1 Purpose and Scope

2 Functional and Operational Requirements

3 ADS-B and Airborne System Definition and Performance Requirements

3.1 System Scope and Definition of Terms

3.2 System Descriptions

3.3 System Application Requirements

3.3.1 Latency

In general, latency is synonymous with data age. As used in this document it is the difference between the time attributed to source data and the time that data are presented at a particular interface. {This definition was adapted from DO-289 section 2.4.5.3.3.4} Some data latency can be compensated with extrapolation techniques; however, there will always be a small amount of latency compensation error that needs to be minimized. This section includes the requirements for the end-to-end latency, referred to as total latency, for ADS-B, ADS-R and TIS-B; the latency allocations to some key subsystems; and the allowable latency compensation error for ADS-B.

Latency Definitions

Total Latency: is the total time between the availability of information at an lower interface 'X' to the time of completion of information transfer at an upper interface 'Y'. Total Latency is the sum of Compensated Latency and Latency Compensation Error and is expressed as a single upper value. The related position error is the product of Total Latency and acceleration uncertainty valid for the duration of the Total Latency.

Compensated Latency: is that part of Total Latency that is compensated for to a new time of applicability, valid at an interface 'Y', through data extrapolation aiming at reducing the effects of latency. Compensated Latency may change for each new received/processed track. The related position error is the product of Compensated Latency and the accuracy error of the A/V velocity used for the extrapolation.

Latency Compensation Error (formerly referred to as "Uncompensated Latency")**:** is that part of Total Latency that is not compensated and/or under-/overcompensated for. The value is usually positive but overcompensation might produce negative values as well. The Latency Compensation Error may change for each new received/processed track. The related position error is the product of Latency Compensation Error and true A/V velocity.

Time of applicability (TOA): at an interface 'Y', is the TOA as valid at a lower interface 'X' plus the amount of Compensated Latency applied to and valid at an upper interface 'Y'. Therefore, the Time of Applicability uncertainty is the (sum of) Latency Compensation Errors up to interface 'Y'. Regarding the notion of a "common" TOA, it is noted that the time of applicability uncertainty will generally vary between tracks.

The ground segment interfaces used to define latency are shown in Figure 1-1 and the airborne interfaces used to define latency measurements shown in Figure 3.3.1-1.

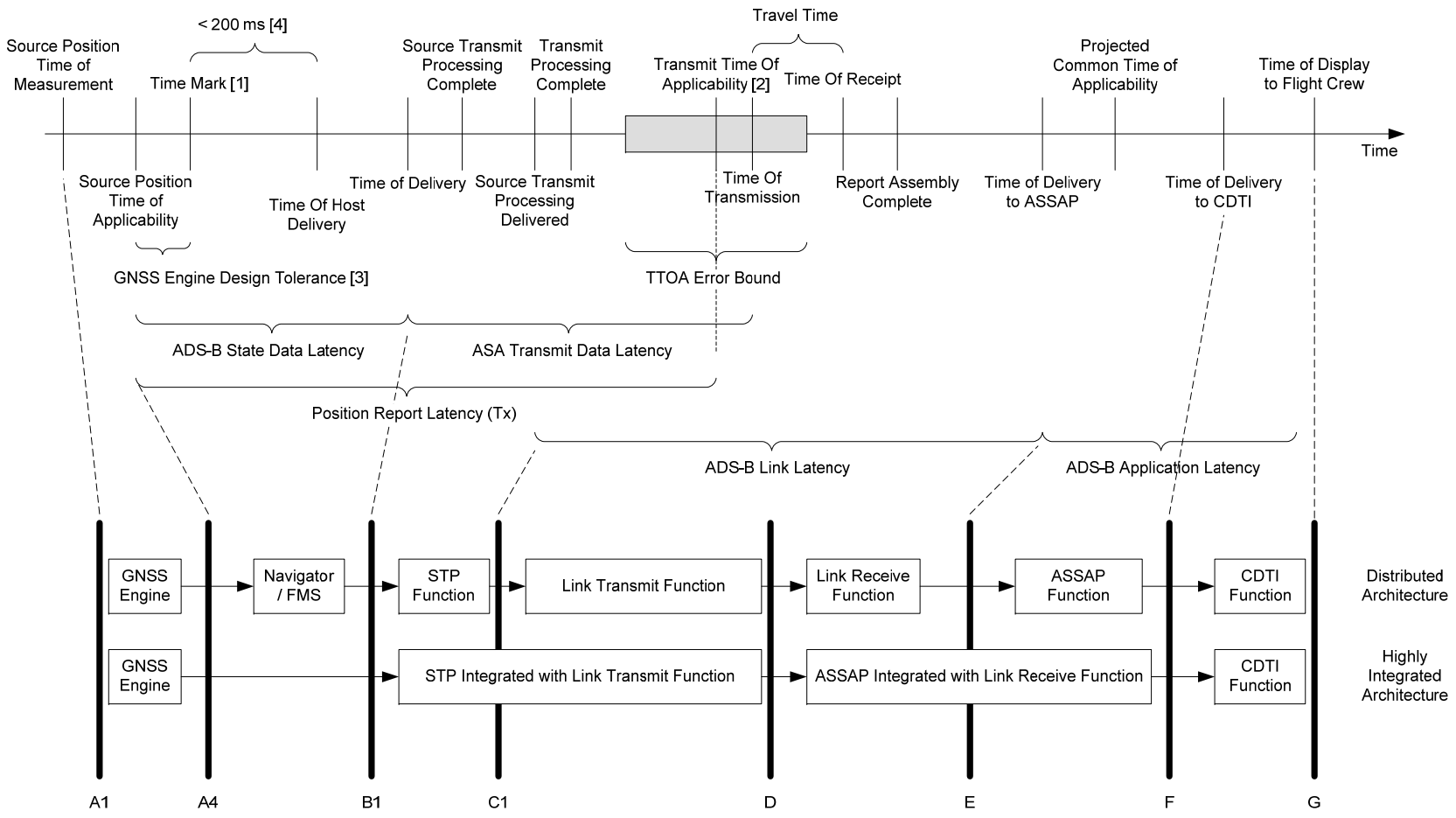

Figure 3.3.1-1 End to End ASA System Latency Diagram

Notes:

1. *The Time Mark is an implementation detail of an ARINC 743A compliant GNSS. Other position sensors do not typically output a Time Mark.*
2. *Transmit Time of Applicability (TTOA) may occur before, after, or coincide with Time of Transmission (TOT) depending on the ADS-B link implementation.*
3. *GNSS Engine Design Tolerance is dependent on the implementation of the GNSS engine, but typically is on the order of microseconds.*
4. *DO-229D requires that the digital solution associated with the Time Mark be delivered in 200 ms.*
5. *The bold lines indicate defined interfaces and match Figure 2-7 in DO-289. The exception is interface A4 which doesn't appear in DO-289 and was added to clarify the latency allocation to the transmit subsystem.*

System Interface Definitions

In the following, the term “system interface” expresses timing reference points. With respect to timing requirements, each interface is associated with the time the last bit of a complete data (or signal) set has been transferred over that interface.

Figure 3.3.1-1 provides for a detailed end-to-end latency diagram, showing the latency components of both ADS-B Transmit aircraft and ASA aircraft.

The following Figure 3.3.1-2 provides for a simple indication of the ASA System latency interfaces with respect to both own-ship and traffic position information.

Figure 3.3.1-2 ASA System Latency Diagram

Interface A1

Interface A1 is defined as the input to the position sensor of an ASA Transmit Participant. The time associated with this physical interface is called the Time of Measurement.

The term Time of Measurement has a very specific meaning in the GNSS literature. It is the time that the Satellite Measurements are sampled with the GNSS RF hardware. Depending on the regulatory document and the equipment class that the GNSS is certified to, the time between the Time of Measurement (A1) and the Time of Applicability (A4) can be 300 ms to 1 second. To meet the Latency allocations in these MOPS, the maximum Total latency Latency between A1 and A4 may not exceed 500 ms.

Interface A2

Interface A2 is defined as the input to the position sensor of a TIS-B Participant or the reception of position data of an ADS-R Participant. The time associated with this physical interface is called the Time of Measurement or Time of Reception respectively. This interface is not depicted in Figure 3.3.1-1, refer to Figure 1-1.

Interface A3

Interface A3 is identical to A1 but is defined as applicable to the ownship position source. This interface is not depicted in Figure 3.3.1-1, refer to Figure 1-1.

Interface A4

Interface A4 is introduced in this appendix and defined as the output of the position sensor of an ASA Transmit Participant. The time associated with this physical interface is called the Time of Applicability.

The term Time of Applicability has a very specific meaning in the GNSS literature. It is the time that the digital solution transmitted from the sensor is applicable. This Time of Applicability coincides with the leading edge of a pulse known as the Time Mark. A GNSS sensor provides this pulse on a dedicated set of pins; usually as a differential pair to provide better noise immunity.

The reported digital solution quality metrics (accuracy, integrity) are also valid at the Time of Applicability. Latency present in the system after Interface A4 is NOT accounted for in the quality metrics provided by the GNSS including the Latency inherent in delivering the data to Host/Link Equipment. The latency between A4 and B1 is to be included when establishing the ADS-B State Data Latency.

Interface A5

This interface is identical to A4 but is defined as applicable to the ownship position source. As between A4 and B1, the latency between A5 and B3 resulting from the various system elements that can be included between both interfaces, has to be included when establishing the ownship State Data Latency. This interface is not depicted in Figure 3.3.1-1.

Interface B1

Interface B1 is defined as the input to the ADS-B Transmit Subsystem. The requirements of this function are controlled by DO-260()/E-102(), DO-282() and ED-108(). In a distributed architecture, there could be various system elements between A4 and B1. For instance, a modern integrated cockpit with a high speed databus may require a block of circuitry on either side of it to transfer PVT data on and off of the bus.

For GNSS systems, the maximum Total Latency between A4 and B1 may not exceed 400 ms. This latency is usually not compensated for and, hence, becomes part of the Latency Compensation Error budget.

Interface B2

Interface B2 is defined as the input to the TIS-B & ADS-R Surveillance Processing and Distribution system. This interface is not depicted in Figure 3.3.1-1, refer to Figure 1-1.

Interface B3

Interface B3 is defined as the input to the ASSAP function on ownship. This interface is not depicted in Figure 3.3.1-1, refer to Figure 1-1.

Interface D

Interface D is defined as the Time of Transmission (i.e., the RF message leaving the transmit antenna). Depending on which transmit case is implemented in the link equipment, the Transmit Time of Applicability may coincide with the Time of Transmission or be within some specified time tolerance between these.

For the purposes of latency allocation, Travel Time is not significant. Therefore, Interface D also defines the Time of Reception (i.e., the RF message arriving at the receive antenna).

The Link Transmit and Receive Equipment requirements are controlled by DO-260()/E-102(), DO-282() and ED-108().

Interface E

Interface E is defined as the time an ADS-B (or TIS-B/ADS-R) Report is delivered to ASSAP. ASSAP requirements are controlled by this document. The ASSAP function will extrapolate the traffic positions to a common time of applicability, within required tolerances, prior to performing application specific calculations and passing the traffic to the CDTI interface (F).

In an integrated architecture, Interface E may not be observable. For example, in an Air Transport installation, it is possible that the ADS-B Receiver will be integrated with the TCAS II equipment that may also implement the ASSAP requirements.

Interface F

Interface F is defined as the time the ownship and traffic tracks are delivered to the CDTI. For architectures that do not process ownship and traffic data together, the Time of Delivery at interface F might differ.

The latency budget allocated between E and F was relaxed by the ASA MOPS Working Group from the numbers published in DO-289 and the numbers published in DO-322 / ED-165. Analysis by the ASA MOPS Working Group established a latency allocation presented in Table 2-2 and 2-3 [TBV] based on a feasibility study of implementing ASSAP in TCAS II equipment and supporting legacy equipment upgrades.

Interface G

Interface G is defined as the Time of Display, i.e. the time when the track information appears on the display.

The CDTI function may translate and rotate the traffic as needed to maintain a smooth and consistent display. The CDTI function is not required to extrapolate the traffic from the ASSAP Time of Applicability to the Time of Display. However, it may be desirable for the ASSAP Time of Applicability (at interface F) to coincide with the Time of Display by design to minimize display latency.

3.3.1.1 Total Latency for ADS-B and ADS-R

The total latency for ADS-B and ADS-R is the time difference between the Time of Measurement (TOM) of the source data at the transmitting aircraft (Interface A1) and the time that data are displayed to the user on the receiving aircraft (Interface G).

The total latency for source position and velocityState data in ADS-B and ADS-R **shall** (Rx.xxx) be no greater than 5.5 seconds from A1 to G to support the applications included in section 2.2.1.1 for ADS-B and 2.1.1 for ADS-R. {This requirement is consistent with the ASA MOPS draft version 5.00, September4.10, 16 July 2011, but is less stringent than the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010, which requires 5 seconds.}

The total latency for updated ID/Status (DO-289 2.4.5.1) information in ADS-B and ADS-R from interface A1 to G **shall** (Rx.xxx) be no greater than 30 seconds. {This requirement is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010} ➔ May need a Note here to explain: (1) Check App-L from DO-242A, (2) And, additional concern about the mixing of update and latency requirements. ←

The total latency for own-ship position data sources shall (R3.xxx) be no greater than 1 second from the Time Of Measurement (Interface A3) to the time the data is supplied to ASSAP (Interface B3, see Figure 1-1).

The total latency for source position and velocityState data in ADS-B and ADS-R from Interface B1 to D **shall** (Rx.xxx) be no greater than 1.1 seconds.

The total latency for source position and velocityState data in ADS-B and ADS-R from Interface D to G **shall** (Rx.xxx) be no greater than 3.5 seconds.

3.3.1.2 Navigation Subsystem Latency Allocation

The total latency allocation for the navigation subsystem that measures the source position and velocity for the ADS-B transmitting aircraft/vehicle shall (Rx.xxx) is assumed to be no greater than 0.5 seconds from Interface A1 to A4. The total latency allocation from Interface A1 to B1 is assumed to be no greater than 0.9 seconds. {TheseThis requirements areis consistent with the ASA MOPS draft version 4.10, 16 July 2011 5.00, September 2011}

Note: TheseThis subsystem latency allocationsare is included in the total latency.

3.3.1.3 TIS-B Subsystem Latency Allocation

The TIS-B subsystem latency is the difference between the TOM of the source position data and the time of transmission of the TIS-B Message by the ground radio station, interfaces A2 to D in Figure 1-1.

The latency allocation for the TIS-B ground subsystem **shall** (Rx.xxx) be no greater than 3.25 seconds to support the applications included in section 2.2.1.1. {This requirement is consistent with DO-289 section 3.1.1.5, (no number assigned to the shall in this section), 286R2.5-01, and the FAA Essential Services Specification for SBS, version 2.2, 29 November 2010} ➔In the future there may be a need for separate requirements for airborne and/or surface TIS-B ←

3.3.1.4 Latency Compensation Error

The latency compensation error is the residual after the TOM on the transmitting aircraft/vehicle or the Time of Applicability (TOA) of the position data on the receiving aircraft/vehicle has been estimated. The

allowable errors in the following requirements are included in the total latency defined above. {The requirements in this section are expected to be consistent with version 4.105.00 of the ASA MOPS. The transmit-side latency compensation error is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010, however, the receive-side error is not accounted for in the fPR.}

The latency compensation error of measured geometric position and velocity data in the aircraft/vehicle transmitting ADS-B (interfaces A1 to D in figure 3.3.1-1) **shall** (Rx.xxx) be no greater than ±0.6 seconds (at 95% probability). {reference AC20-165, and DO-260B, Apndx-U}

The latency over-compensation error of measured geometric position data in the aircraft/vehicle transmitting ADS-B (interfaces A1 to D) **shall** (Rx.xxx) be limited to 200 ms (at 95% probability). {reference AC20-165, and DO-260B, Apndx-U}

The latency compensation error of retransmitted geometric position and velocity data by the ADS-R ground subsystem (interfaces B2 to D in figure 1-1) **shall** (Rx.xxx) be no greater than 0.1 seconds (at 95% probability).

The latency compensation error of source position data by the TIS-B ground subsystem (interfaces A2 to D in figure 1-1) **shall** (Rx.xxx) be no greater than ±0.5 seconds (at 95% probability). {Reference 286R2.5-02}

The latency compensation error of measured geometric position data in the aircraft/vehicle receiving ADS-B, ADS-R or TIS-B (interfaces D to E in figure 3.3.1-1) **shall** (Rx.xxx) be no greater than 0.5 seconds (at 95% probability). Ed Note: In DO-317A Table 2-2 this is a total latency requirement, not a LCE requirement. {reference DO-242A 3.3.3.2.2}

The latency compensation error of measured geometric position data (from Interface E to G) **shall** (Rx.xxx) be no greater than +/- 500 ms (at 95% probability).

3.3.2 ADS-R/TIS-B Service Status Update Interval

The update interval is the time between successive updates of particular information at the receiving aircraft/vehicle.

The update interval of ADS-R or TIS-B Service Status information in the receiving aircraft **shall** (Rx.xxx) be less than 30 seconds (measured at Interface D). {This requirement is consistent with the FAA final Program Requirements (fPR) for SBS, version 3.0, 23 July 2010}