraft or ground equipment, as well as the transmitting aircraft.

--Failures of transmitting aircraft's ADS-B equipment. Failures in controller equipment, other surface vehicle equipment, or other aircraft equipment to detect misleading information from transmitting aircraft.
--Failures in transmitting aircraft's navigational equipment or other sensors and systems which provide information to the transmitting aircraft's ADS-B system.
--Failure to procedurally report transmitting aircraft's ID, speed, altitude, position, and intent from properly operating on-board navigational equipment and other on-board sensors and systems.

EXISTING CONTROLS Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc.

HAZARD EFFECT: Significant increase in workload, Significant reduction in safety margins or functional capacity. Increase is due to ATC and pilot increase in communication demands and operational demands in resolving the problem.

Potential Severity: Major

RQMTS & RECOM-MENDATIONS: Remarks:

This hazard would be most severe when extending radar-like positive ATC into non-radar environments or to non-radar covered aircraft in low visual cue environments.

Candidate requirements:

1. The occurrence of this hazard should be remote (or improbable)r.

2. Retain procedural requirements for flights in non-radar airspace.

3. The ADS-B avionics should warn the crew if the ADS-B set ceases to transmit.

THRESHOLD: remote

OBJECTIVE: extremely remote

HAZ: 503 PROGRAM: ADS-B Capability: ALL Surveillance

TITLE: Detected loss of ADS-B information from a vehicle. DomainName: All ATC

SubSystemName: Aircraft Systems

FUNCTION NAME:

Service ATC Advisory

DESCRIPTION The function is to determine the position, altitude, and vectoring information for purposes of air and ground traffic surveillance and control.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including final approach spacing for instrument approach, station keeping, and collision avoidance, and enhanced visual approaches.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot, including airport surface situational awareness and enhanced IMC airport surface operations (CAT3-B), maneuvering, station keeping, collision avoidance and surface traffic management, runway and final approach occupancy awareness.

OSED 4.5 Enhanced Surface Surveillance for the Controller, including surveillance coverage at airports without ASDE for surface traffic management, including surface collision avoidance and surface incursion avoidance.

OSED 4.6 ADS-B Surveillance in Non-Radar Airspace, including expanded surveillance coverage in en route non-radar airspace, and expanded surveillance coverage in terminal areas without radar, including terminal area radar-like separation procedures on approach or departure, non-radar, cooperative and other separation, conflict management, and airborne collision avoidance and prevention of flight into terrain, structures and flying

WORST CASE: Low Visual Cue Environment (VCE) (e.g IMC and/or night) in Non Radar coverage.

HAZARD CONDITIONS: Detected loss of aircraft ID, position, altitude, or vectoring ADS-B information from an aircraft in low visual cue environment.

HAZARD CAUSE: Aircraft equipment failures or signal interference in transmission media.

EXISTING CONTROLS Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc.

HAZARD EFFECT: Slight increase in workload to ATC and flight crew.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: Remarks:

This hazard would be most severe when extending radar-like positive ATC into non-radar environments or to non-radar covered aircraft in low visual cue environments.

Candidate requirements:

1. Retain procedural requirements for flights in non-radar airspace.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 504	PROGRAM: ADS-B	Capability:	ALL Surveillance
TITLE: Loss of TIS-B information		DomainName:	Terminal
		SubSystemName:	National Airspace System
FUNCTION NAME:		Service	ATC Advisory

DESCRIPTION: The function is to determine the position, altitude, and vectoring information of other aircraft for purposes of traffic situational awareness.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including use of automatic dependent surveillance broadcast (ADS-B), cockpit display of traffic information (CDTI) and traffic information services broadcast (TIS-B) during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish visual flight rule (VFR) approaches at lower minimums.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot including runway and final approach occupancy awareness (using ADS-B and TIS-B).

WORST CASE: Low Visual Cue Environment (VCE) in Radar Coverage

HAZARD CONDITIONS: Loss of a portion of displayed traffic. Traffic still displayed would be either ADS-B equipped aircraft (aircraft to aircraft display), or squitter aircraft under secondary radar surveillance (common cause aircraft ADS-B failures.)

Assumption made is that TIS-B supplies:
--ground course
--altitude
--ID
--position

HAZARD CAUSE: This hazard could be caused by equipment failures in ground system, or transmission signal interference or blocking, or a common cause failure affecting all aircraft in a service volume e.g., GPS outage.)

EXISTING CONTROLS: Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc. Only the airborne generators will lose the TIS-B info. ATC will retain full capability for surveillance

HAZARD EFFECT: ADS-B equipped aircraft will lose their non-ADS-B targets or ADS-B targets. Slight reduction in safety margins or functional capability. Slight increase in flight crew workload due to loss of a portion of display targets.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: Candidate requirements:

1. Maintain current radar displays as alternate to TIS-B.

2. Assure that ADS-B is independent of secondary surveillance function such that loss of secondary surveillance function does not result in loss of ADS-B information to ATC.

3. Loss of the TIS-B function should not result in loss of the ADS-B function on board the aircraft.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 505	PROGRAM: ADS-B	Capability:	ALL Surveillance
TITLE: Undetected misleading information from TIS-B		DomainName:	Terminal
FUNCTION NAME:		SubSystemName:	National Airspace System
		Service	ATC Advisory

DESCRIPTION The function is to determine the position, altitude, and vectoring information of other aircraft for purposes of traffic situational awareness.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including use of automatic dependent surveillance broadcast (ADS-B), cockpit display of traffic information (CDTI) and traffic information services broadcast (TIS-B) during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish visual flight rule (VFR) approaches at lower minimums.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot including runway and final approach occupancy awareness (using ADS-B and TIS-B).

WORST CASE: Low Visual Cue Environment (VCE) in Radar Coverage

HAZARD CONDITIONS: Undetected misleading information is provided to the air crews.

HAZARD CAUSE: This hazard could be caused by equipment failures in the ground system or in one or more aircraft systems, or by EMI in transmission medium combined with failures to detect by either ground or aircraft equipment or

EXISTING CONTROLS Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc.

HAZARD EFFECT: Pilot sees misleading information and makes decisions based on erroneous position or altitude, and vector info. ATC still retains the ability to separate A/C. Large reduction in safety margin due to the loss of info to the crew.

Potential Severity: Hazardous

RQMTS & RECOM-MENDATIONS: Candidate requirements:

1. Target "Ground track" function on ground display should be required and ON.

2. Limiting function in TIS-B system, to limit position "jumping" within 4.5 seconds.

3. The TIS-B system shall employ detection and enunciation of erroneous data and warning to the ATC operators of malfunctions.

4. The end ATC system shall employ a checking function that compares ADS-B and TIS-B locations for each ADS-B target. This function should warn the ATC operators when the two target positions are different.

THRESHOLD: extremely remote

OBJECTIVE: extremely

HAZ: 506	PROGRAM: ADS-B	Capability:	ALL Surveillance
TITLE: Detected misleading information from TIS-B		DomainName:	Terminal
FUNCTION NAME:		SubSystemName:	National Airspace System
		Service	ATC Advisory

DESCRIPTION: The function is to determine the position, altitude, and vectoring information of other aircraft for purposes of traffic situational awareness.

From the OSED, the function will be used as follows:

OSED 4.1 Improved Terminal Operations in Low Visibility, including use of automatic dependent surveillance broadcast (ADS-B), cockpit display of traffic information (CDTI) and traffic information services broadcast (TIS-B) during low visibility approach operations so that the crew will be better able to identify the aircraft to follow and accomplish visual flight rule (VFR) approaches at lower minimums.

OSED 4.4 Improved Surface Surveillance and Navigation for the Pilot including runway and final approach occupancy awareness (using ADS-B and TIS-B).

WORST CASE: Low Visual Cue Environment (VCE) in Radar Coverage

HAZARD CONDITIONS:

1. Detected misleading aircraft information transmitted from ground equipment to aircraft.
2. Detected misleading information transmitted by an aircraft to the ground or other aircraft.
3. Discontinue using the erroneous data.

HAZARD CAUSE:

Equipment failures in the ground system.

Equipment failures in one or more aircraft systems.

Signal interference in transmission media.

EXISTING CONTROLS: Procedural based on communication, and on-board aircraft navigational, altitude, heading, and speed sensors, etc.

HAZARD EFFECT: Essentially the same as for loss of TIS-B information. Increased workload.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: Candidate requirements:

1. Maintain current radar displays as alternate to TIS-B.
2. Assure that ADS-B is independent of secondary surveillance function such that loss of secondary surveillance function does not result in loss of ADS-B information to ATC.
3. Procedure should be required for ATC to notify flight crews of misleading TIS information.
4. Limiting system should not shut the system down, but rather, flag the potential erroneous data.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 600 PROGRAM: ADS-B Capability: ALL Surveillance

TITLE: Human factors: Erroneous pilot report of traffic in sight. DomainName: Air Traffic Flow Management

SubSystemName: Surveillance

FUNCTION NAME: Other Information

Service ATC Separation Assurance

DESCRIPTION This function is the input of information from the pilot to the controller. Controller uses pilot visual reports of nearby traffic as one input to assess separation in the controlled airspace.

WORST CASE: Congested airspace (e.g. some terminal or Class B)

HAZARD CONDITIONS: Aircraft equipped with ADS-B CDTI reports visual sighting of aircraft not actually seen.

HAZARD CAUSE: ADS-B data displayed on CDTI.
Over-reliance on automation (automation bias) leads pilot to trust what she sees on CDTI.
Inadequate pilot training.
Inadequate cockpit procedures.

EXISTING CONTROLS ATS radar separation, voice communication, other aircraft visual sightings.

Reports of traffic in sight are based on OTW sighting, not on TCAS or other on-board surveillance display.

HAZARD EFFECT: Controller has an incorrect understanding of pilot situation awareness and capabilities.
Controller instructs the pilot to maintain visual separation behind or maneuver to avoid a aircraft seen only on CDTI. Pilot's response may not match the controller's expectation.

Pilot may have difficulty finding the aircraft OTW or fail to find it at all. The resultant delay could lead to interference with and a need to revise the controller's plan for the traffic.

Reduced margin of safety.

Increased ATC workload.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. Pilot training and procedures shall include proper use of CDTI.
2. ATC procedures shall include mixed equipage scenarios.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 601 PROGRAM: ADS-B Capability: VFR See and Avoid

TITLE: Human factors: False ADS-B targets seen on both CDTI and ATS display. DomainName: Air Traffic Flow Management

SubSystemName: Aircraft Systems

FUNCTION NAME: Human

Service ATC Advisory

DESCRIPTION This function begins with a pilot report of OTW traffic sighting when no traffic is actually sighted. Pilot reports sighting to ATC who checks the ATS display and finds the same target. In this case both ATC and pilot are seeing false information.

WORST CASE: Congested airspace (e.g. some terminal or Class B)

HAZARD CONDITIONS: False targets on CDTI and controller's ADS-B display.

False target is violating separation requirements, too close to subject aircraft. Maneuver to avoid false target results in conflict with second actual aircraft.

HAZARD CAUSE: ADS-B data displayed on CDTI.
Inadequate pilot training.
Inadequate procedures.
Ghosting.

EXISTING CONTROLS Radar, existing Navaids.

HAZARD EFFECT: Pilot follows unintentional false aircraft target while approaching busy airfield.

Pilot Distraction

Abrupt change of course or speed.

If the false target were unintentional, it would probably be easy to identify as false because it would not appear to move in a way that would be mistaken for an aircraft.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: 1. Discrepancy between radar and ADS-B on existence of target shall be detected. ATS display shall include warning to ATS that a specified target may be erroneous.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 604 PROGRAM: ADS-B Capability: ALL Surveillance

TITLE: Human factors: Integration of CDTI in the Cockpit DomainName: Aircraft

SubSystemName: Surveillance

FUNCTION NAME: Display

Service ATC Advisory

DESCRIPTION: If CDTI is integrated with NAV display, ADS-B data may not be usable to the pilot because the NAV display is in a different mode, or because superimposed ADS-B and other (e.g., weather) data creates display clutter.

If CDTI is integrated as a stand-alone display, the pilot(s) may have difficulty reaching its controls.

WORST CASE: Low Visual Cue Environment (VCE) in the Airport Movement Area (AMA); single pilot operation

HAZARD CONDITIONS: With NAV or stand-alone display: a hazard may arise when the situation changes rapidly, as when traffic, terrain, or a thunderstorm suddenly appears and the display doesn't happen to be in the right mode to display the information, or the (especially single) pilot is unable to obtain information sufficiently quickly from CDTI or OTW to take effective action.

HAZARD CAUSE:

Integration with NAV display.
Size and resolution of NAV.
Display clutter and superimposed data
Mode error.

Integration as a stand-alone display.
Distance of controls from pilot reach distance.

EXISTING CONTROLS: ATS radar or non-radar separation. FARs specify pilot responsibility for maintaining separation in VMC conditions.

HAZARD EFFECT: Tradeoff between head down time and OTW

Incomplete visual search of CDTI under time pressure

Incomplete OTW scan under time pressure

Distraction

Increased workload.

Potential Severity: Major

RQMTS & RECOMMENDATIONS:

1. All CDTI controls shall be located within the 10th percentile adult US civilian female grip reach length.

2. Pilots shall be trained to incorporate CDTI into visual instrument and OTW scan so that OTW scan remains primary.

3. The ADS-B system developers shall demonstrate compliance with Human factors criteria contained in MIL-STD-1472 and the FAA's AMS. These requirements will be validated and verified in accoradnce with the FAA system engineering manual and system engineering management plan.

4. The CDTI display shall include provisions for declaring the displays are in accordance with MIL-STD-1472.

THRESHOLD: remote

OBJECTIVE: extremely remote

HAZ:	606	PROGRAM:	ADS-B	Capability:	Terminal Seperation
TITLE:	Human Factors: Reduced spacing on final approach			DomainName:	Aircraft
				SubSystemName:	Communication
FUNCTION NAME:	Human			Service	ATC Separation Assurance

DESCRIPTION	This function involves self separation based on pilot's view of traffic on ADS-B display. Pilot uses ADS-B display to separate from traffic ahead and ADS-B data is lost.
WORST CASE:	Congested airspace (e.g. some terminal or Class B)
HAZARD CONDITIONS:	Closer spacing than at present for ADS-B equipped aircraft. The trailing aircraft might not have time to slow up and increase its separation to what is now a safe distance (without ADS-B). Most likely the trailing aircraft would then execute a missed approach, but if this were not possible, a more hazardous maneuver might be required.
HAZARD CAUSE:	Loss of ADS-B data while on visual approach. Closer spacing than at present for ADS-B equipped aircraft.
EXISTING CONTROLS	Visual separation ATS procedure or radar separation.
HAZARD EFFECT:	Abrupt change of course or speed like that associated with a missed approach. Inadequate separation. Increased pilot/ATC workload
Potential Severity:	Minor
RQMTS & RECOM-MENDATIONS:	1. ATS training should include scenarios simulating loss of ADS-B data for one or all aircraft in a series of aircraft closely spaced on visual approach.
THRESHOLD:	probable
OBJECTIVE:	remote

HAZ: 607 PROGRAM: ADS-B Capability: Terminal Seperation

TITLE: human Factors: Increased ATS workload and demand for communications

DomainName: Air Traffic Flow Management

SubSystemName: Communication

FUNCTION NAME:

Service ATC Separation Assurance

DESCRIPTION An anticipated result of ADS-B data is increased throughput due to increased pilot situation awareness leading to decreased spacing requirements. With increased throughput, communications rates could also increase. More aircraft departing and landing would require proportionately more instructions and clearances from ATS as well as more pilot messages.

WORST CASE: Congested airspace (e.g. some terminal or Class B) and need for urgent communication

HAZARD CONDITIONS: Frequency congestion

HAZARD CAUSE: Increased traffic density.

Limited communications bandwidth.

EXISTING CONTROLS ATS increases spacing.

HAZARD EFFECT: slight reduced margin of safety

Increased ATC workload

Greater likelihood of mis-communication.

Simultaneous transmissions (step-ons)

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS: Note: Programs such as CPDLC (data link) may alleviate voice communications in favor of visually displayed communications. However, like ADS-B/CDTI, they would increase pilot head down time.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 609 PROGRAM: ADS-B Capability: ALL Surveillance

TITLE: Human Factors: ATS Display of ADS-B Equipage DomainName: National Airspace System

SubSystemName: Automation

FUNCTION NAME:

Service ATC Advisory

DESCRIPTION In a mixed environment, ATS needs to have a way of immediately determining the equipage of each aircraft. In particular, they need to know whether an aircraft is broadcasting (squittering), and whether it can display ADS-B data. Although this information could be transmitted by voice, like ATIS information, this method leaves room for error as the controller might forget or incorrectly record it on a flight strip. Nonetheless, this method might be better than displaying equipage on the controller's traffic display because it could result in either a larger full data block, adding to display clutter, or require a new display mode to show the information when needed. If controllers working in a high-workload sector had to select either a cluttered display that included ADS-B information or no display of ADS-B information (radar only), it is likely that ADS-B would often not be displayed. Controllers would display the information when the situation permits, and would rely on memory when the added clutter would present a problem. Perhaps the best location for this information is on the pre-printed or electronic flight strip so that it would always be visible to the controllers without adding clutter to the primary radar/ADS-B display. However, this location is not perfect in that the controllers would need to refer to this information in many of their communications with pilots, requiring either memory or frequent reference to the flight strip. Given the role of human memory in these scenarios, forgetting and miscommunication need to be considered.

WORST CASE: Congested airspace (e.g. some terminal or Class B)

HAZARD CONDITIONS: The worst case might be one in which ATS forgets that a aircraft is not equipped, and call it out as ADS-B traffic when it is not visible on the pilot's CDTI. This could result in a delay as the pilot searches the display for the traffic (with head down) and in additional communications between pilot and controller.

Second, ATS might forget that an aircraft is ADS-B equipped and call it out as traffic without using its call-sign, indicating to the pilot that the traffic would not be found on CDTI. The pilot in this case would resort to an OTW search for traffic that is not displayed on CDTI. This would result in some head-up delay and additional communications.

Third, ATS might call out ADS-B traffic using its call sign to an aircraft not equipped with CDTI. The pilot would reply that the aircraft is not equipped with CDTI, and the controller would provide the appropriate type, bearing, and distance for the traffic.

Fourth, ATS might forget that an aircraft is equipped with CDTI, and call out ADS-B traffic without using its call sign. This case, like the second, would indicate to the pilot that the traffic is not to be found on CDTI, and might cause the pilot to search OTW for an aircraft that is not displayed on CDTI. Again, this would result in some head-up delay and additional communications.

HAZARD CAUSE: Human memory requirements of various ways of displaying ADS-B and / or CDTI equipage for controller use (ADS-B mode, flight strip, scratch pad) if used instead of integrated ATS display because integrated display is too cluttered or for other reasons.

Miscommunication: ATS calls out ADS-B traffic when traffic is actually non-ADS-B

Miscommunication: ATS calls out non-ADS-B traffic when traffic is actually ADS-B equipped

Miscommunication: ATS calls out ADS-B traffic to non-CDTI equipped aircraft

Miscommunication: ATS calls out ADS-B traffic to CDTI-equipped aircraft as the aircraft receiving the communication were not equipped with ADS-B or CDTI

EXISTING CONTROLS: ATS radar separation

Visual separation

HAZARD EFFECT: Head-down time

Slight Workload

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:	1. ADS-B and / or CDTI equipage shall be displayed to the controller automatically as a controller-selected option.
THRESHOLD:	probable
OBJECTIVE:	remote

HAZ: 610 PROGRAM: ADS-B Capability: Surface Surveillance for

TITLE: Human factorsExcessive search time on the airport surface DomainName: Airports

SubSystemName: CNS Avionics

FUNCTION NAME: Human

Service ATC Advisory

DESCRIPTION Aircraft on the airport surface are receiving ADS-B information. The CDTI designed for airport use is likely to be more cluttered than that for use in flight due to the density and variety of information that needs to be displayed. Non-movement areas such as ramp and gate are most heavily occupied. The cluttering of the display is especially dangerous in the case of a single pilot who has to decipher the display and coordinate with what he sees out the window.

WORST CASE: Low Visual Cue Environment (VCE) in the Airport Movement Area (AMA), maneuvering in ramp and gate areas in low visibility conditions, and/or single pilot operation.

HAZARD CONDITIONS: Heavy traffic in airport surface area, especially traffic without ADS-B.

HAZARD CAUSE: Excessive amounts of information on CDTI (clutter and overlap of symbols and characters).

Inadequate resolution in display.

Excessive head down time.

EXISTING CONTROLS ASDE. TCAS. COMM

Gate or ramp control

HAZARD EFFECT: Pilot disorientation

Mis-interpretation of CDTI data

Increased search time

Reduced time to identify non-equipped vehicles

Reduced margin of safety

Time pressure on pilot to move aircraft.

OTW - head down search trade-off reduces time to identify vehicles and signs on airport surface.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. The ADS-B display shall be able to be decluttered to the extent that ownership, nearby vehicles, taxiways, and runways are easily distinguishable and identifiable.
2. Require clearances and confirmations at all runway intersections.
3. Pilot training shall be provided for ADS-B operation in heavy traffic airport surface areas.
4. Requirement for screen resolution TBD
5. Requirement for selectable option to zoom in and out TBD

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 614 PROGRAM: ADS-B

TITLE: Excessive crew workload

FUNCTION NAME: Human

Capability: Surface Surveillance and

DomainName: Aircraft

SubSystemName: CNS Avionics

Service ATC Advisory

DESCRIPTION In two-pilot operations, one pilot can maintain OTW scan while the second pilot uses the CDTI. The CDTI pilot would also handle communications with ATS, checklist procedures, and maintain situation awareness using airport charts. This situation could result in excessive workload causing the CDTI pilot to concentrate on the CDTI and reduce her OTW situation awareness.

WORST CASE: Low Visual Cue Environment (VCE) in the Airport Movement Area (AMA)

HAZARD CONDITIONS: Congested airport movement areas with low visibility.

1 pilot on CDTI, other flying. Additional take of A/C separation.

HAZARD CAUSE: Excessive pilot workload reduces situation awareness.

Display complexity increases head down time.

EXISTING CONTROLS ASDE, Communications

Training (CRM)

HAZARD EFFECT: Increased pilot workload.

Increased head down time.

Reduced OTW vigilance.

Undetected non-ADS-B equipped vehicles.

Reduced margins of safety.

Potential Severity: Major

RQMTS & RECOM-MENDATIONS:

1. Training for pilots using ADS-B on airport movement area shall include provisions for one pilot maintaining OTW surveillance and coordinating movement with ground crew.
2. Procedures shall include provisions for reporting surface objects to ATC.
3. The effect shall be examined in a simulator to validate the concern.

THRESHOLD: remote

OBJECTIVE: extremely remote

HAZ: 615 PROGRAM: ADS-B Capability: Surface Surveillance and

TITLE: Human factors: Miscommunication between OTW and CDTI pilots on the airport surface

DomainName: Aircraft

SubSystemName: Aircraft Systems

FUNCTION NAME: Other Information

Service ATC Advisory

DESCRIPTION When one pilot navigates with eyes only OTW and the second pilot uses the CDTI with his head down, the two may not share the same visual reference points for use in communication. Because of limited size and resolution, the CDTI will display less information than is found on paper airport charts.

WORST CASE: Low Visual Cue Environment (VCE) in the Airport Movement Area (AMA)

HAZARD CONDITIONS: Congested airport movement areas with low visibility.

HAZARD CAUSE: CDTI reference points differ from OTW and / or NOAA chart references.

Limited number of reference points displayed on CDTI.

Limited CDTI size and resolution.

EXISTING CONTROLS ASDE, ATC communication

HAZARD EFFECT: Miscommunication between OTW pilot and CDTI observer.

Reduced situation awareness of CDTI pilot

Crew coordination errors regarding airport ground features, aircraft and ground vehicles.

Confusion and increased workload.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. ADS-B avionics shall have sufficient resolution to provide accurate representation of all airport surface areas intended for use by ADS-B equipped aircraft.

2. Procedures shatt require that airport map for use with ADS-B CDTI shall be current with respect to NOAA airport charts.

3. Critical reference points are those obstacles that require marking in accordance with the FARs. The airports, runaways, taxiways, and critical reference points shall be displayed on the ADS-B display with an accuracy that is within those specified in AC 150/5300-14 table 4-1. The obstacles must be verified to be within 10 meters of the displayed position.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 616 PROGRAM: ADS-B Capability: Surface Surveillance and

TITLE: Human factors: Additional voice frequency occupancy on the airport surface DomainName: Air Traffic Flow Management

FUNCTION NAME: Communication

SubSystemName: Communication

Service ATC Advisory

DESCRIPTION ADS-B data will include aircraft identification. Having this information available for all aircraft may cause the information to be misused by pilots requesting preferential sequencing. This hazard is the same as 405, except that it occurs on the airport surface where communications frequency occupancy is commonly highest.

WORST CASE: Low Visual Cue Environment (VCE) in the Airport Movement Area (AMA)

HAZARD CONDITIONS: Congested airport surface movement area with low visibility.

HAZARD CAUSE: Pilot misuses ADS-B information to request preferential sequencing leading to increases in radio transmissions.

Addition of aircraft call signs (obtained from ADS-B) to pilot messages and readbacks increases message

EXISTING CONTROLS Airport communications discipline.

Bans on complete readback (acknowledge only).

HAZARD EFFECT: Increase in simultaneous transmissions.

Misunderstood clearances.

Failure to communicate urgent ATC instructions.

Reduced safety margin.

Potential Severity: Minor

RQMTS & RECOM-MENDATIONS:

1. Procedures shall include provisions for clearing frequencies for ATC instructions, including restrictions on message contents and duration (radio protocol).

2. Operational test of the ADS-B system shall measure any change in frequency occupancy.

THRESHOLD: probable

OBJECTIVE: remote

HAZ: 700 PROGRAM: ADS-B Capability: ALL Surveillance

TITLE: Deliberate transmittal of false ADS-B data (spoofing) DomainName: National Airspace System

FUNCTION NAME: Communication SubSystemName: Aircraft Systems

Service ATC Advisory

DESCRIPTION This is not a normal function of the ADS-B system but rather an external event which broadcasts false ADS-B information in an effort to disrupt or sabotage air traffic. It is assumed that the ADS-B system is functioning normally and will receive all properly formatted information.

WORST CASE: Congested airspace (e.g. some terminal or Class B)

HAZARD CONDITIONS: Congested airspace, low visibility and use of ADS-B for separation a false ADS-B target is generated maliciously.

HAZARD CAUSE: Deliberate broadcast of false or misleading ADS-B information.

EXISTING CONTROLS
Lighting for fixed objects.
Radar, comm
TCAS, GCAWS

HAZARD EFFECT: Sufficiently misleading false information displayed by the ADS-B system in congested airspace with low visibility may cause controllers to issue incorrect clearances and pilots to take inappropriate action based on the bad information. In either case, there is potential that the action taken may lead to collision between aircraft, the ground or fixed objects. This is considered potentially catastrophic.

Potential Severity: Catastrophic

RQMTS & RECOM-MENDATIONS:

1. The ADS-B data shall be encoded/encrypted so that the probability of successful spoofing is extremely improbable.

2. The ADS-B system shall employ a unique identifier for each legitimate unit produced.

3. The ADS-B system shall check each message for the presence of the unique identifier and provide a warning to the operator if the identifier is not present.

4. ADS-B shall consider frequency hopping and spread spectrum techniques to protect against spoofing.

THRESHOLD: extremely improbable

OBJECTIVE:

APPENDIX D: ASOR REPORTS

ADS-B ASOR - HAZARD 102

HAZARD 102 - INTRODUCTION

This allocation uses a hazard of ***Corruption of "known object" position data into local ADS-B subsystem*** as its basis. It assumes that ADS-B will be utilized to extend radar-like positive air traffic control (ATC) into non-radar environments or to non-radar covered aircraft in low visual cue environments. Some of these aircraft may currently operating under VFR only. For these aircraft, it is assumed that ADS-B will be utilized to enhance their capabilities in low visual cue VFR environments (meteorological and night VMC) or extend aircraft and ATC capabilities such that these VFR approved aircraft may operate in IMC conditions under special circumstances.

HAZARD 102 - CANDIDATE REQUIREMENTS

In the operational hazard assessment (OHA), the following series of candidate requirements, without allocation, was proposed:

1. *Airports/runways/taxiways shall be marked, located, and displayed in the ADS-B system.*
2. *Obstacles requiring lighting in accordance with existing FARs shall be marked, located, and displayed in the ADS-B system.*
3. *The ADS-B display shall indicate the nature, location (relative and actual lat/long), name, MSL and AGL altitude of the object.*
4. *The A/C displays shall include the ability to overlay the ADS-B information on a moving map display consistent with other charts.*
5. *The ATC display shall include the ability to overlay the ADS-B information onto a map display covering the airport ops and terminal areas consistent with terminal area charts.*
6. *The system data containing the "known object information shall comply with existing validation, verification, qualification, and current requirements in the FAR as they apply to aeronautical charts.*
7. *It shall be shown by system engineering verification methods the threshold of likelihood for the worst-case hazard effects shall be less than remote and the objective should be less than extremely remote.*

These candidate requirements are modified as necessary, and allocated, along with other requirements since determined, in this ASOR.

HAZARD 102 - REQUIREMENTS ALLOCATION

This section presents two tables of allocated requirements: one for vehicle systems and procedures (table 1), and one for Air Traffic Control systems and procedures (table 2). The term "vehicle" includes aircraft and mobile ground equipment. "Vehicle" is used in order to recognize that ADS-B may, at some point in the future, be installed on ground vehicles at airports as well as aircraft.

Some requirements are dependent on the implementation of other requirements. These other requirements have been termed "corollary requirements". Corollary requirements are provided in the right-hand column, in the same row as their dependent requirements which have been termed as "primary requirements." If the corollary requirements are not satisfied, then the associated primary requirement will be insufficient to meet the overall safety objectives and requirements. Vehicle primary requirements may have both corollary vehicle system and procedural requirements and corollary ATC system and procedural requirements, and vice versa.

Table 1: Vehicle System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
102-V-1	It shall be shown by system engineering verification methods the threshold of likelihood for the worst-case hazard effects shall be less than remote and the objective should be less than extremely remote.	102-V-2	The ADS-B display shall indicate the nature, location (relative and actual lat/long), name, MSL and AGL altitude of the object.
		102-V-3	The A/C displays shall include the ability to overlay the ADS-B information on a moving map display consistent with other charts.
		102-V-4	The system data containing the “known object information shall comply with existing validation, verification, qualification, and current requirements in the FAR as they apply to aeronautical charts.

Table 2: ATC System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
102-A-1	It shall be shown by system engineering verification methods the threshold of likelihood for the worst-case hazard effects shall be less than remote and the objective should be less than extremely remote.	102-A-2	Airports/runways/taxiways shall be marked, located, and displayed in the ADS-B system.
		102-A-3	Obstacles requiring lighting in accordance with existing FARs shall be marked, located, and displayed in the ADS-B system.
		102-V-2	The ADS-B display shall indicate the nature, location (relative and actual lat/long), name, MSL and AGL altitude of the object.
		102-A-5	The ATC display shall include the ability to overlay the ADS-B information onto a map display covering the airport ops and terminal areas consistent with terminal area charts.
		102-V-4	The system data containing the “known object information shall comply with existing validation, verification, qualification, and current requirements in the FAR as they apply to aeronautical charts.

ADS-B ASOR - HAZARD 104

HAZARD 104 - INTRODUCTION

This allocation uses a hazard of ***Corruption of vehicle navigation solution as input to the local ADS-B unit*** as its basis. It assumes that ADS-B will be utilized to extend radar-like positive air traffic control (ATC) into non-radar environments or to non-radar covered aircraft in low visual cue environments. Some of these aircraft may currently operating under VFR only. For these aircraft, it is assumed that ADS-B will be utilized to enhance their capabilities in low visual cue VFR environments (meteorological and night VMC) or extend aircraft and ATC capabilities such that these VFR approved aircraft may operate in IMC conditions under special circumstances.

HAZARD 104 - CANDIDATE REQUIREMENTS

In the operational hazard assessment (OHA), the following series of candidate requirements, without allocation, was proposed:

1. *The ADS-B system shall cross check position data with vehicle velocity data and if the comparison indicates an error with the position data, the system shall indicate an error to all the operators.*
2. *The ADS-B avionics shall employ redundant cross checking navigation sources.*
3. *It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than extremely remote and the objective should be less than extremely improbable.*

HAZARD 104 - REQUIREMENTS ALLOCATION

This section presents two tables of allocated requirements: one for vehicle systems and procedures (table 1), and one for Air Traffic Control systems and procedures (table 2). The term "vehicle" includes aircraft and mobile ground equipment. "Vehicle" is used in order to recognize that ADS-B may, at some point in the future, be installed on ground vehicles at airports as well as aircraft.

Some requirements are dependent on the implementation of other requirements. These other requirements have been termed "corollary requirements". Corollary requirements are provided in the right-hand column, in the same row as their dependent requirements which have been termed as "primary requirements." If the corollary requirements are not satisfied, then the associated primary requirement will be insufficient to meet the overall safety objectives and requirements. Vehicle primary requirements may have both corollary vehicle system and procedural requirements and corollary ATC system and procedural requirements, and vice versa.

Table 1: Vehicle System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
104-V-5	It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than extremely remote and the objective should be less than extremely improbable.	104-V-6 104-V-7	The ADS-B system shall cross check position data with vehicle velocity data and if the comparison indicates an error with the position data, the system shall indicate an error to all the operators. The ADS-B avionics shall employ redundant cross checking navigation sources.

TABLE 2: ATC SYSTEM AND PROCEDURAL REQUIREMENTS

Req No.	Primary Requirement		Corollary Requirements
104-A-6	It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than extremely remote and the objective should be less than extremely improbable.	104-V-6	The ADS-B system shall cross check position data with vehicle velocity data and if the comparison indicates an error with the position data, the system shall indicate an error to all the operators. .

ADS-B ASOR - HAZARD 109

HAZARD 109 - INTRODUCTION

This allocation uses a hazard of ***Operator error integrating ADS-B information and ATC communications related to ADS-B surveillance*** as its basis. It assumes that ADS-B will be utilized to extend radar-like positive air traffic control (ATC) into non-radar environments or to non-radar covered aircraft in low visual cue environments. Some of these aircraft may currently operating under VFR only. For these aircraft, it is assumed that ADS-B will be utilized to enhance their capabilities in low visual cue VFR environments (meteorological and night VMC) or extend aircraft and ATC capabilities such that these VFR approved aircraft may operate in IMC conditions under special circumstances.

HAZARD 109 - CANDIDATE REQUIREMENTS

In the operational hazard assessment (OHA), the following series of candidate requirements, without allocation, was proposed:

1. *The ADS-B system shall incorporate a moving map system in which ADS-B targets and the local ADS-B information are displayed and references to the moving map coordinates.*
2. *The ADS-B display shall be located within the vehicle or facility to optimize visibility and interpretation and to prevent spatial disorientation during critical maneuvers.*
3. *For the ATC display, the ADS-B horizontal position and velocity shall be referenced to the ground, i.e. ground speed and course.*
4. *The ADS-B system shall employ FAA display symbology standards when defining target symbology.*
5. *The ADS-B altitude shall use both pressure altitude (MSL) and ground (AGL) references.*
6. *Both altitude types (MSL and AGL) shall be displayed however the AGL altitude may be selectable for de-cluttering.*
7. *Both altitude types (MSL and AGL) shall be clearly distinguishable from each other.*
8. *The impact to crew and ATC workload shall be evaluated in simulation considering the re-allocation of rules and responsibilities that are proposed in the ADS-B MOPS found in RTCA DO-242.*

9. *It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than remote and should be less than extremely remote.*

HAZARD 109 - REQUIREMENTS ALLOCATION

This section presents two tables of allocated requirements: one for vehicle systems and procedures (table 1), and one for Air Traffic Control systems and procedures (table 2). The term "vehicle" includes aircraft and mobile ground equipment. "Vehicle" is used in order to recognize that ADS-B may, at some point in the future, be installed on ground vehicles at airports as well as aircraft. Some requirements are dependent on the implementation of other requirements. These other requirements have been termed "corollary requirements". Corollary requirements are provided in the right-hand column, in the same row as their dependent requirements which have been termed as "primary requirements." If the corollary requirements are not satisfied, then the associated primary requirement will be insufficient to meet the overall safety objectives and requirements. Vehicle primary requirements may have both corollary vehicle system and procedural requirements and corollary ATC system and procedural requirements, and vice versa.

Table 1: Vehicle System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
109-V-8	It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than remote and should be less than extremely remote.	109-V-9	The ADS-B system shall incorporate a moving map system in which ADS-B targets and the local ADS-B information are displayed and references to the moving map coordinates.
		109-V-10	The ADS-B display shall be located within the vehicle or facility to optimize visibility and interpretation and to prevent spatial disorientation during critical maneuvers
		109-V-11	The ADS-B system shall employ FAA display symbology standards when defining target symbology.
		109-V-12	The ADS-B altitude shall use both pressure altitude (MSL) and ground (AGL) references.
		109-V-13	Both altitude types (MSL and AGL) shall be displayed however the AGL altitude may be selectable for de-cluttering.
		109-V-14	Both altitude types (MSL and AGL) shall be clearly distinguishable from each other.
		109-V-15	The impact to crew and ATC workload shall be evaluated in simulation considering the re-allocation of rules and responsibilities that are proposed in the ADS-B MOPS found in RTCA DO-242.

Table 2: ATC System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
109-A-7	It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than remote and should be less than extremely remote.	109-V-9	The ADS-B system shall incorporate a moving map system in which ADS-B targets and the local ADS-B information are displayed and references to the moving map coordinates.
		109-V-10	The ADS-B display shall be located within the vehicle or facility to optimize visibility and interpretation and to prevent spatial disorientation during critical maneuvers.
		109-V-11	The ADS-B system shall employ FAA display symbology standards when defining target symbology.
		109-V-12	The ADS-B altitude shall use both pressure altitude (MSL) and ground (AGL) references.
		109-V-13	Both altitude types (MSL and AGL) shall be displayed however the AGL altitude may be selectable for de-cluttering.
		109-V-14	Both altitude types (MSL and AGL) shall be clearly distinguishable from each other.
		109-V-15	The impact to crew and ATC workload shall be evaluated in simulation considering the re-allocation of rules and responsibilities that are proposed in the ADS-B MOPS found in RTCA DO-242.

ADS-B ASOR HAZARD 500

HAZARD 500 - INTRODUCTION

This allocation uses a hazard of ***UNDETECTED MISLEADING INFORMATION FROM A VEHICLE*** as its basis. It assumes that ADS-B will be utilized to extend radar-like positive air traffic control (ATC) into non-radar environments or to non-radar covered aircraft in low visual cue environments. Some of these aircraft may currently operating under VFR only. For these aircraft, it is assumed that ADS-B will be utilized to enhance their capabilities in low visual cue VFR environments (meteorological and night VMC) or extend aircraft and ATC capabilities such that these VFR approved aircraft may operate in IMC conditions under special circumstances.

HAZARD 500 - INITIAL CANDIDATE REQUIREMENTS

In the operational hazard assessment (OHA), a series of initial candidate requirements, without allocation, was proposed:

1. *If ADS -B is to be used for airport surveillance and ground movement, then the accuracy shall be within the requirements for runway and taxi areas widths in AC 150/5300-13 (table 4-1). This may mean that aircraft taking advantage of surface movement in LVC environments may require WAAS or LAAS equipage to gain the required accuracy.*

2. *The occurrence of this hazard should be extremely improbable, with a quantitative probability of occurrence of less than 1x10-9 per operational hour.*

3. *There should be a check of vehicle navigation data integrity.*

4. *There should be a velocity vector data integrity comparison function in the vehicle based on two independent sources (e.g., GPS derived velocity vector checked against airspeed, heading, and rate of climb indicators.)*

5. *Tracking on the ATC display should be ON.*

6. *There should be a limiting function in ADSB system, to limit position "jumping" to 4.5 seconds. This function should be based on an independent speed check or independent navigation source in the vehicle.*

7. *There should be a procedure in the vehicle checklist for entering correct identification for flight information.*

8. *On system initiation, the system should require the vehicle crew to confirm or enter a new call sign before it will operate.*

9. *There should be a check of altitude data integrity, using either redundant pressure altitude sources with a checking function, or a checking function between AGL altitude from GPS and one pressure altitude source.*

These candidate requirements are modified as necessary, and allocated, along with other requirements since determined, in this ASOR.

HAZARD 500 - REQUIREMENTS ALLOCATION

This section presents two tables of allocated requirements: one for vehicle systems and procedures (table 1), and one for Air Traffic Control systems and procedures (table 2). The term "vehicle" includes aircraft and mobile ground equipment. "Vehicle" is used in order to recognize that ADS-B may, at some point in the future, be installed on ground vehicles at airports as well as aircraft.

Some requirements are dependent on the implementation of other requirements. These other requirements have been termed "corollary requirements". Corollary requirements are provided in the right-hand column, in the same row as their dependent requirements which have been termed as "primary requirements." If the corollary requirements are not satisfied, then the associated primary requirement will be insufficient to meet the overall safety objectives and requirements. Vehicle primary requirements may have both corollary vehicle system and procedural requirements and corollary ATC system and procedural requirements, and vice versa.

Table 1: Vehicle System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
500-V-1	Transmittal of misleading ADS-B information from a vehicle, without annunciation of failure, shall be remote.	500-V-2	Vehicle operator shall obtain ATC clearance upon area/sector entry and update controlling ATC at regular intervals regarding position, altitude, speed, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of ADS-B.
		500-V-3	If ADS-B is to be used for airport surveillance and ground movement, then the accuracy shall be within the requirements for runway and taxi areas widths in AC 150/5300-13. (This may mean that aircraft taking advantage of surface movement in LVC environments may require augmentation equipage to gain the required accuracy.)
		500-A-2	(ATC requirement A-2) ATC shall accomplish positive handoff control when vehicle transits between area/segments. Controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications.
		500-A-3	(ATC requirement A-3) Airports without a second independent means of ground surveillance shall implement a "one in-one out" procedure to clear all runways, ramps, and taxi-ways of vehicles prior to allowing the landing or taxiing of an aircraft, during IMC or low visibility VMC.

Req No.	Primary Requirement		Corollary Requirements
500-V-4	There shall be a check of vehicle navigation data integrity immediately prior to operation.		
500-V-5	There shall be a velocity vector data integrity comparison function in the vehicle based on two independent sources.		
500-V-6	There shall be a limiting function in ADSB system, to limit position "jumping" to 4.5 seconds. This function shall be based on an independent speed check or independent navigation source in the vehicle.		
500-V-7	There shall be a procedure in the vehicle checklist for entering correct identification for flight information.		
500-V-8	On system initiation, the system shall require the vehicle crew to confirm or enter a new call sign before it will operate.		
500-V-9	There shall be a check of altitude data integrity, using either redundant pressure altitude sources with a checking function, or a checking function between AGL altitude from GPS and one pressure altitude source.		
500-V-10	Vehicle ADS-B systems shall be developed to Level C development assurance requirements as defined for airborne systems or ground vehicle systems.		
500-V-11	ADS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional pilot skill or strength.		

Req No.	Primary Requirement		Corollary Requirements
500-V-12	Display of misleading ADS-B data on a single pilot's (or ground vehicle operator's) display equipment, without annunciation of failure, shall be improbable.		
500-V-13	Vehicle position shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates.		

Table 2: ATC System and Procedural Requirements

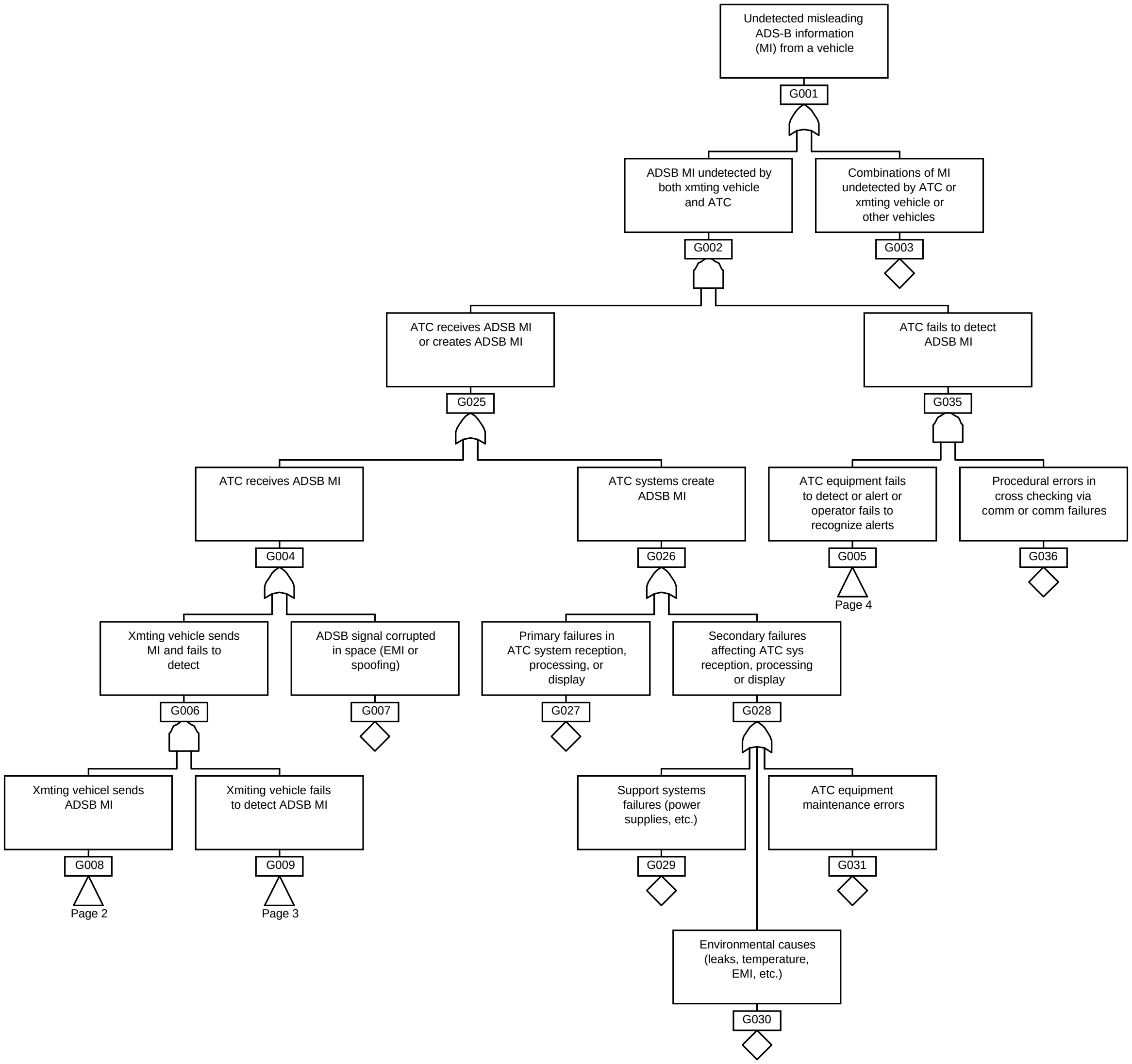
Req No.	Primary Requirement		Corollary Requirements
500-A-1	Display of misleading ADS-B data to an ATC operator's display equipment, without annunciation of failure, shall be improbable.	500-A-2	ATC shall contact the next area/segment control when vehicle leaves their respective control area/segment for vehicle handoff. Controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications.
		500-A-3	Airports without a second independent means of ground surveillance shall implement a "one in-one out" procedure to clear all runways, ramps, and taxi-ways of vehicles prior to allowing the landing or taxiing of an aircraft, during IMC or low visibility VMC.
		500-V-2	(Vehicle requirement V-2) Vehicle operator shall obtain ATC clearance upon area/sector entry and update controlling ATC at regular intervals regarding position, altitude, speed, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of ADS-B.
		500-V-3	(Vehicle requirement V-3) If ADS-B is to be used for airport surveillance and ground movement, then the accuracy shall be within the requirements for runway and taxi areas widths in AC 150/5300-13
500-A-4	Tracking on the ATC display shall be ON.		

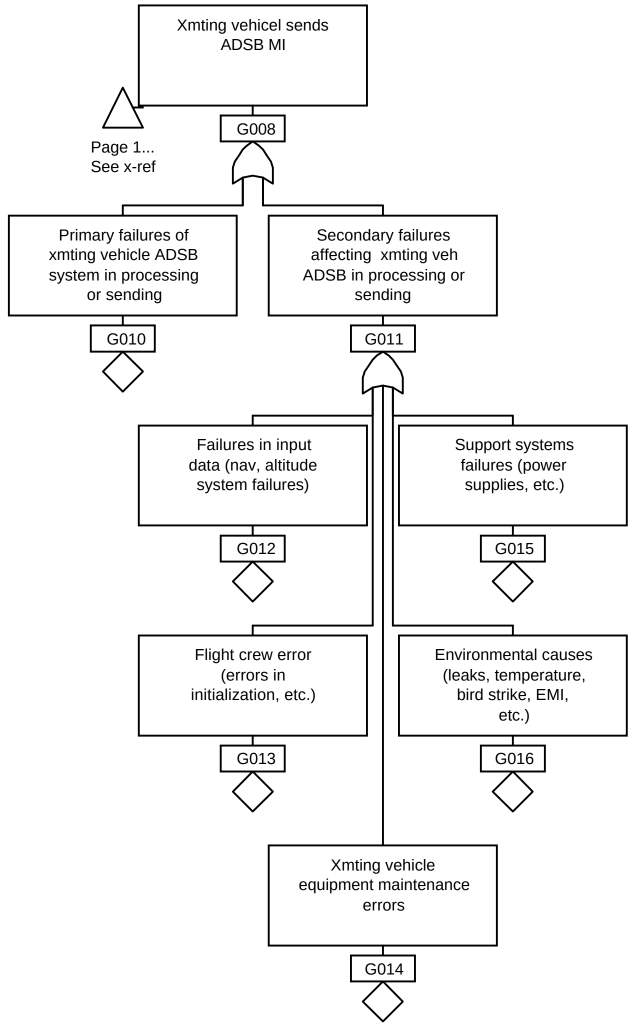
Req No.	Primary Requirement		Corollary Requirements
500-A-5	ATC systems shall be developed to Level C development assurance requirements as defined for acquired and developed ground systems.		
500-A-6	ADS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional operator skill or strength.		
500-A-7	Vehicle position shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates.		

HAZARD 500 - FAULT TREE ANALYSIS OF THE OPERATIONAL HAZARD CONDITION

In order to better allocate safety objectives and requirements by qualitatively assessing the relationships of ADS-B related faults, failures, and errors, a fault tree analysis at the operational level was produced.

Automatic Dependent Surveillance - Broadcast
Operational Safety Assessment Report - Appendix D

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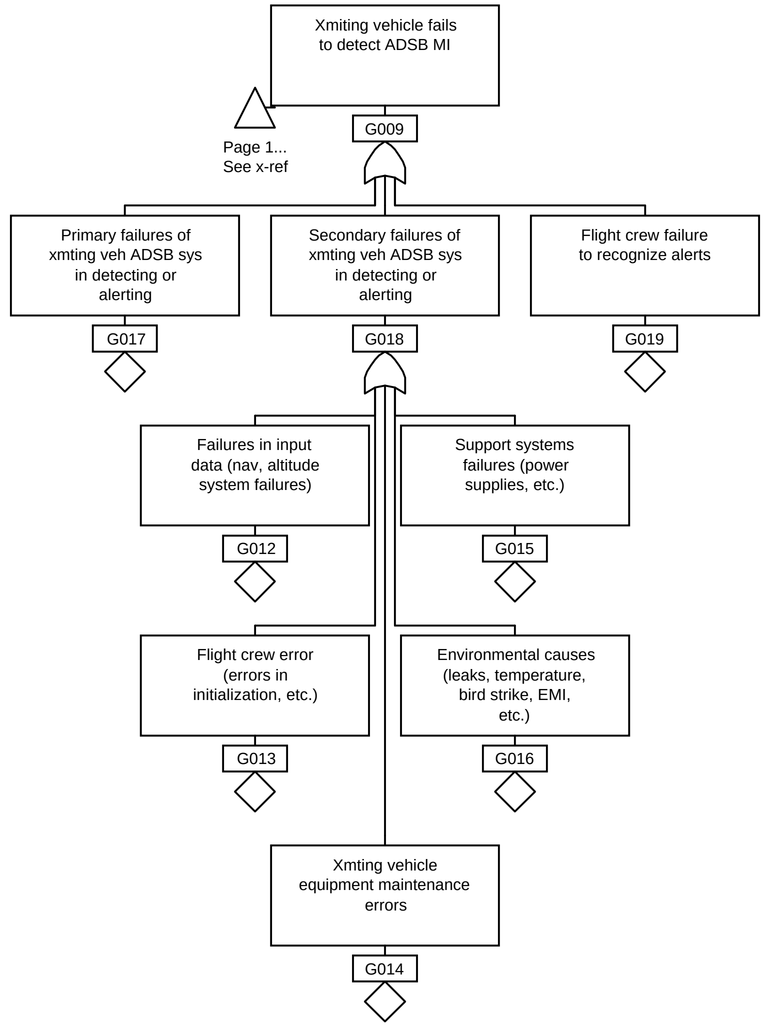
G010
Secondary failures affecting xmting veh ADSB in processing or sending
G011
Failures in input data (nav, altitude system failures)
G012
Support systems failures (power supplies, etc.)
G015
Flight crew error (errors in initialization, etc.)
G013
Environmental causes (leaks, temperature, bird strike, EMI, etc.)
G016
Xmting vehicle equipment maintenance errors
G014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G009
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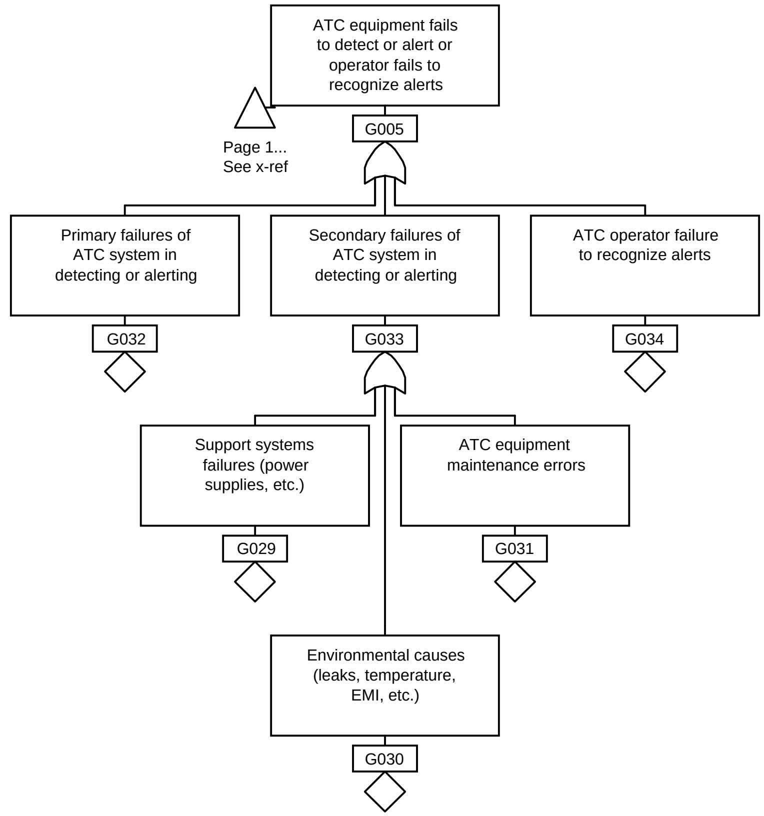
See x-ref
Primary failures of
xmting veh ADSB sys
in detecting or
alerting
G017
Secondary failures of
xmting veh ADSB sys
in detecting or
alerting
G018
Flight crew failure
to recognize alerts
G019
Failures in input
data (nav, altitude
system failures)
G012
Support systems
failures (power
supplies, etc.)
G015
Flight crew error
(errors in
initialization, etc.)
G013
Environmental causes
(leaks, temperature,
bird strike, EMI,
etc.)
G016
Xmting vehicle
equipment maintenance
errors
G014


ATC equipment fails to detect or alert or operator fails to recognize alerts
G005
Page 1...
See x-ref
Primary failures of ATC system in detecting or alerting
G032
Secondary failures of ATC system in detecting or alerting
G033
ATC operator failure to recognize alerts
G034
Support systems failures (power supplies, etc.)
G029
ATC equipment maintenance errors
G031
Environmental causes (leaks, temperature, EMI, etc.)
G030

TIS-B ASOR - HAZARD 505

HAZARD 505 - INTRODUCTION

This allocation uses a hazard of ***UNDETECTED MISLEADING INFORMATION FROM TIS-B*** as its basis. It assumes that TIS-B will be utilized to enhance traffic situational awareness in low visual cue environments. Some aircraft to be TIS-B equipped may be currently operating under VFR only. For these aircraft, it is assumed that TIS-B will be utilized in concert with ADS-B to enhance their capabilities in low visual cue VFR environments (meteorological and night VMC) or provide capability to operate these aircraft in IMC conditions under special circumstances.

HAZARD 505 - CANDIDATE REQUIREMENTS

In the operational hazard assessment (OHA), a series of candidate requirements, without allocation, was proposed:

1. *Target "Ground track" function on ground display should be required and ON.*

2. *Limiting function in TIS-B system, to limit position "jumping" within 4.5 seconds. Should be based on TBD.*

3. *The TIS-B system shall employ built in test and warning to the ATC operators of malfunctions.*

4. *The end ATC system shall employ a checking function that compares ADS-B and TIS-B locations for each ADS-B target. This function should warn the ATC operators when the two target positions are different.*

5. *It shall be shown by system engineering verification methods the threshold of likelihood of the worst-case hazard effects shall be less than Extremely Improbable.*

These candidate requirements are modified as necessary, and allocated, along with other requirements since determined, in this ASOR.

HAZARD 505 - REQUIREMENTS ALLOCATION

This section presents two tables of allocated requirements: one for vehicle systems and procedures (table 1), and one for Air Traffic Control systems and procedures (table 2).

The term "vehicle" includes aircraft and mobile ground equipment. "Vehicle" is used in order to recognize that TIS-B may, at some point in the future, be installed on ground vehicles at airports as well as aircraft.

Some requirements are dependent on the implementation of other requirements. These other requirements have been termed "corollary requirements". Corollary requirements are provided in the right-hand column, in the same row as their dependent requirements which have been termed as "primary requirements." If the corollary requirements are not satisfied, then the associated primary requirement will be insufficient to meet the overall safety objectives and requirements. Vehicle primary requirements may have both corollary vehicle system and procedural requirements and corollary ATC system and procedural requirements, and vice versa.

Table 1: Vehicle System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
505-V-1	Display of misleading TIS-B data on a single pilot's (or ground vehicle operator's) traffic information display equipment, without annunciation of failure, shall be improbable.	505-V-2 505-A-2	Vehicle operator shall obtain ATC clearance upon area/sector entry and update controlling ATC at regular intervals regarding position, altitude, speed, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of TIS-B and ADS-B. (ATC requirement A-2) ATC shall accomplish positive handoff control when vehicle transits between area/segments. Controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications.
505-V-3	There shall be a limiting function in TIS-B system, to limit position "jumping" to 4.5 seconds. This function shall be based on an independent speed check or independent navigation source in the vehicle.		
505-V-4	Vehicle TIS-B systems shall be developed to Level C development assurance requirements as defined for airborne systems or surface vehicle systems.		
505-V-5	TIS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional pilot skill or strength.		
505-V-6	The TIS-B system shall employ built in test and annunciation to the ATC operator of failures and malfunctions.		

Req No.	Primary Requirement		Corollary Requirements
505-V-7	Vehicle position shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates.		

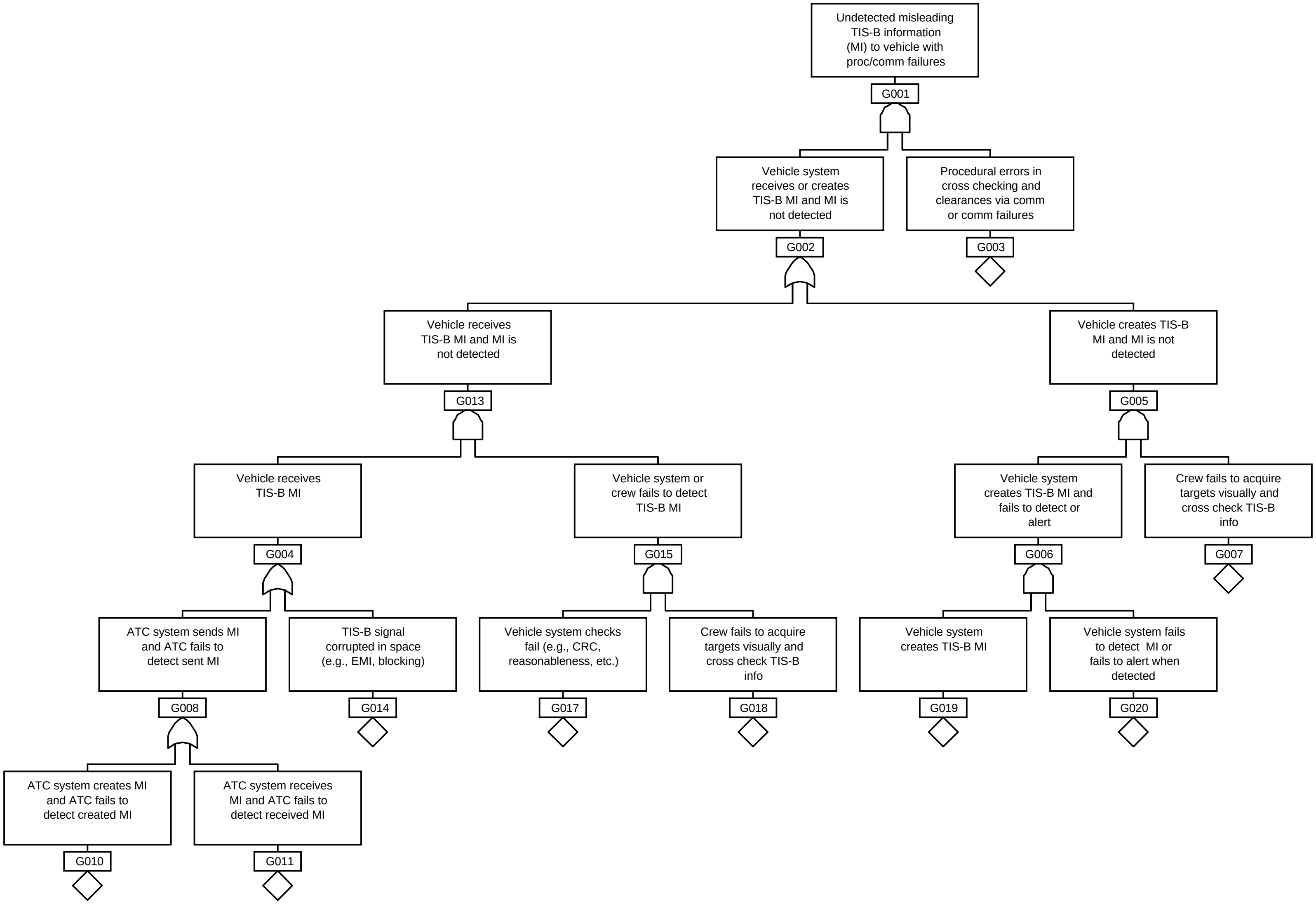
Table 2: ATC System and Procedural Requirements

Req No.	Primary Requirement		Corollary Requirements
505-A-1	Transmittal of misleading TIS-B information from ATC systems, without annunciation of failure, shall be improbable.	505-A-2 505-V-2	ATC shall contact the next area/segment control when vehicle leaves their respective control area/segment for vehicle handoff. Controlling ATC shall update vehicle position, altitude, speed, and intent at regular intervals by voice or data link communications. (Vehicle requirement V-2) Vehicle operator shall obtain ATC clearance upon area/sector entry and update controlling ATC at regular intervals regarding position, altitude, speed, and intent as provided by raw navigation and altitude source data or navigation and altitude data from a system independent of TIS-B.
505-A-3	Target "ground track" function on the ATC display shall be ON.		
505-A-4	The end ATC system shall employ a checking function that compares ADS-B and TIS-B locations for each ADS-B target. This function should warn the ATC operators when the two target positions are different.		
505-A-5	ATC systems shall be developed to Level C development assurance requirements as defined for acquired and developed ground systems.		
505-A-6	TIS-B related procedures shall be qualitatively assessed, and shall be likely to be successfully performed without requiring exceptional operator skill or strength.		

Req No.	Primary Requirement		Corollary Requirements
505-A-7	The TIS-B system shall employ built in test and annunciation to the ATC operator of failures and malfunctions.		
505-A-8	Vehicle positions shall be calculated, transmitted, received, and displayed at a rate of at most 4.5 seconds between updates.		

HAZARD 505 - FAULT TREE ANALYSIS OF THE OPERATIONAL HAZARD CONDITION

In order to better allocate safety objectives and requirements by qualitatively assessing the relationships of TIS-B related faults, failures, and errors, a fault tree analysis at the operational level was produced. Appendix A of this document provides that analysis.


Undetected misleading TIS-B information (MI) to vehicle with proc/comm failures
G001
Vehicle system receives or creates TIS-B MI and MI is not detected
G002
Procedural errors in cross checking and clearances via comm or comm failures
G003
Vehicle receives TIS-B MI and MI is not detected
G013
Vehicle creates TIS-B MI and MI is not detected
G005
Vehicle receives TIS-B MI
G004
Vehicle system or crew fails to detect TIS-B MI
G015
Vehicle system creates TIS-B MI and fails to detect or alert
G006
Crew fails to acquire targets visually and cross check TIS-B info
G007
ATC system sends MI and ATC fails to detect sent MI
G008
TIS-B signal corrupted in space (e.g., EMI, blocking)
G014
Vehicle system checks fail (e.g., CRC, reasonableness, etc.)
G017
Crew fails to acquire targets visually and cross check TIS-B info
G018
Vehicle system creates TIS-B MI
G019
Vehicle system fails to detect MI or fails to alert when detected
G020
ATC system creates MI and ATC fails to detect created MI
G010
ATC system receives MI and ATC fails to detect received MI
G011

APPENDIX E: SAFETY TEAM MEMBERS

Team Leader:

Van Buren, Scott	scott.vanburen@faa.gov

Participants:

Capezzuto, Vincent	vincent.capezzuto@faa.gov
Balderston, Dave	dave.balderston@faa.gov
Blumenstiel, Alexander	blumenstie@volpe.dot.gov
Bui, Don	don.bui@faa.gov
Dutch, Keith	keith.dutch@faa.gov
Fontaine, Paul	paul.fontaine@faa.gov
Hwoschinsky, Peter	peter.hwoschinsky@faa.gov
Joseph, Mark	mj@mitre.org
Livack, Garret	garret.livack@faa.gov
Moore, Ann	ann.moore@faa.gov
Nauman, Maria	maria.nauman@faa.gov
Paasch, Steve	steve.paasch@certification.com
Passman, Robert	robert.passman@faa.gov
Rice, William	wrice@adsystech.com
Smith, Russell	russell.smith@faa.gov
Smith, Steven D	steven.smith@faa.gov
Tedford, Ann	ann.tedford@faa.gov
Temple, Dick	dick.temple@faa.gov
Thibedeau, Richard	richard.ctr.thibedeau@faa.gov
Zeitlin, Andrew	azeitlin@mitre.org