Latency

Revision 1

(Prepared by: Johan Martensson, Jörg Steinleitner)

Summary
The working paper addresses minimum required ASA system performance with respect to Latency, in response to action (ALN) 27 and 71. The paper proposes inclusion of detailed latency descriptions and references to SPR and other MOPS documents in appendix J. The paper also proposes related updates of the latency requirements and assumptions in the main body of the document.

1- Proposed modifications & Comments

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Appendix J is using tacked changes	

1.2.1 Aircraft Surveillance Applications

[…]

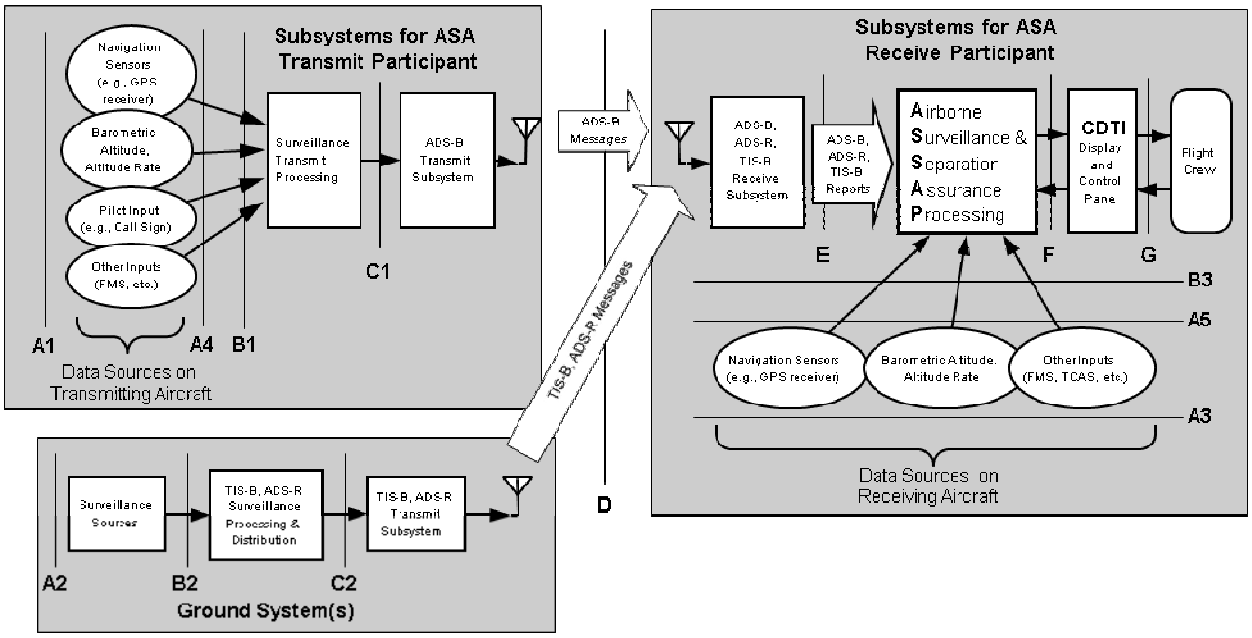


Figure 1-1 Overview of ASA Architecture

Appendix J describes the system interfaces depicted in Figure 1-1. It also provides a mapping of latency requirements to relevant SPR and other MOPS documents.

1 PURPOSE AND SCOPE

1.5 Assumptions

1.5.1 ASSAP Assumptions

1.5.1.1 Ownship Position

The position source for ownship provides position updates at least once per second. Ownship horizontal position data will be delivered to ASSAP such that the uncompensated latency (between interfaces A3 and B3) is less than 600 ms. [JM1]Global Positioning System (GPS) sensors compliant with ARINC 743A and Required Navigation Performance (RNP) Flight management System (FMS) compliant with ARINC 702A Supplement 3 are examples of acceptable position sources.

Note: The 600 ms assumption applies from A5 to B3 (see Figure 1-1).[JM2]

It is assumed that ASSAP and CDTI use the same ownship position source. Section 3.1.9 provides requirements for installations where this assumption does not apply.

1.5.1.2 ADS B Reports

All ADS B Reports generated by the ADS B link receiver are subject to track initiation and update criteria as defined by the appropriate link MOPS (DO 260() and DO 282()). Therefore, ASSAP is required to track all reports received from the ADS B receiver. ASSAP uses state vector and mode status reports as defined in DO 242(). Traffic horizontal position data will be delivered to ASSAP such that the uncompensated latency between time of reception (interfaces D) and time of delivery of data to ASSAP (interface E) is less than 500 ms[JM3]. Time of Applicability at interface D is assumed to equal time of reception at interface D.

Note: In case that the horizontal position is delivered such that introduced latency can be compensated for and such methods are deployed, any remaining portion of this uncompensated latency budget for the receiver may be re-allocated to ASSAP or CDTI.

The installation's report format supports distinction between ADS B, ADS R and TIS B sources.

1.5.2 CDTI Assumptions

1.5.2.2 CDTI Display Platform

The CDTI data may be presented on a standalone display dedicated to traffic information only, or part of a shared/multi-function display, or an EFB.

This MOPS does not include an exhaustive or comprehensive list of shared/multi-function display considerations or requirements.

With respect to minimum performance of the display it is assumed that all traffic horizontal positions and ownship horizontal position are refreshed at the same time.

Note: Ownship horizontal position may still be refreshed more frequently than traffic.

[JM4]

2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.8 Latency Requirements

These MOPS contain a series of latency requirements. The latency requirements are expressed both as end-to-end ASA system requirements in this section and as requirements allocated to ASSAP and CDTI in section 2.2 and section 2.3. There are also latency assumptions made in section 1.5 on systems outside the scope of these MOPS. All the latency requirements and assumptions in these MOPS are to be considered as not to exceed (NTE) values, i.e. upper or lower bounds.

2.1.8.1 Total Latency Requirements

These total latency requirements apply end-to-end for all ASA subsystems (from interface A3 or D up to interface G, see Figure 1), consequently it extends outside the boundaries of these MOPS.[JM5] These MOPS recommends allocations of the total latency for individual functions in Table 2-2. For interchangeability reasons it is recommended that manufacturers follow these allocations. For the same reason it is also recommended that manufacturers publish latency specifications for their equipment.

The total latency of ownship State Data measured from the time of measurement (at interface A3) to actual time of display (at interface G) **shall** be less than 2.5 seconds.

Note: Actual time of display refers to when the information appears on the display. Data ageing of information while being displayed is not part of the latency budget, given compliance to the display update requirement in section 2.3.2.2.

The total latency of traffic State Data measured from initial time of applicability (at interface D) to actual time of display (at interface G) **shall** be less than 3.0 seconds.

Note: Actual time of display refers to when the information appears on the display. Data ageing of information while being displayed has been accounted for in accordance with the display update requirement in section 2.3.2.2.

2.1.8.2 Latency Compensation Requirements

Data processing and update intervals results in increased data age which reduces the usability of dynamic data. To improve the usability of the horizontal position data for traffic and ownship it has been deemed necessary to require a maximum difference between the Time of Applicability of the data and the time at which the data is being used. For requirements relating to display of data, the time at which the data is being used has here been defined to be the time the data first appears on the display (interface G).

The absolute difference in Time of Applicability of ownship's horizontal position between interface A3 and interface G (see Figure 1.1) **shall** be no more than 1.0 second.

Note: This requirement represents the ASSAP and CDTI part of the total ASA system requirement on Time of Applicability. In these MOPS this requirement has been allocated as assumptions on compensation errors introduced outside the scope of the MOPS (see section 1.5.1.1) and as requirements for maximum compensation error induced by MOPS compliant equipment (see section 2.2.3.6).

The absolute difference in Time of Applicability of traffic's horizontal position between interface D and interface G (see Figure 1.1) **shall** be no more than 1.0 second.

Note: This requirement represents the ASSAP and CDTI part of the total ASA system requirement on Time of Applicability. In these MOPS this requirement has been allocated as assumptions on compensation errors introduced outside the scope of the MOPS (see section 1.5.1.2) and as requirements for maximum compensation error induced by MOPS compliant equipment (see section 2.2.3.6).

Time of Applicability at interface D is assumed to equal time of reception at interface D. In the case that the data is delivered such that compensation for any uncompensated latency induced before the time of reception at interface D is possible, it is recommended that such methods are deployed.

2.2 Airborne Surveillance and Separation Assurance Processing (ASSAP) Subsystem Requirements

2.2.2 ASSAP Input / Output Requirements

2.2.2.5 ASSAP Output Requirements to CDTI

2.2.2.5.2 Ownship Information Output Requirements

2.2.2.5.2.1 Ownship Horizontal Position

a. The ASSAP function shall (2096) provide the Ownship Horizontal Position in WGS 84 latitude/longitude to the CDTI.

b. The position provided shall (2097) meet the requirements defined in Table 2-3.

~~c. The time registration between ownship TOA and the common TOA of the target tracks shall (2098) be within +/-500 ms.~~

2.2.2.6 ASSAP Processing Latency

ASSAP shall (2111) receive ADS B, ADS R and TIS B reports from the input interface and output correlated tracks to the CDTI within 2.0 seconds.[JM6]

Note: This requirement applies between the input (E) and output (F) of the ASSAP function per Figure 1-1 and Table 2-2.The requirement relates to when the last bit becomes available to ASSAP until the last bit has been made available to the CDTI.

2.2.3 Surveillance Processing

2.2.3.5 Common[JM7] Time of Track Extrapolation and Traffic State File Generation

Track estimates shall (2131) be generated and output at a rate of 1 Hertz (Hz) or greater. ~~Track estimates shall (2132) include target horizontal position, barometric altitude, and geometric altitude (when barometric altitude is not available), estimated to a common time of applicability (within +/- 200 ms) for all tracks.~~

The absolute difference in Time of Applicability between any traffic horizontal positions at interface F (see Figure 1.1) **shall** (####) be no more than 200 ms.

Note: The difference in Time of Applicability at interface F applies to the Initial Time of Applicability as measured from interface D.

Note: The requirement implies that ASSAP forwards all traffic and ownship horizontal position data as one data set to the CDTI (the implication is only applicable for ownship in the case that CDTI uses ownship horizontal position data from ASSAP for display). [JM8]

~~Ownship state information is estimated to the same common time of applicability as the traffic tracks (see section 2.2.2.5.2.1). Estimation of ownship state information shall (2134) include ownship horizontal position, barometric altitude, and geometric altitude (when barometric altitude is not available), estimated to a common time of applicability (within +/- 500 msec) of the time of display.~~

The absolute difference in Time of Applicability between ownship's and any traffic's horizontal positions at interface F (see Figure 1.1) **shall** (####) be no more than 200 ms.

Note: The difference in Time of Applicability at interface F applies to the Initial Time of Applicability as measured at interface D(time of reception) and interface A3 (time of measurement) respectively.

2.2.3.6 Individual Time of Track Extrapolation and Traffic State File Generation

The absolute difference in Time of Applicability of ownship's horizontal position between interface B3 and interface G (see Figure 1.1) **shall** (####) be no more than 400 ms.

Note: This requirement represents the ASSAP and CDTI part of the total ASA system Ownship Time of Applicability requirement, as described in section 2.1.8.2.

The absolute difference in Time of Applicability of traffic's horizontal position between interface E and interface G (see Figure 1.1) **shall** (####) be no more than 500 ms.

Note: This requirement represents the ASSAP and CDTI part of the total ASA system Traffic Time of Applicability requirement, as described in section 2.1.8.2.

Table 1-2 Traffic Vehicle Application Specific Requirements Summary[JM9]

Requirement Category	Requirement	Applicable Subsystem Interfaces (See Figure 1-1)	AIRB	SURF (Note 6)	VSA	ITP
State Data	Horizontal Position Uncertainty (95%)	A1→B1	0.5 NM (NACp ≥ 5)	30 meter (m) (NACp ≥ 9)	0.3 NM (NACp ≥ 6)	0.5NM
	Degraded Position Uncertainty (95%)	A1→B1	Not Applicable (N/A)	185.2 m (NACp ≥7) Optional	N/A	N/A
	Horizontal Velocity Uncertainty (95%)	A1→B1	< 10 m/s (NACv ≥ 1)	N/A	< 10 m/s (Note 1)	<10m/s
	Vertical Position Uncertainty (95%)	A1→B1	Valid Pressure (Note 4)	On Ground or Valid Pressure or Valid Geo (Notes 4 & 5)	Valid Pressure (Note 4)	Valid Pressure
	Vertical Velocity Uncertainty (95%)	A1→B1	N/A	N/A	N/A	NA
State Data Integrity	Source Integrity Level	A1→B1	N/A	N/A	10e-3/hr (SIL ≥ 1)	1e-5 (SIL ≥ 2)
	Navigation Integrity Category	A1→B1	N/A	N/A	0.6 NM (NIC ≥ 6)	1.0 NM (NIC ≥ 5)
	System Design Assurance (Note 3)	A1→D	1	1	1	2 (1e-5 corruption requirements)
State Data Timing	Maximum Total Latency	A4→G	4.5 s	4.5 s	4.5 s	4.5 s
		A1→A4	0.5 s	0.5 s	0.5 s	0.5 s
		A4→B1	0.4 s	0.4 s	0.4 s	0.4 s
		B1→D	1.1 s	1.1 s	1.1 s	1.1 s
		~~D→E~~	~~0.5 s~~	~~0.5 s~~	~~0.5 s~~	~~0.5 s~~
		~~E→F~~	~~2 s~~	~~2 s~~	~~2 s~~	~~2 s~~
		~~F→G~~	~~0.5 s~~	~~0.5 s~~	~~0.5 s~~	~~0.5 s~~
	Maximum Data Age until Dropped	at E	25 s	11 s (moving) 25 s (static)	15 s	25s
ID/Status Information	Maximum Total Latency	A1→G	30 s	30 s	30 s	30 s

Table 1-1 Ownship Application Specific Requirements Summary

Requirement Category	Requirement	Applicable Subsystem Interfaces (See Figure 2-1)	AIRB	SURF	EVApp	ITP
State Data Uncertainty	Max Horizontal Position Uncertainty (95%)	A3→B3	≤ 0.5 NM	≤ 50 m (Note 1)	≤ 0.3 NM	≤ 0.5 NM
	Maximum Horizontal Velocity Uncertainty (95%)	A3→B3	N/A	N/A	≤ 10 m/s	≤ 10 m/s
	Vertical Position Uncertainty (95%)	A3→B3	Valid Baro (Note 3)	On Ground Status or Valid Pressure (airborne) (Note 2)	Valid Pressure Altitude (Note 2)	Valid Pressure
	Vertical Velocity Uncertainty (95%)	A3→B3	N/A	N/A	N/A	N/A
State Data Integrity	Surveillance Integrity Risk	A3→B3	N/A	N/A	10e-3/hr (SIL ≥ 1)	1e-5 (SIL ≥ 2)
	Horizontal Position Integrity Containment Region	A3→B3	N/A	N/A	0.6 NM	≤ 1.0 NM
State[JM10] Data Timing	Maximum Total Latency	D→E	0.5 s	0.5 s	0.5 s	0.5 s
		E→F	2 s	2 s	2 s	2 s
		F→G	0.5 s	0.5 s	0.5 s	0.5 s

Notes:

1. *This constraint is based on a total system error (TSE) budget derived from RTCA/DO-272A and RTCA/ DO-257A (Aerodrome Moving Map Display (AMMD)), using more restrictive allocations for runway and taxiway database accuracies.*
2. *If valid pressure altitude is unavailable, geometric altitude may be used when VFOM < 45m.*

2.3 Cockpit Display of Traffic Information (CDTI) Subsystem Requirements

2.3.2 Interfaces

2.3.2.1 Latency Requirement

Note: Refer to Figure 1-1.

a. Maximum Total Latency between interfaces F and G shall (3010) be 0.5 seconds.[JM11]

b. Human Interface Latency: The ASA latency from activation of a control input to the appearance of the response on the CDTI shall (3011) be less than 1.1 seconds (0.25 seconds is recommended). If this value exceeds 0.25 seconds, an indication that the system has recognized the input shall (3012) be provided until the response appears on the CDTI.

2.3.2.2 Time of Applicability of Traffic State Vector (SV) Data

a. The CDTI shall (3013) update the traffic data at a minimum of once per second.

Note: ASSAP provides CDTI an updated traffic state file at least once per second.

Note: Latency requirements in these MOPS may impose higher update rates depending on architecture.

b. The[JM12] CDTI shall (3014) show the position of all displayed traffic and ownship position at the same time of applicability[JM13] at interface G. (see section 2.2.3.5)

APPENDIX J NOTE: THE ASSAP SUBSYSTEM WILL ASSURE THAT THE POSITION OF TRAFFIC IS EXTRAPOLATED TO A COMMON TIME OF APPLICABILITY WHEN THE SYSTEM SENDS THE TRAFFIC POSITIONS TO THE CDTI FUNCTION. IF THE DISPLAY UPDATE IS PERFORMED MORE THAN ONCE PER SECOND, THE TIME OF APPLICABILITY REQUIREMENT STILL APPLIES.

APPENDIX J SYSTEM INTERFACE BOUNDARIES AND LATENCY ALLOCATION

J.1 Introduction

The complete ADS-B Air-to-Air (and Ground-to-Air) system consists of several interfaces (refer to Figure J-1). The existing literature (DO-289, DO-~~242A~~242(), DO-~~282A~~282(), and DO-~~260A~~260()/ED-102()) defines several names for these interfaces and allocates latency between them. This Appendix will present and amend the terms used~~, introduce a new one,~~ and clarify which parts of the latency budget are allocated between the various interfaces. The definitions discussed in this Appendix are meant to aid the reader when interpreting the latency allocation requirements in Table 2-2 and Table 2-3.

It is important to manage latency at the system integration level to minimize the latency and the uncertainty of the latency (i.e., how the latency differs between position updates). The easiest way to ensure this design goal is met, is to provide a direct connection between the position source and the ADS-B equipment. Any other system blocks between them will increase latency and uncertainty. In some cases, this increase in uncertainty can have a more detrimental effect than the latency itself.

J.1.1 Latency Definitions

Total Latency: is the total time between the availability of information at interface 'X' to the time of completion of information transfer at the upper interface 'Y'. Total Latency is the sum of Compensated Latency and Latency Compensation Error (including uncompensated latency) 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 upper interface 'Y', through data extrapolation aiming at reducing the position error effects of latency. In general, Compensated Latency spans between two values which may change for each new received/processed track. The related position error is the product of Compensated Latency and accuracy error of the A/V velocity used for the extrapolation.

Latency Compensation Error: 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 spans between two values which 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

J.2 System Interfaces

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.

J.2.1 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 be compliant with these MOPS, the maximum Total ~~latency~~ Latency between A1 and A4 may not exceed 500 ms, refer to Table 2-2.

When the position sensor is not GNSS equipment, the Time of Measurement and Time of Applicability may not be regulated with as much rigor. The Latency allocations still apply to other equipment, but there may be no certification basis that guarantees the latency between Interface A1 and A4. In this case, the system integrator will need to establish the latency using information provided by the sensor manufacturer.

J.2.2 Interface A2

Description to be added.

~~J.2.2~~J.2.3 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 J-1, refer to Figure 1-1.

~~J.2.3~~J.2.4 Interface A4

Interface A4 is introduced in this document 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 and uncertainty. For GNSS systems, the maximum Total Latency between A4 and B3 may not exceed 200 ms This

latency is usually not compensated for and, hence, becomes part of the Latency Compensation Error budget.

When the position sensor is not GNSS equipment, the Time of Applicability may not be observable external to the position sensor. In this case, the system integrator will need to establish the latency using information provided by the sensor manufacturer.

~~J.2.4~~J.2.5 Interface A5

This interface is identical to A4 but is defined as applicable to the ownship position source. ~~Like~~ 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 and uncertainty. ~~This interface is also defined for the first time in this document.~~ This interface is not depicted in Figure J-1, refer to Figure 1-1.

~~J.2.5~~J.2.6 Interface B1

Interface B1 is defined as the input to the (usually notional) STP function. Although this could be a separate box, in most cases the STP function will be integrated with ~~a~~ the ~~1090 MHz Transponder or a UAT~~Link Transmit function. 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. The latency of that type of architecture would need to be characterized by the system integrator and included when establishing the ADS-B State Data Latency and uncertainty.

In the simple case of a direct connection from the Position Source to the Link Transmit Equipment, there is no additional latency contributed between B1 and C1.

J.2.7 Interface B2

Description to be added.

~~J.2.6~~J.2.8 Interface B3

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

~~J.2.7~~J.2.9 Interface C1

Interface C1 is defined as the input to the Link Transmit function. The requirements of this function are controlled by DO-~~260A~~ 260()/E-120(), ~~and~~ DO-~~282A~~282() and ED-VM4().

~~J.2.8~~J.2.10 Interface D

Interface D is defined as the Time of Transmission (i.e., the RF message leaving the ownship 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 (refer to Appendix M). [JM14]The

Travel Time is utilized by the UAT equipment to validate position measurements with a range measurement.

For the purposes of latency allocation, Travel Time is not considered significant.

The Link Receive Equipment requirements are controlled by DO-260()/E-120(), DO-282() and ED-VM4()~~DO-260A and DO-282A~~.

~~J.2.9~~J.2.11 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 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. The TCAS II equipment may implement the Link Receive and ASSAP requirements.

~~J.2.10~~J.2.12 Interface F

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

The latency budget allocated between E and F was relaxed by the ASA MOPS Working Group from the original numbers published in DO-289 (Table J-1). Analysis by the ASA MOPS Working Group established the requirements in Table 2-1 based on a feasibility study of implementing ASSAP in TCAS II equipment.

~~J.2.11~~J.2.13 Interface G

Interface G is defined as the Time of Display, i.e. the time when the track information appears on the display ~~to the Flight Crew~~. CDTI requirements are controlled by this document.

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 Common Time of Applicability to the Time of Display. However, it may be desirable for the ASSAP Common Time of Applicability (at interface F) to coincide with the Time of Display by design to minimize display latency.

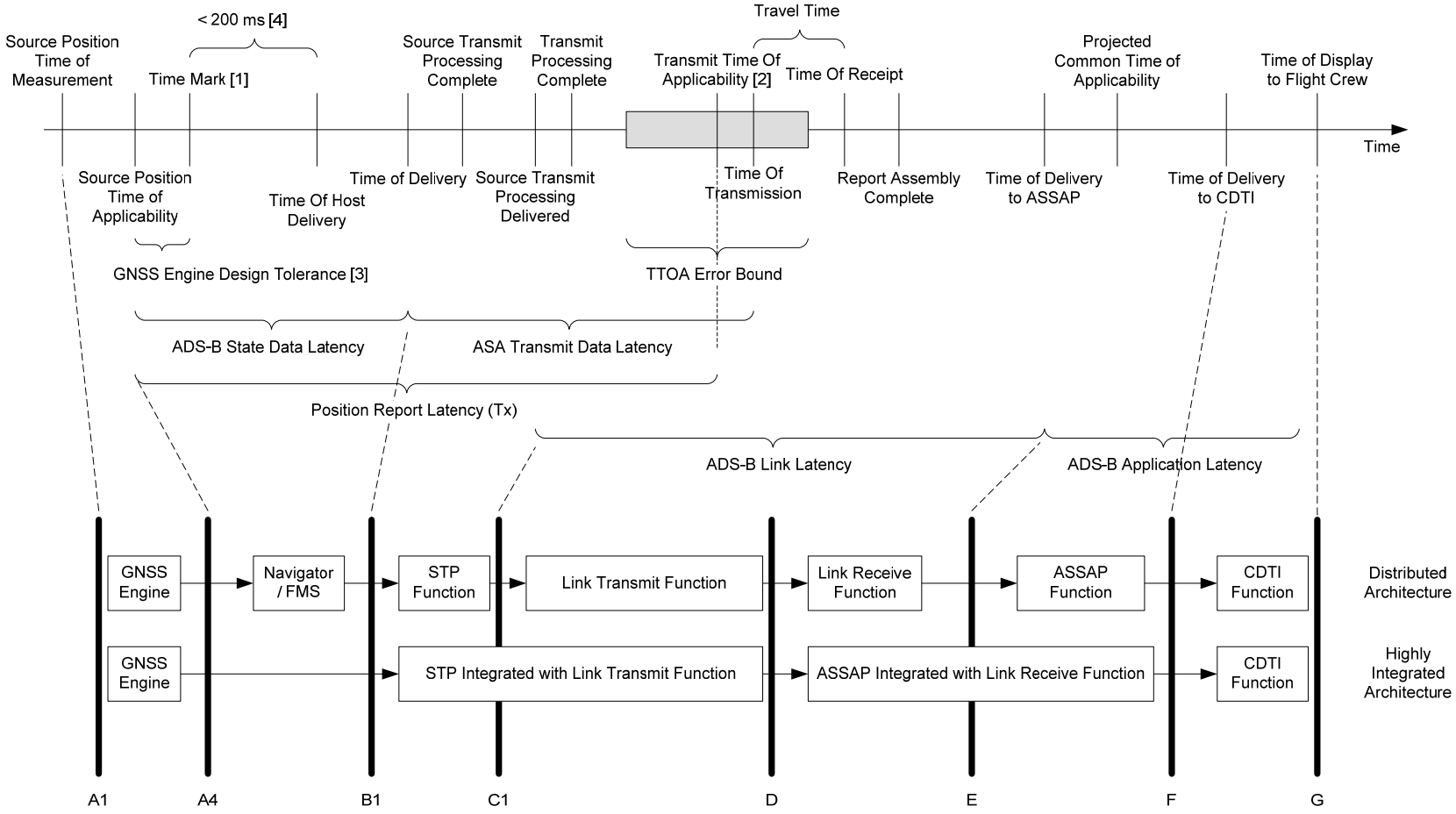


Figure J-1 ASA End-End Latency Diagram[JM17]

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. ARINC 743A 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.

TBD: add simplified Figure showing ADS-B IN system interfaces only, including for ownship.

J.3 Decomposition of ADS-B In Latency Components

To enhance clarity in the definition and application of the ASA MOPS latency requirements, the ADS-B In latency components are proposed to be first described as follows, see also Figure J-x. For simplicity, interfaces B3/E are not shown.

CEF: compensation error at interface F, i.e. valid between A3/D<=>F

CLF: compensated latency at interface F, i.e. valid between A3/D<=>F

DL: display latency, i.e. DL=TG-TF (F<=>G)

CLG: (forward) compensated latency (within ASSAP or CDTI), valid between F<=>G

CEG: compensation error,, valid between F<=>G: **ULG = DL - CLG**

TCL/TCE: total latencies: TCL = CLF + CLG; TCE = CEF + CEG

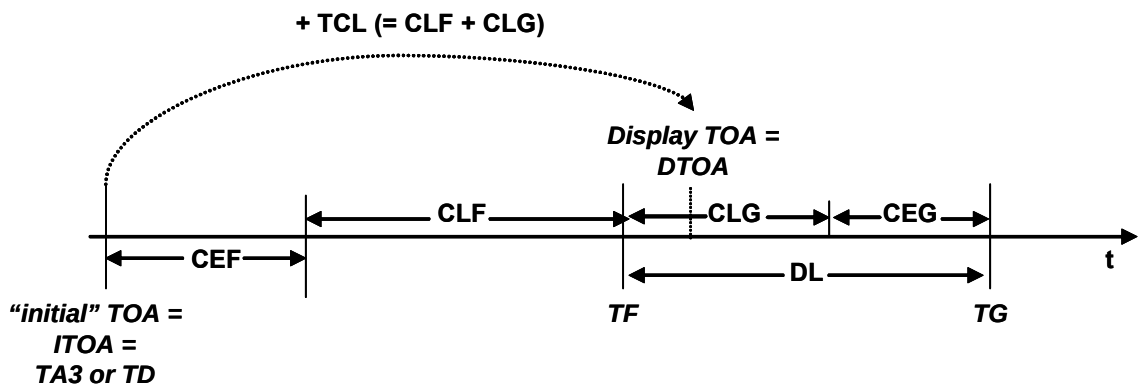


Figure J-x Decomposition of ADS-B In Latency Components

Thereby, the compensation error is defined as the sum of uncompensated latency, latency compensation uncertainty (e.g. due to time stamp uncertainty) and possible deliberate overcompensation (i.e. forward compensation, by convention expressed as a negative latency value).

The "Initial" TOA coincides with the time valid at interface A3 or D, respectively. In general, between two interfaces 'X' and 'Y', the TOA at interface 'Y' equals TOA at interface 'A' plus CLX. The Display TOA is the time valid at interface G. Its difference with the actual display of track information, i.e. the time TG at interface G, is the total compensation error from A3/D to G.

It is noted that the Display Latency (DL) can be greater or smaller than the latency compensation valid between F<=>G (CLG). It is further noted that the Display Latency (DL) might differ between the individual tracks included in a batch provided by ASSAP

for display. On a similar token, the TOA at interface F might differ between the individual tracks included in an ASSAP batch.

J.3.1 Application of Latency Dccomposition to ASA MOPS Latency Requirements

Total Latency (TL), between initial time of applicability and actual time of display ('A3/D'⇔'G') (applies to both position and velocity):

- TL Own-ship: TG- TA3 ≤ 2.5 s/3.0 s (add ref #)
- TL Traffic: TG – TD ≤ 3 s (add ref #)

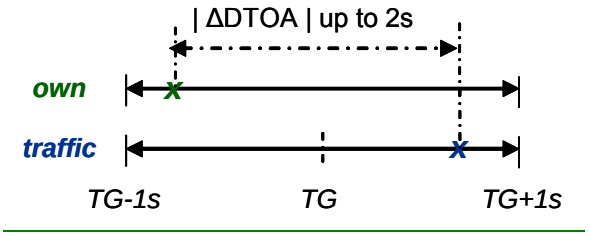
The Total Latency is a single value and established as the total maximum not-to-exceed end-to-end latency between A3/D and G, as per design of the given architecture.

Individual Display TOA Uncertainty, per own-ship & traffic ('A3/D'⇔'G')**:**:

- Independently per each own-ship and traffic positions, the absolute difference in display TOA and actual time of display shall be within 1.0 s (add ref #, see also Figure J-y below)
- Hence, TCE = | CEF + DL - CLG | <= 1.0 s.
- It is noted that, in line with this requirement, the "Differential Display TOA" between own-ship/traffic and traffic/traffic might be up to 2 seconds. This difference of common time of applicability at display can be described by the difference of the total compensation uncertainty "ΔTCU", i.e. ΔTCU = | ΔCUF + ΔDL – ΔCLG |

  However, it is noted that not much forward extrapolation beyond TG is expected to be applied by the ASA system. Hence, the individual Display TOA values are expected to be smaller rather than larger than TG.

The Individual Display TOA Uncertainty spans between two values and is established as the total not-to-exceed end-to-end latency compensation error between A3/D and G, i.e. the sum of the minimum and maximum values, respectively, of the various contributing latency compensation error components. These minimum and maximum values are to be established as per design of the given architecture.

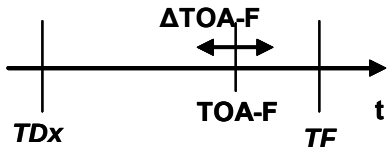


Differential TOA Uncertainty between any traffic at 'F', (i.e. between 'A3/D' and F'):

- The absolute difference in TOA between any traffic positions at interface 'F' shall be within 0.2 s (add ref #, see also figure below)

- Hence, the corresponding ΔTOA-TT at interface F (between any traffic '1' and '2') can be described as: ΔCEF-TT = | CEF-T2 – CEF-T1 | ≤ 0.2 s

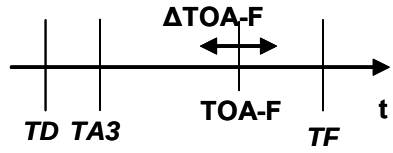
The Differential TOA Uncertainty at interface F spans between two values, i.e. between the difference of the maximum value of CEF-T2 and the minimum value of CEF-T1 on the one hand, and the difference of the minimum value of CEF-T2 and the maximum value of CEF-T1 on the other. These minimum and maximum values are to be established as per design of the given architecture.



Differential TOA Uncertainty between own-ship & any traffic at 'F', (i.e. between 'A3/D' and F'):

- The absolute difference in TOA between own-ship and any traffic positions at interface 'F' shall be within 0.2 s (add ref #, see also figure below)
- Hence, the corresponding ΔTOA-OT at interface F (between ownship 'o' and any traffic 't') can be described as: ΔCEF-OT = | CEF-O – CEF-T | ≤ 0.2 s

The Differential TOA Uncertainty at interface F spans between two values, i.e. between the difference of the maximum value of CEF-O and the minimum value of CEF-T on the one hand, and the difference of the minimum value of CEF-O and the maximum value of CEF-T on the other. These minimum and maximum values are to be established as per design of the given architecture.



For discussion: need to control individual CUF bounds ('A3/D'⇔'F'), bearing in mind non-CDTI application requirements (ITP≤1.575s) ?

J.3.2 Proposed Allocation of ASA MOPS Total Latency Requirements

TBD: add references to Main Body.

Ownship				
A1-A4	A4-B3	B3-F	F-G	Total

0.5s	0.2s	1.3s/1.8s	0.5s	2.5s/3.0s
Traffic				
D-E		E-F	F-G	Total
0.5s		2.0s	0.5s	3.0s

Notes:

- As a consequence of the ownship F-G requirement, an ASA system deploying a 1 Hz display update rate without some synchronization between ASSAP output and display (i.e. a sufficiently small DL) would not be compliant.
- The total ownship budget between A1 and B3 of 0.7s deviates from the guidance used in the US rulemaking (0.9s) to yield additional budget for the B3-F budget.

J.4 Traceability between ASA MOPS and SPR/INTEROP Latency Requirements

Table J-1 Latency Requirements Summary from RTCA/EUROCAE SPR/INTEROP Documents

Application	Own-ship		Traffic	
	TL	TCU	TL	TCU
VSA ED160/DO314	not specified	B2->G1: 1.6 s * => 1.6 s – max 1 s	(B1->D: 1.5 s/95%) D->G1: 4 s/95% *	(B1->D: 1.5 s/95%) D->G1: 2.5 s/95% => 2.5 s – max 1 s
AIRB ED164/DO319	not specified	B2->G1: 1.6 s * => 1.6 s – max 1 s	(B1->D: 1.5 s/95%) D->G1: 4 s/95% *	(B1->D: 1.5 s/95%) D->G1: 2.5 s/95% => 2.5 s – max 1 s
SURF ED165/DO321	B2->G1: 2.0 s	B2->G1: +/- 0.5 s	(A1-B1: 0.5 s) (B1-D: 1.5 s) D->G1: 3.0 s	(B1->D: 0.6 s/95%) D->G1: +/- 0.5 s
ITP ED159/DO303 (outside AC scope)	not specified	A2->F1: 4.575 s	not specified	(A1->D: 3 s) D->F: 1.575 s

Notes:

- For VSA and AIRB, the interface G corresponds to the "time of observation by flight crew". Assuming a 1 Hz display refresh rate, the corresponding ASA MOPS Interface G requirements for Total Compensation Uncertainty would therefore be 1.5s for traffic and 0.6s for ownship.
- For ITP, the overarching assumption is that the maximum differential uncompensated latency of 4.575 s is met for worst-case scenario of the applicable individual compensation uncertainty requirements.

  It is further noted that ITP requirements are expressed as 99.999% values, scaled from 95% values (e.g. MASPS 1.5s/95% for own-ship uncompensated latency)

Table J-2 Latency Requirements Summary from DO-289

Max Latency	EV Acq	CD	ASSA, FAROA	EV Approach	DO-289 Reference
End to End A1-G	6 s	3 s	3 s	6 s	Table 2-3
ASA Transmit Data Latency B1-D	1.1 s	1.1 s	1.1 s	1.1 s	Table 3-1
ADS-B State Data Latency A1 – B1	1 s	1 s	1 s	1 s	Table 3-1
ADS-B Link Latency C1 – E	1.2 s	1.2 s	1.2 s	1.2 s	3.2.3.1.1.2.2 Table 3-12
ADS-B Application Latency E – G	(0.4) 1 s	(0.4) 1 s	(0.4) 1 s	0.4 s	3.3.2.2

~~**Table J-3 RTCA DO-289 Latency Decomposition**~~

~~A1-B1~~	~~B1-C1~~	~~C1-D~~	~~D-E~~	~~E-G~~
~~**1**~~	~~0.4~~	~~0.7~~	~~0.5~~	~~**0.4**~~

~~*Note: To derive the numbers in Table J-2, start with the End to End requirement of 3 seconds. Take the **A1-G** number, subtract **A1-B1**, **C1-E**, and **E-G** to get B1-C1. To get C1-D, subtract B1-C1 from **B1-D**. To get D-E, subtract C1-D from **C1-E**.*~~

Table J-4 Latency Requirements Traceability

TB updated to align with final draft text.

Own-ship		Traffic	
Total Latency	**Compensation**	**Total Latency**	**Compensation**

	Uncertainty		Uncertainty
Only specified in SURF B2->G1: 2.0 s To confirm if in line with ASA MOPS B3=>G	Most stringent: SURF B2->G1: +/- 0.5 s VSA/AIRB TBD if +/- 0.6 s TBD if in line with ASA MOPS +/- 1.0 s (A3=>G)	Most stringent: SURF D->G1: 3.0 s Fully in line with ASA MOPS	Most stringent: SURF D->G1: +/- 0.5s Not in line with ASA MOPS +/- 1.0 s (D=>G) (note that AIRB/VSA should be ok if effective req't reads +/- 1.5 s)

J.5 Latency Analysis – Worked Examples

For the following worked examples of a latency analysis for traffic and owhship, for both cases of ownship being processed by ASSAP or another non-ASSAP function, the latency compensation error is refined as follows for the three steps of data read, data processing and data write.

With respect to Total Latency calculations, the following is used:

Tr: time span for reading data at the lower interface.

Tp: time span for processing data.

Tw: time span for writing data at the upper interface.

With respect to Total Compensation Error calculations, the following is used:

ULr: amount of uncompensated latency applicable to data reading.

CA: compensation accuracy

FCp: forward compensation applied on the processed data beyond the applicability of the upper interface

ULw: amount of uncompensated latency applicable to data writing across the upper interface.

FCw: forward compensation applied to compensate for latency due to data writing.

J.5.1 Latency Analysis of Traffic Track

	Traffic Latency					
	D => E		E => F		F => G	
	min	max	min	max	min	max
Total Latency						
Tr	0.10	0.10	0.00	0.10	0.10	0.10
Tp	0.30	0.30	1.00	1.40	0.00	0.00
Tw	0.10	0.10	0.30	0.50	0.10	0.40
TL	**0.50**	**0.50**	**1.30**	**2.00**	**0.20**	**0.50**
req'd		**0.50**		**2.00**		**0.50**
Total Compensation Error						
ULr	0.10	0.10	0.00	0.10	0.10	0.10
CA	0.00	0.00	0.00	0.10	0.00	0.00
FCp	0.00	0.00	0.00	0.00	0.00	0.00
ULw	0.10	0.10	0.00	0.00	0.10	0.40
FCw	0.00	0.00	0.10	0.10	0.00	0.00
TCE	**0.20**	**0.20**	**0.10**	**0.30**	**0.20**	**0.50**
Individual Display TOA Uncertainty						
TCE-G	**D=>G**				**0.50**	**1.00**
req'd	**D=>G**				**-1.00**	**1.00**
Differential TOA Uncertainty between any traffic at 'F'						
|ΔTCE|	**0.00**		**0.20**			
	D=>F		**0.20**			
req'd	**D=>F**		**0.20**			

J.5.2 Latency Analysis of Ownship Tracks when routed through ASSAP

	Ownship Latency - ASSAP					
	A3 => B3		E => F		F => G	
	min	max	min	max	min	max
Total Latency						
Tr	0.00	0.00	0.00	0.10	0.10	0.10
Tp	0.50	0.50	1.00	1.20	0.00	0.00
Tw	0.20	0.20	0.30	0.50	0.10	0.40
TL	**0.70**	**0.70**	**1.30**	**1.80**	**0.20**	**0.50**
req'd		**0.70**		**1.80**		**0.50**
Total Compensation Error						
ULr	0.00	0.00	0.00	0.10	0.10	0.10
CA	0.00	0.00	0.00	0.10	0.00	0.00
FCp	0.00	0.00	0.00	0.00	0.00	0.00
ULw	0.20	0.20	0.00	0.00	0.10	0.40
FCw	0.00	0.00	0.10	0.10	0.00	0.00
TCE	**0.20**	**0.20**	**0.10**	**0.30**	**0.20**	**0.50**
Individual Display TOA Uncertainty						
TCE-G	**D=>G**				**0.50**	**1.00**
req'd	**D=>G**				**-1.00**	**1.00**
Differential TOA Uncertainty between any traffic at 'F'						
|ΔTCE|	**0.00**		**0.20**			
	D=>F - O/T		**0.20**			
req'd	**D=>F - O/T**		**0.20**			

J.5.3 Latency Analysis of Ownship Tracks when not routed through ASSAP

	Ownship Latency - no ASSAP					
	A3 => B3		B3 => F		F => G	
	min	max	min	max	min	max
Total Latency						
Tr	0.00	0.00	0.00	0.10	0.00	0.00
Tp	0.50	0.50	1.00	1.60	0.00	0.00
Tw	0.20	0.20	0.00	0.10	0.10	0.50
TL	**0.70**	**0.70**	**1.00**	**1.80**	**0.10**	**0.50**
req'd		**0.70**		**1.80**		**0.50**
Total Compensation Error						
ULr	0.00	0.00	0.00	0.10	0.00	0.00
CA	0.00	0.00	0.00	0.10	0.00	0.00
FCp	0.00	0.00	0.00	0.00	0.00	0.00
ULw	0.20	0.20	0.00	0.10	0.10	0.40
FCw	0.00	0.00	0.00	0.00	0.00	0.00
TCE	**0.20**	**0.20**	**0.00**	**0.30**	**0.10**	**0.40**
Individual Display TOA Uncertainty						
TCE-G	**D=>G**				**0.30**	**0.90**
req'd	**D=>G**				**-1.00**	**1.00**