242A-WP-11-01A2
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RTCA SC- 186/WG-6 (Working Group On DO-242A MASPS)
Meeting #11, Seattle WA

Draft Text for DO-242A
Revised SV, MS, and OC Report Contents

Presented by James Maynard

This paper is in support of Action Items 10-3 and 10-4: AI 10-3, for Richard Barhydt: "Supply text for remaining TBDs for TSR and TCR requirements to Jim Maynard for incorporation into 242A-WP-11-01." AI 10-4, for Jim Maynard: "Incorporate material from 242A-WP-10-10 into next draft of the SV, MS, and OC Report Reorganization paper (242A-WP-11-01)." <<Questions for which a resolution is needed are highlighted in yellow.>> Tentative values are placed in square brackets and highlighted in yellow, thus: [100 m] Values to be determined are indicated thus: TBD.
This version of the paper, 242A-WP-01A, supersedes the previous version, 242A-WP-11-01. This "revision A" includes text edited into the working paper during the Seattle meeting while the working paper was being reviewed.

Richard Barhydt's proposed changes on short term intent have been incorporated into subparagraphs 2.1.2.20 and 3.4.7.2.1 in section 2, and into subparagraph 3.4.7 in section 3. (There are problems here in organizing the text, and it may be better to just have it in section 3. I don't want to include detailed descriptions of all report elements in section 2, as some of the elements are artifacts of the report structure definition given in section 3.)
Tony Warren's proposed changes on intent update rates have been incorporated into paragraph 3.3.3 and its subparagraphs. This uses text from an e-mail from Tony dated Monday, 2002 January 21.
The proposed resolution of Issue Paper 242A-IP-14, "ADS-B Position Reference Point," has been incorporated into subparagraph 2.1.2.7.
The "TCR cycle number" and "TCR+0 transition flag" have been moved from the OM Codes (subparagraph 2.1.2.12) to the TCR report structure (subparagraph 3.4.8 and its subparagraphs,).
I propose a home for the new "IDENT switch activated" and "using ATC services" report elements in the OM (Operational Modes) codes of the MS report (subparagraphs 2.1.2.12, 3.4.4.9.4, 3.4.4.9.5 in Section 2).
I have added a new subparagraph 3.4.3.1," "Air/Ground Determination," to the SV report description in order to define the conditions for transmitting the "required from airborne participants" or the "required from surface participants" SV report elements. This subparagraph is based on DO-260's subparagraph 2.2.3.2.1.1.2.
I have included text received from Richard Barhydt on Thursday, January 24, providing an overview of the intent parameters and providing additional details about some of the intent reports. I inserted the overview information in subparagraph 2.1.2.20 of Section 2, while I inserted the additional report details in the appropriate subparagraphs of Section 3.
I have proposed draft text for "IDENT switch activated" and "using ATC services" OM codes to the MS report (paragraph 3.4.4and to the description of the OM codes in subparagraph 2.1.2.12.
Also new is text about the required resolution of some of the fields in the various reports. We discussed this in the WG-6 meeting on 29 January to 1 February 2002, and I agreed to draft some text. To provide guidance to the designers of the various ADS-B data link MOPS, we want to be explicit about the resolution or granularity required for the report data elements, so that the MOPS can determine how many bits will be required in messages that convey the information in those report elements. For those fields for which the accuracy is declared with the various NAC report elements (NAC_P, NAC_P, NAC_{baro}) the required report resolution should be matched to the accuracy declared with the corresponding NAC parameters. (Finer resolution would be permitted, but not required.)

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2.1 General Requirements

2.1.1 General Performance

2.1.2 Information Transfer Requirements

The ADS-B system shall (R2.4) be capable of transmitting messages and issuing reports containing the information specified in the following subsections. This MASPS does not specify a particular message structure or encoding technique. The information specified in the following subparagraphs can be sent in one or more messages in order to meet the report update requirements specified in Section 3.

2.1.2.1 Time of Applicability (TOA)

The time of applicability (TOA) of ADS-B reports indicates the time at which the reported values were valid. Time of applicability shall (R2.3) be provided in all reports. Requirements on the accuracy of the time of applicability are addressed in Section 3.

2.1.2.2 Call Sign

ADS-B shall (R2.7) be able to convey an aircraft call sign of up to 8 alphanumeric characters in length. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Note: The call sign is conveyed in the Mode-Status report (paragraph 3.4.4 below).

2.1.2.3 Address and Address Qualifier

The ADS-B system design shall (R2.8) include a means (e.g., an address) to (a), correlate all ADS-B messages transmitted from the A/V and (b), differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services may be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address shall (R2.9) use the same 24 bit address for ADS-B. All aircraft/vehicle addresses shall (R2.10) be unique within the applicable operational domain(s).

The ADS-B system design shall (R2.6) accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode.

Notes

1. *Some flight operations do not require one to fully disclose either the A/V call sign or address. This feature is provided to encourage voluntary equipage and operation of ADS-B by ensuring that ADS-B messages will not be traceable to an aircraft if the operator requires anonymity.*

2. *Correlation of ADS-B messages with Mode A transponder codes ~~will~~may facilitate the integration of radar and ADS-B information on the same A/V .for cases in which the A/V is not Mode S equipped*

2.1.2.3.1 Participant Address

The Participant Address field shall (R2.xx) be included in all ADS-B reports. This 24-bit field contains either the ICAO 24-bit address assigned to the particular aircraft about which the report is concerned, or another kind of address, as determined by the Address Qualifier field.

2.1.2.3.2 Address Qualifier

The Address Qualifier field shall (R2.xx) be included in all ADS-B reports. This field consists of one or more bits and describes whether or not the Address field contains the 24-bit ICAO address of a particular aircraft, or another kind of address.

Notes:

1. *The particular encoding used for the Address Qualifier is not specified in this MASPS, but is left for specification in lower level documents, such as the MOPS for a particular ADS-B data link. Experience in developing the MOPS for several proposed ADS-B data links suggests that 4 bits is sufficient for the Address Qualifier field.*

2. *Surface vehicles for a given airport need to have unique addresses only within range of the airport; vehicle addresses may be reused at other airports.*

3. *A participant's address and address qualifier are included as parts of all reports about that participant.*

2.1.2.4 ADS-B Emitter Category

An ADS-B participant's "emitter category" is conveyed in the Mode-Status report (paragraph 3.4.4 and subparagraph 3.4.4.4). The emitter category describes the type of A/V or other AD-B participant. The ADS-B system (R2.11) provide for at least the following emitter categories:

- Light (ICAO) - 7,000 kg (15,500 lbs) or less
- Small aircraft – 7,000 kg to 34,000 kg (15,500 lbs to 75,000 lbs)
- Large aircraft – 34,000 kg to 136,000 kg (75,000 lbs to 300,00 lbs)
- High vortex large (aircraft such as B-757)
- Heavy aircraft (ICAO) - 136,000 kg (300,000 lbs) or more
- Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise)
- Rotorcraft
- Glider/Sailplane
- Lighter-than-air
- Unmanned Aerial vehicle
- Space/Trans-atmospheric vehicle
- Ultralight / Hang glider / Paraglider
- Parachutist/Skydiver
- Surface Vehicle - emergency vehicle
- Surface Vehicle - service vehicle
- Point obstacle (includes tethered balloons)
- Cluster obstacle
- Line obstacle

Notes:

1. *ICAO Medium aircraft – 7,000 to 136,000 kg (15,500 to 300,000 lbs) can be represented as either small or large aircraft as defined above.*

2. *Obstacles can be either fixed or movable. Movable obstacles would require a position source.*

3. *Weights given for determining participant categories are maximum gross weights, not operating weights.*

4. The following category code assignments should be considered for aircraft operating in the United States national air space (NAS).

Light : Less than 7,000 kg (15,500 lb)
Small: ^{3} 15,500 and < 41,000 lb
Large: ^{3} 41,000 lb and < 255,000 lb and not in "High Vortex Large" category
High Vortex Large: Certain other aircraft, including B-757
Heavy: ^{3} 255,000 lb

2.1.2.5 A/V Length and Width Codes

The A/V length and width codes describe the amount of space that an aircraft or ground vehicle occupies and are components of the Mode-Status report (paragraph 3.4.4, subparagraph 3.4.4.5). The aircraft length and width codes are not required to be transmitted by all ADS-B participants all of the time. However, they *are* required to be transmitted by aircraft above a certain size, at least while those aircraft are in the airport surface movement area.

2.1.2.6 Position

Position information shall (R2.14) be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, geometric height, and barometric pressure altitude. The position report elements may be further categorized as geometric position and barometric altitude.

- The geometric position report elements are horizontal position (latitude and longitude), and geometric height. All geometric position elements shall (R2.15) be referenced to the WGS-84 ellipsoid.
- Barometric pressure altitude shall (R2.18) be reported referenced to standard temperature and pressure.

2.1.2.7 ADS-B Position Reference Point

The ADS-B position reference point is the position on an A/V that is broadcast in ADS-B messages as the nominal position of that A/V. For aircraft and ground vehicles, this position shall (R2.xx) be the center of the smallest rectangle that contains all the extremities of A/V and is oriented parallel to the longitudinal axis of the A/V. Figure 2.1.2.7 illustrates the location of the ADS-B reference point.

If the length code part of an aircraft's size code (Table 3.4.4.5~~3.4.4.53.4.4.5~~ in subparagraph below) is 1 or greater and its NAC_P code (subparagraph 2.1.2.14) is 10 or greater, then the horizontal position sent by that aircraft's ADS-B transmitting subsystem shall (R2.xx) be the position of the ADS-B position reference point.

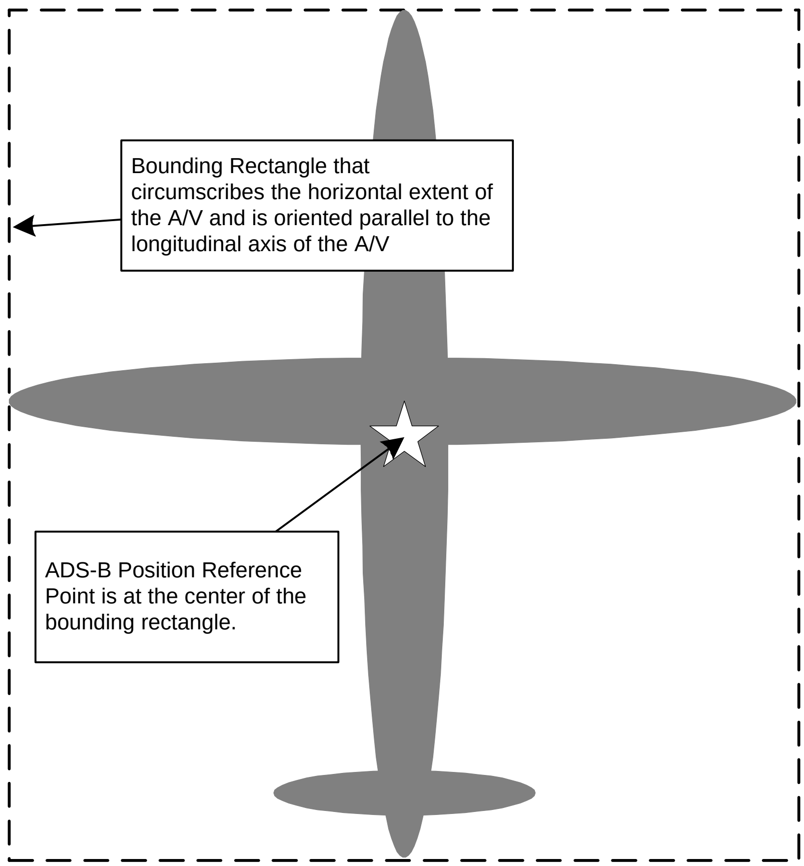

Figure 2.1.2.7: ADS-B Position Reference Point

Note: The accuracy of the location of the ADS-B position reference point with respect to the body of the A/V should be included when determining the NAC_P code to be transmitted from a transmitting ADS-B participant.

2.1.2.8 Altitude

Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) shall (R2.17) be reported, if available to the transmitting ADS-B subsystem. Some applications may have to compensate if only one source is available. However, when an A/V is operating on the airport surface, the altitude is not required to be reported, provided that the A/V indicates that it is on the surface.

Altitude shall (R2.19) be provided with a range from -1,000 ft up to +100,000 ft. For fixed or movable obstacles, the altitude of the highest point should be reported.

Note: *In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its horizontal velocity may be ignored.*

2.1.2.8.1 Pressure Altitude

Barometric pressure altitude is the reference for vertical separation within the NAS and ICAO airspace. Barometric pressure altitude is reported referenced to standard temperature and pressure.

Pressure altitude, which is currently reported by aircraft in SSR Mode C and Mode S, will also be transmitted in ADS-B messages and reported to client applications in SV reports. The pressure altitude reported shall (R3.34) be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.

2.1.2.8.2 Geometric Altitude

Geometric altitude is defined as the shortest distance from the current aircraft position to the surface of the WGS-84 ellipsoid. It is positive for positions above the WGS-84 ellipsoid surface, and negative for positions below that surface.

2.1.2.9 Horizontal Velocity

There are two kinds of velocity information:

- "Ground-referenced" or "geometric" velocity is the velocity of an A/V relative to the earth, or to a coordinate system (such as WGS-84) that is fixed with respect to the earth. Ground-referenced velocity is communicated in the SV report (paragraph 3.4.3, subparagraphs 3.4.3.8 and 3.4.3.16).

- Air-referenced velocity is the velocity of an aircraft relative to the air mass through which it is moving. Airspeed, the magnitude of the air-referenced velocity vector, is communicated in the ARV report, paragraph 3.4.6. The ARV report also includes heading (subparagraph 2.1.2.10), which is used in that report as an estimate of the direction of the air-referenced velocity vector.

Transmitting A/Vs that are not fixed or movable obstacles shall (R2.20) provide ground-referenced geometric horizontal velocity.

ADS-B geometric velocity information shall (R2.21) be referenced to WGS-84 [7].

2.1.2.9.1 Vertical Rate

Transmitting A/Vs that are not fixed or movable obstacles and that are not known to be on the airport surface shall (R2.xx) provide vertical rate.

Note 1: In this context, a "movable obstacle" means an obstacle that can change its position, but only slowly, so that its horizontal velocity may be ignored.

Vertical Rate shall (R2.23) be designated as climbing or descending and shall (R2.xx) be reported up to 32,000 feet per minute (fpm). Barometric altitude rate is defined as the current rate of change of barometric altitude. Likewise, geometric altitude rate is the rate of change of geometric altitude. At least one of the two types of vertical rate (barometric and geometric) shall (R2.xx) be reported.

If only one of these two types of vertical rate is reported, it shall (R2.xx) be obtained from the best available source of vertical rate information. If differentially corrected GPS (WAAS, LAAS, or other) is available, geometric altitude rate as derived from the GPS source should be transmitted. If differentially corrected GPS is not available, but inertial augmented barometric altitude rate is available, inertial augmented barometric altitude rate will be the preferred source of altitude rate information.

Note 2: Future versions of this MASPS are expected to include requirements on the accuracy and latency of barometric altitude rate.

Note 3: Vertical rate is reported in the SV report (paragraph 3.4.3) below.

2.1.2.10 Heading

Heading indicates the orientation of an A/V, that is, the direction in which the nose of the aircraft is pointing. Heading is described as an angle measured clockwise from true north or magnetic north. The heading reference direction (true north or magnetic north) is conveyed in the Mode-Status report (subparagraph 3.4.4).

Heading occurs not only in the SV report (subparagraph 3.4.3) for participants on the airport surface, but also in the ARV report (subparagraph 3.4.6) for airborne participants.

2.1.2.11 Capability Class (CC) Codes

Capability class codes are used to indicate the capability of a participant to support engagement in various operations. Known specific capability class codes are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available class codes, including appropriate combinations thereof.

- CDTI based traffic display capability (subparagraph 3.4.4.8.1)
- TCAS/ACAS installed and operational (subparagraph 3.4.4.8.2)
- Service Level of the transmitting A/V (subparagraph 3.4.4.8.3)
- ARV capability (subparagraph 3.4.4.8.4)
- TSR capability (subparagraph 3.4.4.8.5)
- TCR capability level (subparagraph 3.4.4.8.6~~3.4.4.8.6~~~~3.4.4.8.5~~)
- Other capabilities, to be defined in later versions of this MASPS

Note: Capability Class (CC) codes are conveyed in the MS report (subparagraph 3.4.4 below).

2.1.2.12 Operational Mode (OM) Codes

Operational Mode (OM) codes are used to indicate the current operational mode of transmitting ADS-B participants. Specific operational mode codes are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available OM codes, including appropriate combinations thereof.

- TCAS/ACAS resolution advisory active (subparagraph 3.4.4.9.1).
- Current TCR cycle number (subparagraph 3.4.4.9.2)
- "Reserved for TCR+0 transition" flag (subparagraph 3.4.4.9.3)
- IDENT switch activated flag (subparagraph 3.4.4.9.4)
- Using ATC services (subparagraph 3.4.4.9.5)
- Other operational modes, to be defined in later versions of this MASPS.

2.1.2.13 Navigation Integrity Category

The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported position has an acceptable level of integrity for the intended use. The NIC parameter described in this subsection is intimately associated with the SIL (Surveillance Integrity Level) parameter described in subsection 2.1.2.16 below. The NIC parameter specifies an integrity containment radius, R_C. The SIL parameter specifies the probability of the true position lying outside that containment radius without alerting, including the effects of the airborne equipment condition, which airborne equipment is in use, and which external signals are used.

Note: "NIC" and "NAC_P" as used in the current version (DO-242A) of this MASPS replace the earlier term, "NUC_P", used in the first edition (DO-242) of this MASPS.

The Navigation Integrity Category is reported in the State Vector (SV) report (paragraph 3.4.3 below).

Table 2.1.2.13 defines the navigation integrity categories that transmitting ADS-B participants shall (R2.xxx) use to describe the integrity containment radius, R_C, associated with the horizontal position information in ADS-B messages from those participants.

Table 2.1.2.13: Navigation Integrity Categories (NIC).

NIC (Notes 1, 2)	Horizontal and Vertical Containment Bounds	Comment	Notes
0	$R_C \geq$ 37.04 km (20 NM)	Unknown Integrity	
1	$R_C <$ 37.04 km (20 NM)	RNP-10 containment radius	6
2	$R_C <$ 14.816 km (8 NM)	RNP-4 containment radius	3, 6
3	$R_C <$ 7.408 km (4 NM)	RNP-2 containment radius	6
4	$R_C <$ 3.704 km (2 NM)	RNP-1 containment radius	6
5	$R_C <$ 1852 m (1 NM)	RNP-0.5 containment radius	6
6	$R_C <$ 1111.2 m (0.6 NM)	RNP-0.3 containment radius	6
7	$R_C <$ 370.4 m (0.2 NM)	RNP-0.1 containment radius	6
8	$R_C <$ 185.2 m (0.1 NM)	RNP-0.05 containment radius	6
9	$R_C <$ 75 m and VPL < [112 m]	e.g., WAAS HPL, VPL	4, 5
10	$R_C <$ 25 m and VPL < [37.5 m]	e.g., WAAS HPL, VPL	4, 5
11	RC < 7.5 m and VPL < [11 m]	e.g., LAAS HPL, VPL	4, 5

Notes for Table 2.1.2.13:

1. *NIC is reported by an aircraft because there will not be a uniform level of navigation equipage among all users. Although GNSS is intended to be the primary source of navigation data used to report ADS-B horizontal position, it is anticipated that during initial uses of ADS-B or during temporary GNSS outages an alternate source of navigation data may be used by the transmitting A/V for ADS-B position information. The integration of alternate navigation sources is a function that must be performed by a navigation set that is certified to use multiple sources, which then is responsible for supplying the corresponding integrity containment radius (e.g.., HPL). It is important to point out that this is not a function that can be performed by the ADS-B equipment.*

2. *"NIC" in this column corresponds to "NUC_P" of Table 2-1(a) in the first version of this MASPS, DO-242, dated February 19, 1998.*

3. *The containment radius for NIC = 2 has been changed (from the corresponding radius for NUC_P = 2 in the first edition of this MASPS) so as to correspond to the RNP-4 RNAV limit of DO-236A, rather than the RNP-5 limit of the earlier DO-236. This is because RNP-5 is not a recognized ICAO standard RNP value.*

4. *HPL may be used to represent RC for GNSS sensors.*

5. *If geometric altitude is not being reported than the VPL tests are not assessed.*

6. *RNP containment integrity refers to total system error containment including sources other than sensor error, where as horizontal containment for NIC only refers to sensor position error containment.*

It is recommended that the coded representations of NIC should be such that:

(a) Equipment that conforms to the current version of this MASPS ("version 1" equipment) will recognize the equivalent NUC_P codes from the first edition of this MASPS, and

(b) Equipment that conforms to the initial, DO-242, edition of this MASPS ("version 0" equipment) will treat the coded representations of NIC coming from version 1 equipment as if they were the corresponding "NUC_P" values from the initial, DO-242, version of this MASPS.

2.1.2.14 Navigation Accuracy Category for Position (NAC_P)

The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use.

Table 2.1.2.14 defines the navigation accuracy categories that shall (R2.xxx) be used to describe the accuracy of positional information in ADS-B messages from transmitting ADS-B participants.

<u>Notes</u>:

1. *"NIC" and "NAC_P" as used in this MASPS replace the earlier term, "NUC_P", used in the initial, DO-242, edition of this MASPS .*

2. *The Estimated Position Uncertainty (EPU) used in Table 2.1.2.14 is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GPS or GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

3. *Likewise, Vertical Estimated Position Uncertainty (VEPU) is a 95% accuracy limit on the vertical position. VEPU is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05. When reported by a GPS or GNSS system, VEPU is commonly called VFOM (Vertical Figure of Merit).*

4. *The EPU limit for $NAC_P = 2$ has been changed (from the corresponding limit for $NUC_P = 2$ in the first edition of this MASP) so as to correspond to the RNP-4 RNAV limit of DO-236A, rather than the RNP-5 limit of the earlier DO-236. This is because RNP-5 is not an ICAO standard RNP value.*

Table 2.1.2.14: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU)	Comment	Notes
0	EPU ≥ 18.52 km (10 NM)	Unknown accuracy	
1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1
2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1
3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1
4	EPU < 1852 m (1NM)	RNP-1 accuracy	1
5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1
6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1
7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1
8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA)	1
9	EPU < 30 m and VEPU < 45 m	e.g., GPS (SA off)	2
10	EPU < 10 m and VEPU < 15 m	e.g., WAAS	2
11	EPU < 3 m and VEPU < 4 m	e.g., LAAS	2

Notes for Table 2.1.2.14:

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for NAC_P only refers to horizontal position error uncertainty.*

2. *If geometric altitude is not being reported than the VEPU tests are not assessed.*

2.1.2.15 Navigation Accuracy Category for Velocity (NAC_V)

The velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data shall (R2.27) be as indicated in Table 2.1.2.15.

Note: NAC_V is another name for the parameter that was called NUC_R in the initial (DO-242) version of this MASPS.

<<[AI]: Should we delete the value of NAC_V = 4? Steve Heppe to prepare an IP on this, for Stu to send to WG-4. Jonathan Hammer, please comment!! >>

Table 2.1.2.15: Navigation Accuracy Categories for Velocity (NAC_V).

NAC_V	Horizontal Velocity Error (95%)	Vertical Geometric Velocity Error (95%)
0	Unknown or ≥ 10 m/s	Unknown or ≥ 50 feet (15.24 m) per second
1	< 10 m/s	< 50 feet (15.24 m) per second
2	< 3 m/s	< 15 feet (4.57 m) per second
3	< 1 m/s	< 5 feet (1.52 m) per second
4	< 0.3 m/s	< 1.5 feet (0.46 m) per second

Notes -for Table 2.1.2.15:

1. *When an inertial navigation system is used as the source of velocity information, error in velocity with respect to the earth (or to the WGS-84 ellipsoid used to represent the earth) is reflected in the NACV value.*

2. *When any component of velocity is flagged as not available the value of NAC_V will apply to the other components that are supplied.*

Note:

Navigation sources, such as GNSS and inertial navigation systems, provide a direct measure of velocity which can be significantly better than that which could be obtained by position differences.

2.1.2.16 Surveillance Integrity Level (SIL)

The Surveillance Integrity Level (SIL) defines the probability of the integrity containment radius used in the NIC parameter (subsection 2.1.2.13above) being exceeded, without alerting, including the effects of the airborne equipment condition, which airborne equipment is in use, and which external signals are used by the navigation source. The Surveillance Integrity Limit encoding shall (R2.xxx) be as indicated in Table 2.1.2.16.

Note: It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used.

Table 2.1.2.16: Surveillance Integrity Level (SIL) Encoding.

SIL	Probability of Exceeding the R_C Integrity Containment Radius Without Detection	Comment
0	Unknown	"No Hazard Level" Navigation Source
1	1×10^{-3} per flight hour or per operation	"Minor Hazard Level" Navigation Source
2	1×10^{-5} per flight hour or per operation	"Major Hazard Level" Navigation Source
3	1×10^{-7} per flight hour or per operation	"Severe Major Hazard Level" Navigation Source

2.1.2.17 Barometric Altitude Quality Code (BAQ)

The Barometric Altitude Quality Code, BAQ, is a 2-bit field which shall be ZERO for equipment that conforms to this version (DO-242A) of the ADS-B MASPS.

Notes:

1. *Non-zero values of the barometric altitude accuracy code will be defined in future versions of this MASPS. One proposed encoding is given in Table 2.1.2.17; however, it is not certain that this encoding will be the one specified in future versions of this MASPS.*

Table 2.1.2.17: Possible Future Encoding for BAQ

BAQ	*Meaning*
0	*Barometric altitude Not Certified for IFR use*
1	*Barometric altitude with 100 feet resolution*
2	*Barometric altitude with 25 feet resolution*
3	*Barometric altitude meets RVSM requirements*

2. *BAQ, the barometric altitude accuracy code, is reported in the Mode-Status report (subparagraph 3.4.4.13 below).*

2.1.2.18 Barometric Altitude Integrity Code (NIC_{baro})

The Barometric Altitude Integrity Code, NIC_{baro}, is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude.

Note: NIC_{baro}, the barometric altitude integrity code, is reported in the Mode-Status report (subparagraph 3.4.4).

2.1.2.19 Emergency/Priority Status

The ADS-B system shall (R2.28) be capable of supporting broadcast of emergency and priority status. Emergency/priority status is reported in the MS report (paragraph 3.4.4 and subparagraph 3.4.4.7 below).

2.1.2.20 Intent Information

The reason for considering broadcast of intent information in ADS-B systems is to extend the domain of predictability of aircraft trajectories beyond short-term extrapolations using current aircraft position and velocity states. Many applications of ADS-B currently under consideration could require intent information to extend look-ahead time for trajectory predictions beyond the current flight segment, or as a means of enhancing integrity of extrapolated path predictions. Proposed air-air applications of intent information include airborne separation planning where more than a few minutes look-ahead time is desirable for conflict detection and conflict prevention, and conflict resolution, where broadcast of intended resolution maneuvers may be important for situation awareness of all nearby equipped aircraft. ADS-B intent information is also proposed to enable advanced air-ground applications such as sequencing and merging of terminal area flow streams, conformance monitoring, and use of precision trajectory separation concepts for aircraft arrival and departure flows in congested airspace.

Intent information may be categorized as “short tem” and “long term” intent information.

Long-term intent is reported in the Trajectory Change Reports (TCRs, subparagraph 3.4.8) and includes information on Trajectory Change Points (TCPs, defined in subparagraph 2.1.2.20.3) and their connecting flight segments.

~~2.1.2.18.1~~2.1.2.20.1 Short Term Intent

Short-term intent is reported in the Target State Report (TSR, subparagraph 3.4.7) and consists of the target altitude (or appropriate substitutes for target altitude) and target heading (or target track angle) that the A/V’s guidance system is being commanded to follow.

While short-term intent is available in almost all operational flight modes, four dimensional long-term intent is only available when equipped aircraft are using sophisticated FMS and area navigation (RNAV) systems.

The TSR provides information on the horizontal and vertical targets for the active flight segment. The active flight segment refers to the current path and automation states being used for guidance and control of the aircraft. Primary TSR elements include the target altitude and target heading or track. These parameters reflect short-term tactical intent and are typically input by the pilot. Examples include selected altitude for limiting a descent or climb transition or selected heading or track when These targets may be a command to hold and maintain the current altitude or heading. Target altitude and target heading or track can also refer to the next intended targets flown by an autopilot in more automated modes, such as those supported by RNAV and FMS. The OC-TSR provides a way for aircraft equipped with less sophisticated automation systems or flying in tactical flight modes to exchange short-term intent information.

Short term vertical intent is conveyed in the Target State Report (TSR, paragraph 3.4.7) and includes the following report elements:

- Target Altitude (section 3.4.7.4)
- Target Altitude Type (section 3.4.7.4.1)
- Target Altitude Capability (section 3.4.7.4.2)
- Vertical Target Source Indicator (section 3.4.7.4.3)
- Vertical Mode Indicator (section 3.4.7.4.4)

2.1.2.20.2 Long-Term Intent

Long-term intent is conveyed in the Trajectory Change Report (TCR, paragraph 3.4.7) and contains the following report elements:

•

2.1.2.18.32.1.2.20.3 Trajectory Change Intent (Current and Future)

Track extrapolations based on the use of intent data alone are increasingly inaccurate as look-ahead times are increased. The state vector can be augmented with trajectory change points (i.e., intent information) for applications on the receiving A/V or ATS to:

a) support stable separation predictions for long look-ahead times, and in monitoring required operational separations and

b) re-plan flight paths when necessary to resolve detected conflicts (deconfliction) while minimizing deviations from planned flight trajectories.

The Trajectory Change Report (TCR) described in subparagraph 3.4.8 provides long-term intent, including information about Trajectory Change Points (TCPs) and their connecting flight segments. Additional elements help facilitate path re-generation, data confidence assessment, and conformance monitoring.

A TCP may be described as a 3D location or interception of a 2D plane with the aircraft's velocity vector where the current aircraft trajectory is intended to change. This definition includes cases where flight segment changes do not occur at a known 3D point. For example, an aircraft may be climbing in a constant vertical speed mode towards a target altitude. In this case, the aircraft may not take actual wind conditions into account when predicting the level-off location. Level-off prediction in a climb may also depend on changing aircraft performance. These uncertainties make it difficult to predict an accurate 3D intercept point. An analogous lateral situation may occur when an aircraft flies at constant heading to intercept a flight plan route. The intercept point is also dependent on wind parameters that may not be accurately known.

TCR fields are filled based on information availability aboard the transmitting aircraft and the TCP type. Example TCP types include 2D routing changes, the start and end points of a specified turn transition, FMS predicted Top of Climb and Top of Descent points, and selected altitude from an altitude control panel when currently in climb or descent transitions. A full list of ADS-B supported TCP types is provided in subparagraph ?? below.

The ADS-B system shall (R2.xx) provide the capability to exchange the Trajectory Change Report information described in subparagraph 3.4.8 below. ~~ADS-B transmissions shall (R2.31) indicate the ability of the transmitting participant to engage in path monitoring and/or de-confliction operations. The transmitting A/V shall (R2.32) also indicate its capability to use intent information received from other participants.~~

For certain pairwise operations, an addressed crosslink may be used external to the ADS-B system.

~~2.1.2.18.3.1~~2.1.2.20.3.1 Current Trajectory Change Information

<<Need to re-work this section!>> The TCP from the transmitting aircraft is the point in three-dimensional space where the current operational trajectory is planned to change, and estimated remaining flight time to that point. A TCP transmission indicates that the aircraft intends to fly directly, via a great circle route, to that point. The TCP is defined as a four-element vector consisting of the following:

- Latitude (WGS-84)
- Longitude (WGS-84)
- Altitude (pressure altitude or flight level)
- Time to go (TTG) to the indicated point in space

The TCP required received update rate may be lower than for the state vector. The rate shall (R2.33) be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes (5 minutes within the range limitations specified in Table 2-3) prior to reaching closes point of approach for class A2 (A3) equipage. In the event of an immediate trajectory change generated via the RNav, new TCP information should be issued immediately.

The augmentation data should be provided as data transmitted indicating planned changes in trajectory. These indications should be provided as TCP information and TCP+1 information described below. This data is required only from participants intending operations based on some level of cooperative conflict management. [JHM1]The TCP and TCP+1 should be used to convey information operationally significant to separation and conflict management. Points constructed by RNav equipment to generate curvilinear paths (e.g., curved transitions between flight legs) should not be conveyed as TCP information.

System designs should be flexible enough to support parameters that might not be available from all ADS-B participating A/Vs. Information acquisition of intent information is provided in Appendix L.

2.1.2.20.3.2 Future Trajectory Change Information

De-confliction is most efficient when adjustments to the flight path can be minimized. Knowledge of planned changes to the current path is needed to support the conflict management tools for stable operational re-planning required due to any conflict that may be predicted.

For the de-confliction capability, additional augmenting information should be provided to determine any change in horizontal and/or vertical flight path planned. The aircraft planning the change shall (R2.34) issue the TCP+1 information at least 5 minutes prior to commencing the trajectory change associated with the TCP. The TCP+1 data to be supplied should provide the target or predicted altitude, the target horizontal coordinates and the estimated time remaining from the time of generation of the message to the estimated time to arrive at TCP+1. Upon initiation of the flight path change at TCP, the TCP+1 should increment to become the new TCP. TCP+1 information shall (R2.35) be provided until commencing the change maneuver. The TCP+1 required transmission rate shall (R2.36) be the same as that of the TCP.

Notes:

1. *TCP and TCP+1 data are provided by broadcast media to supply real-time, event-related data to proximate air and ground systems involved in advanced air operations requiring real time intent detail. Details of more complete flight plan or detailed procedures are conveyed, when required, via addressed datalink media.*

2. *No TCP is needed for speed changes along a trajectory. The data indicating the time to go for TCP and TCP+1 should include any results of planned or predicted changes. For RNav equipment capable of such predictions or scheduling, the time data should include the impacts. Less capable equipment should provide the best estimate available. Air or Ground systems receiving the TCP/TCP+1 data should be capable of applying these data as appropriate to their respective applications in conflict management, sequencing, spacing or conformance.*

3. *TCP and TCP+1 data are envisioned in current planning future procedures in the terminal area and transitions between en route flight regimes to enhance sequencing in arrival and departure. These data are intended for applications by both air and ground systems. The* ADS-B *system will enable the delivery of TCP and/or TCP+1 data when required by the procedures supported by the RNav onboard the transmitting participant. Receiving participants would use the transmitted capability codes to determine pair-wise compatibility with their respective applications.*

4. *For example, at shorter ranges, a pair of points (TCP and TCP+1) could be issued in conjunction with Terminal Maneuvering Area metering operations and/or when maneuvering to join or depart published procedures.*

5. *Lateral TCPs are fly-by points unless indicated to be fly-over. TCP and tCP+1 points are intended to convey trajectory target and trajectory change only. Accordingly, they are not necessarily RNav flight plan waypoints. They must be represented only in binary data form. Example TCPs are top of descent, reach climb altitude or intercept points used to capture procedures or join the flight plan.*

6. *Under some common operational sequences an aircraft may be manually departing or returning to an RNav flight plan. An example case would result from a period of vectored operation by ATS. In such cases the application should determine when to assume the intent is "direct-to" or if the aircraft is operating with a different intent.*

~~2.1.2.19~~2.1.2.21 Other Information

2.2 System Performance – Standard Operational Conditions

3 ADS-B System definition and Functional Requirements

3.1 System Scope and Definition of Terms

3.2 ADS-B System Description

3.2.1 Context Level Description

3.2.2 Participant Architecture Examples

3.2.3 Equipage Classifications

3.2.3.1 Interactive Aircraft/Vehicle ADS-B Subsystems (Class A)

3.2.3.2 Broadcast-Only Subsystems (Class B)

3.2.3.3 Ground Receive-Only Subsystem (Class C)

3.3 System Requirements

3.3.1 Surveillance Coverage

3.3.2 Information Exchange Requirements By Equipage Class

3.3.3 ADS-B Data Exchange ~~Requirements~~Requirements

3.3.3.1 Report Accuracy, Update Period, and Acquisition Range

The subparagraphs below specify the report accuracy, update period, and acquisition range requirements for state vector, modes status, and specific on-condition reports. For each of these subparagraphs, report acquisition shall (R3.12) be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant. In order to meet these requirements, the receiving participant must begin receiving messages at some range outside the minimum range for a given application. Appendix L illustrates examples of expected acquisition time for state vector, mode-status, and on-condition reports as a function of message period and probability of receipt. Appendix L also treats the necessary acquisition time for segmented state vector messages. << AI for Stan Jones to rework this appendix L >>

3.3.3.1.1 State Vector Report

State vector (SV), mode status (MS), and air-referenced velocity (ARV) report accuracy, update period, and acquisition range requirements are derived from the sample scenarios of Chapter 2 and are specified in Table 3-4(a). The state vector report shall (R3.9) meet the update period and 99 percentile update period requirements for each application operational range listed. The rationale for these values is given in Appendix J. The formulation in Appendix J examines the loss of alert time resulting from data inaccuracies, report update interval, and probability of reception. The scope of the analysis was not sufficient to guarantee that the specific operations considered will be supported. Several range values are specified in the table because the alert time requirements are more demanding for short range than they are for surveillance of targets at longer ranges. The first value is based on minimum range requirements. Beyond this range, update period and/or receive probability may be relaxed for each sample scenario, as given by the other values.

Target state report (TSR) and trajectory change report (TCR) update period and acquisition range requirements are derived from the en-route air-air encounter scenario described in Appendix O <<an extension of Stan's paper, to be written by Tony and Stan>>, and are specified in Table 3-4(b). These requirements are specified in terms of acquisition range and required update interval to achieve a 95% confidence of receiving a TSR or TCR within the specified acquisition range or time interval. [See IP55 – more to be done here!] The values in Table 3-4(b) represent the "best engineering judgment" at the time of MASPS publication and will require subsequent validation via simulations and flight evaluations.

For each of the scenarios included in Table 3-4(a), the state vectors from at least 95% of the observable user population (radio line-of-sight) supporting that application shall (R3.10) be acquired and achieve the time and probability update requirements specified for the operational ranges.For all of the scenarios included in Table 3-4(a), the state vector shall (R3.10) be acquired with a 95% confidence by the range specified for the scenario. The state vector report is constantly changing and is important to all applications including the safety critical ones. Algorithms designed to use the state vector reports will assume that the information provided is correct (some applications may even require that the information is validated before using it).

Table 3-3(a): Interactive Aircraft/Vehicle Equipage Type Operational Capabilities

Domain ®	**Terminal, En-route, Oceanic**										**Approach**		**Airport Surface**	
EquipageClass	**Data Required to Support Operational Capability**		**R £10 NM** e.g. Conflict Detection, Enhanced visual Acquisition		**R £20 NM** e.g., Airborne Conflict management, station keeping		**R £40 NM** e.g., Merging, conflict management, in-trail climb		**R £90 NM** e.g., Long range conflict management		**R £10 NM** e.g., AILS, paired approach		**R £5 NM** e.g., Airport Surface Situation Awareness	
	Tx	Rx	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form
A0 Minimum R=10 NM	SV MS	SV	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes
A1 Basic R=20 NM	SV MS ARV	SV MS ARV	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
A2 Enhanced R=40 NM	SV MS ARV TSR TCR+0	SV MS ARV TSR TCR+0	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
A3 Extended R=90 NM	SV MS ARV TSR TCR+n	SV MS ARV TSR TCR+n	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: SV= State Vector; MS = Mode-Status; ARV = Air=Referenced Velocity; TSR = Target State Report; TCR+0 = Single Trajectory Report capability; TCR+n = Multiple TCR capability, n = 1 to TBD

* *Operation in airspace with high closure rates may require longer range.*

** *Class A2 and A3 users may equip for low visibility taxi following.*

Table 3-3(b): Broadcast and Receive Only Equipage Type Operational Capabilities

	Domain ®		**Terminal, En-route, and** Oceanic / Remote Non-Radar								**Approach**		**Airport Surface**	
Equipage Class	**Data Required to Support Operational Capability**		**R £10 NM** e.g. Conflict Detection, Enhanced visual Acquisition		**R £ 20 NM** e.g., Airborne Conflict management, station keeping		**R £40 NM** e.g., Merging, conflict management, in-trail climb		**R £90 NM** e.g., Long range conflict management		**R £10 NM** e.g., AILS, paired approach		**R £5 NM** e.g., Airport Surface Situation Awareness	
	Tx	Rx	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form	Sup-port	Per-form
B1 Aircraft	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B2 Ground Vehicle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
B3 Fixed Obstacle	SV MS	No	Yes	No	Yes	No	No	No	No	No	No	No	Yes	No
C1 ATS En route & Terminal	No	SV MS ARV TSR TCR+n	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No
C2 Approach & Surface	No	SV MS ARV TSR TCR+n	No	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes
C3 Flight Following	No	SV MS	No	Yes	No	No	No	No	No	No	No	No	No	No

Notes: SV= State Vector; MS = Mode-Status; ARV = Air=Referenced Velocity; TSR = Target State Report; TCR+0 = Single Trajectory Report capability; TCR+n = Multiple TCR capability, *n = 1 to TBD*

Mode-status (MS) and Air-Referenced Velocity (ARV) report update periods are not specified in Table 3-4(a). The minimum range at which mode-status and ARV on-condition reports shall (R3.11) be acquired with 95% confidence is specified in Table 3-4(a). From this minimum range, combinations of acceptable update periods and receive probabilities for MS and OC reports can be derived for media specific ADS-B implementations. <<??>> The ARV reports are on-condition reports with acceptable update periods depending on the triggering conditions for generating reports; that is, these reports may be generated at the full state vector update rate, or at a lower rate depending on ARV trigger conditions.

Required ranges for acquisition shall (R3.13) be as specified in Table 3-4(a). (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3) <<Isn't this redundant with above 95% requirements??>> Acquisition shall (R3.12) be considered accomplished when all report elements required for an operational scenario have been received by an ADS-B participant. Required ranges for acquisition shall (R3.13) be as specified in Table 3-4(a). In order to meet these requirements, the receiving participant must begin receiving messages at some range outside the minimum range for a given application. Appendix L illustrates examples of expected acquisition time for state vector, mode-status, and on-condition reports as a function of message period and probability of receipt. Appendix L also treats the necessary acquisition time for segmented state vector messages. << AI for Stan Jones to rework this appendix L >>

Table 3-4(a) shows accuracy values in two ways: one describing the ADS-B report information available to applications, and the other presenting the error budget component allocated to ADS-B degradation of this information. The ADS-B system shall (R3.14) satisfy the error budget requirements specified in the table in order to assure satisfaction of ADS-B report accuracies. Degradation is defined here to mean additional errors imposed by the ADS-B system on position and velocity measurements above the inherent navigation source errors. The errors referred to in this section are specifically due to ADS-B quantization of state vector information, and other effects such as tracker lag. ADS-B timing and latency errors are treated as a separate subject under heading 3.3.3.2. The maximum errors specified in Table 3-4(a) are limited to contributions from the following two error sources:

- Quantization errors. The relationship between the quantization error and the number of bits required in the ADS-B message are described in Appendix G. This discussion also treats the effect of data sampling time uncertainties on report accuracy.
- Errors due to a tracker. The ADS-B system design may include a smoothing filter or tracker as described in Appendix G. If a smoothing filter or tracker is used in the ADS-B design, the quality of the reports shall be sufficient (R3.15) to provide equivalent track accuracy implied in Table 3-4(a) over the period between reports, under target centripetal accelerations of up to 0.5g with aircraft velocities of up to 600 knots. Tracker lag may be considered to be a latency (Section 3.3.3.2).

Table 3-4 (a): SV and MS Accuracy, Update Period, and Acquisition Range Requirements

Operational Domain ®	**Terminal, En-route, and Oceanic / Remote Non-Radar**				**Approach**	**Airport Surface** (Note 5)
Applicable Range ®	**R £ 10 NM**	**10 NM < R £ 20 NM**	**20 NM < R £ 40 NM**	**40 NM < R £ 90 NM**	**R £ 10 NM**	**(R £ 5 NM)**
Equipage Class ® (note 14)	**A0-A3 B1-B3**	**~~A0~~A1-A3 B1-B3**	**A2-A3**	**A3**	**A1-A3**	**A0-A3 B1-B3**
Example Applications ®	Airborne Conflict Management (ACM): Enhanced Visual Acquisition	Airborne Conflict Management (ACM): Station Keeping	Merging, Conflict Management, In-Trail Climb	Long Range Conflict Management	AILS, Paired Approach	Surface Situational Awareness
Required SV Acquisition Range	10 NM	20 NM	40 NM	90-NM (Notes 3, 12) (120 NM desired)	10 NM	5 NM
Required MS Acquisition Range	10 NM	20 NM	40 NM	90 NM (Notes 3, 12) (120 NM desired)	10 NM	5 NM
Required MS Update Interval (Nominal)	≤ 12 s	≤ 12 s	≤ 12 s	≤ 12 s	≤ 12 s	≤ 12 s
Required MS Update Interval (State Change)	≤ 3 s (3 NM) ≤ 5 s (10 NM)	≤ 5 s (10 NM) ≤ 7 s(20 NM)	≤ 7 s (20 NM) ≤ 12 s (40 NM)	≤ 12 s	≤ 3 s	≤ 3 s
Required SV Nominal Update Period (95th percentile) (Note 6)	≤ 3 s (3 NM) ≤ 5 s (10 NM) (Note 13)	≤ 5 s (10 NM) (1 s desired, note 2) ≤ 7 s (20 NM)	≤ 7 s (20 NM) ≤ 12 s (40 NM)	≤ 12 s	≤ 1.5 s (1000 ft runway separation) ≤ 3 s (1 s desired) (2500 ft runway separation)	≤ 1.5 s
Required 99th Percentile SV Received Update Period (Coast Interval)	≤ 6s (3 NM) ≤ 10 s (10 NM) (Note 13)	≤ 10 s (10 NM) ≤ 14 s (20 NM)	≤ 14 s (20 NM) ≤ 24 s (40 NM)	≤ 24 s	≤ 3s (1000 ft runway separation) (1s desired, note 2) ≤ 7s (2500 ft runway separation)	≤ 3 s
Example Permitted Total SV Errors Required To Support Application (1 sigma, 1D)	σ_{hp} = 200 m σ_{hv} = n/a σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 m / 50 m (note 1) σ_{hv} = 0.6/ 0.75 m/s (note 1) σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 / 50 m (note 1) σ_{hv} = 0.3/ 0.75 m/s (note 1) σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 200 m σ_{hv} = 5 m/s σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 20 m σ_{hv} = 0.3 m/s σ_{vp} = 32 ft σ_{vv} = 1 fps	σ_{hp} = 2.5 m (note ~~9~~7) σ_{hv} = 0.3 m/sσ σ_{vp} = n/a σ_{vv} = n/a
Max. error due to ADS-B (1 sigma, 1D) (Note 8)	σ_{hp} = 20 m σ_{hv} = 0.25 m/s (Note 9) σ_{vp} = 30 ft σ_{vv} = 1 fps					σ_{hp} = 2.5 m (note ~~8~~7) σ_{hv} = 0.25 m/s σ_{vp} = n/a σ_{vv} = n/a

Definitions for Table 3-4 (a):

s_{hp}: *standard deviation of horizontal position error.*

s_{hv}: *standard deviation of horizontal velocity error.*

s_{vp}: *standard deviation of vertical position error.*

s_{vv}: *standard deviation of vertical velocity error.*

Notes for Table 3-4 (a):

1. *The lower number represents the desired accuracy for best operational performance and maximum advantage of ADS-B. The higher number, representative of GPS standard positioning service, represents an acceptable level of ADS-B performance, when combined with barometric altimeter.*

2. *The analysis in Appendix J indicates that a 3-second report received update period for the full state vector will yield improvements in both safety and alert rate relative to TCAS II, which does not measure velocity. Further improvement in these measures can be achieved by providing a one-second report received update rate Further definition of* ADS-B *based separation and conflict avoidance system(s) may result in refinements to the values in the Table.*

3. *The 90 NM range requirement applies in the forward direction. The required range aft is 30 NM (40 NM desired). The required range 90 degrees to port and starboard is 45 NM (60 NM desired) (see Appendix H). <<Tony W claims that the port and starboard ranges should be 0.707 times the forward range. Tony to write and IP on this.>>*

4. *n/a = not applicable; TBD = To be defined*

5. *Requirements apply to both aircraft and vehicles.*

6. *Supporting analyses for update period and update probability are provided in Appendices J and L.*

7. *The position accuracy requirement for aircraft on the airport surface is stated with respect to the aircraft's ADS-B position reference point (subparagraph 2.1.2.7).*

8. *This row represents the allowable contribution to total state vector error from ADS-B.*

9. *The requirements on horizontal velocity error (σ_{hv},) apply to aircraft speeds of up to 600 knots. Accuracies required for velocities above 600 knots are TBD.*

10. *Specific system parameter requirements in Table 3-4(a) can be waived provided that the system designer shows that the application design goals stated in Appendix J or equivalent system level performance can be achieved.*

11. *Update periods for the SV have been emphasized in determining link related performance requirements in this table. Lower rates of MS and ARV are under development. These reports should be made available to support the operational capabilities using considerations equivalent to the SV. The requirement should be optimized to ensure that the refresh/update of reports is appropriate for the equipment classes and the operations being supported..*

12. *Air-to-air ranges extending to 90 nmi are intended to support the application of Flight Path Deconfliction Planning, Cooperative Separation in Oceanic/Low Density En Route Airspace, as described in Section 2.2.2.4. However, operations and applications at these ranges may need to be supported when over-flying high traffic density terminal areas.*

13. *Requirements for applications at ranges less than 10 NM are under development. The 3-second update period is required for aircraft pairs with horizontal separation less than [1.1 NM] and vertical separation less than [1000 feet]. The 3 second update period is also required to support ACM for aircraft pairs within 3 NM lateral separation and 6000 feet vertical separation that are converging at a rate of greater than 500 feet per minute vertically or greater than 6000 feet per minute horizontally. The update rate can be reduced to once per 5 seconds (95%) for aircraft pairs that are not within these geometrical constraints and for applications other than ACM. Requirements for ACM are under development. Requirements for future applications may differ from those stated here.*

14. *Class B1 equipage performance should correspond with the minimum class A transmit characteristics for the operational ranges specified for the columns as discussed in Section 3.3.1.*

3.3.3.1.2 Mode Status Report

Mode Status (MS) accuracy, update period, and acquisition range requirements are derived from the sample scenarios of Chapter 2, and are specified in Table 3-4(a).

Mode-status report update periods are not specified in Table 3-4(a). For each of the equipage classes included in Table 3-4 (a), the mode status reports from at least 95% of the observable (radio line of sight) population shall (R3.11) be acquired at the specified range. (10 NM for A0, 20 NM for A1, 40 NM for A2, and 90 NM for A3)

3.3.3.1.3 Air referenced velocity OC Report

Air referenced velocity (ARV) update periods and acquisition range requirements are derived from the en-route air-air encounter scenario described in Appendix O <<an extension of Stan's paper, to be written by Tony and Stan>>, and are summarized in Table 3-4(b). These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting ARV on-condition reports within the specified acquisition range or time interval.

Conditions under which the broadcasting of Air Referenced Velocity (ARV) reports is required is defined in section 3.4.6.1.

When the ARV report is required due to loss of ground-referenced velocity information from the own-ship navigation equipment, the update period and acquisition range requirements for all equipage classes shall (R3.xx) be equivalent to those for the State Vector Report as specified in 3.3.3.1.2 and table 3-4 (a). These requirements for ARV reports are summarized in table 3-4 (b).

<< the above paragraph or the next two paragraphs >>

When the ARV report is required due to loss of ground-referenced velocity information from the own-ship navigation equipment, the update period requirements are as follows: the nominal update period shall (3.xx) be 5 seconds for A1, A2, and A3 equipment at ranges of 10 NM and closer; the nominal update period shall (R3.xx) be 7 seconds for A1, A2, and A3 equipment at ranges greater than 10 NM and less than or equal to 20 NM; the nominal update period shall (3.xx) be 12 seconds for A2 equipment at ranges greater than 20 NM and less than or equal to 40 NM; the nominal update period shall (3.xx) be 12 seconds for A3 equipment at ranges greater than 20 NM and less than or equal to 90 NM. These report update requirements are summarized in Table 3-4(b).

When the ARV report is required due to loss of ground-referenced velocity information from the own-ship navigation equipment, acquisition requirements are as follows: the acquisition range in the forward direction shall (R3.xx) be 20 NM for equipage class A1; the acquisition range in the forward direction shall (R3.xx) be 40 NM for equipage class A2; the acquisition range in the forward direction shall (R3.xx) be 90 NM for equipage class A3. The range requirements in all other directions shall (R3.xx) be consistent with those stated in Note 3 of Table 3-4(a). These acquisition requirements are summarized in Table 3-4(b).

Note: If ARV is being transmitted under other conditions than those which require its update as specified in 3.4.6.1, acquisition ranges and update periods do not have to meet the above requirements.

Table 3-4(b) Summary of Air Referenced Velocity Report Update Requirements

Operational Domain ®	**Terminal, En-route, and Oceanic / Remote Non-Radar ¯**			
Applicable Range ®	**R £ 10 NM**	**10 NM < R £ 20 NM**	**20 NM < R £ 40 NM**	**40 NM < R £ 90 NM**
Equipage Class ®	A1 required	A1 required	A2 required	A3 required
ARV Acquisition Range		20 NM	40 NM	90 NM
ARV Nominal Update Period (95%) when ground referenced velocity data not available	5 sec	7 sec	12 sec	12 sec

3.3.3.1.4 Target State and Trajectory Change OC-Reports

Target state report (TSR), and trajectory change report (TCR) update period and acquisition range requirements are derived from the en-route air-air encounter scenario described in Appendix O <<an extension of Stan's paper, to be written by Tony and

Stan>>, and are summarized in Table 3-4(c). These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting those on-condition reports within the specified acquisition range or time interval. The requirements for TSRs and TCRs summarized in Table 3-4(c) represent the "best engineering judgment" at the time of MASPS publication and will require subsequent validation via simulations and flight evaluations.

The requirements for the minimum update periods for TSR and TCR On-condition reports are functions of range. Tighter requirements (a smaller required update period) is placed on these reports for a time period equal to two update periods immediately following any change in the intent information previously broadcast. These requirements are specified in terms of acquisition range and required update interval to achieve a 95% confidence of receiving a TSR or TCR within the specified acquisition range or time interval.

When there has been no change in intent information, the nominal update period for A2 equipage at ranges in the forward direction within 40 NM and for A3 equipage at ranges in the forward direction within 90 NM shall (R3.xx) be T_U, such that

$$T_U = \max\left(12\,s, \quad 0.45\frac{s}{NM}\cdot R\right)$$

where R is the range to the broadcasting aircraft and T_U is rounded to the nearest whole number of seconds. If implemented, these requirements are applicable to TSR update rates for A1 equipment for ranges of 20 NM or less.

When there is a change in the broadcast intent information, the update period for A2 equipage at ranges in the forward direction within 40 NM and for A3 equipage at ranges in the forward direction within 90 NM shall (R3.yy) be T_U, such that

$$T_U = \max\left(12\,s, \quad 0.22\frac{s}{NM}\cdot R\right)$$

where R is the range to the broadcasting aircraft and T_U is rounded to the nearest whole number of seconds. This higher update rate shall (R3.zz) be maintained for at least two update periods before returning to the nominal update rate. If implemented, these requirements are applicable to TSR update rates for A1 equipment for ranges of 20 NM or less.

Note: It is desired that requirements R3.xx and R3.yy be met by A2 equipment at ranges up to and including 50 NM and by A3 equipment up to and including 120 NM.

Table 3-4(c) shows the values for the required minimum update periods as calculated by the above formulae at the ranges indicated as required and desired for A2 and A3 aircraft.

For equipage class A2, the acquisition range in the forward direction shall (R3.xx) be 40 NM with 50 NM desired. For equipage class A3, the acquisition range in the forward direction shall (R3.xx) be 90 NM with 120 NM desired. If implemented, equipage class

A1 shall (R3.xx) have a 20 NM acquisition range for TSR in the forward direction. The range requirements in all other directions shall (R3.xx) be consistent with those stated in Note 3 of Table 3-4(a).

Table 3-4(c): Summary of TSR and TCR Acquisition Range and Update Interval Requirements

Operational Domain ®	**Terminal, En-route, and Oceanic / Remote Non-Radar ¯**				
Applicable Range ®	**R £ 20 NM**	**R = 40 NM**	**R = 50 NM**	**R = 90 NM**	**R = 120 NM**
Equipage Class ®	A1 optional A2 required	A2 required	A2 desired, A3 required	A3 required	A3 desired
TSR Acquisition Range	20 NM (A1 optional)	40 NM (A2, A3 required)	50 NM (A2, A3 desired)		
TCR Acquisition Range	20 NM (A1 optional)	40 NM	50 NM (A2 desired)	90 NM	120 NM (A3 desired)
TSR state change update period	12 s	12 s	12 s (desired)	20 s (desired)	26 s (desired)
TCR+0 state change update period	12 s	12 s	12 s (desired)	20 s (desired)	26 s (desired)
TSR nominal update period	12 s	18 s	23 s (desired)	41 s (desired)	54 s (desired)
TCR+0 nominal update period	12 s	18 s	23 s	41 s	54 s

Notes for Table 3-4(c):

1. *Table 3-4(c) is based on an air-air en-route scenario between two aircraft closing at 1200 knots, which is considered a worst case for deriving range requirements for ADS-B conflict alerting. See Appendix O for scenario details.*

2. *The ranges shown in Table 3-4(c) are meant to represent operational airspace with aircraft densities equivalent to those defined in Table 2-3 and Table 3-4(a).*

In addition to the above update rate requirements, this MASPS limits the conditions when a TCR needs to be broadcast. A TCR report for any TCP other than the active TCP would not be required if the TTG to that TCP exceeds 20 minutes. For example, if the TTG to the next trajectory change waypoint is 26 minutes, then no TCR reports beyond the next waypoint (TCR+0) are required. This limitation would prevent indiscriminate broadcast of TCR reports that are not operationally relevant.

3.3.3.2 Report Latency and Report Time Error Requirements

When ADS-B makes a report of aircraft/vehicle position and velocity to an application, this will occur at a time later than when the measurements were made. There are several sources of such delay or *latency* (defined below). Before the information reaches the ADS-B system, delays occur both in the navigation receiving system (a GNSS receiver for example) and in the data bus system that may be used to convey the information to ADS-B. Within the ADS-B system, delay can be caused by the computation time for preparing the transmission and for assembling the report. After the report leaves ADS-B, additional delays may occur.

Delays that occur prior to the information reaching ADS-B are not the subject of requirements in this MASPS. Delays occurring after the information is reported by ADS-B are likewise not considered in this MASPS.

Compensation may be applied to the reported information in order to adjust, at least approximately, for the changes in A/V state between the time of measurement and the time of the report. Compensation may be applied to position information while not being applied to velocity information. As a result, the two parts of a state vector may apply to two different times. This produces a velocity lag error if the reporting aircraft is accelerating.

3.3.3.2.1 Latency Definitions

The following definitions are used in the requirements concerning latency.

- Latency: While the position and velocity of an A/V may be constantly changing, a particular measurement applies to the true state at a certain time, called the "time of measurement". Latency, for cases in which compensation is not used, is the time difference between the time of measurement and the time it is reported at the ADS-B output (the latter minus the former). For cases in which compensation is used, the time of applicability of position and velocity will differ in general, and the report contains the time of applicability of position. Position latency is the difference, if any, between the time of applicability and the time the information is reported at the ADS-B output (the latter minus the former). Velocity latency is defined in the same way, but will in general, have a different value. Latency includes the total time differences, whether it is constant with time or variable, and whether it is known by the application or uncertain.

- ADS-B Latency: This is the component of latency attributable to the ADS-B system. Typically the source will make measurements periodically, and will provide the information to ADS-B once per period. If the ADS-B timing structure is independent of the source timing, as is typical, there will be a waiting time (a contribution to latency) between when the information is provided by the source and when it is transmitted. The average value of this asynchronization wait is one half the source period. This contribution to latency is attributed to ADS-B. If a data bus is used to convey information from the source to ADS-B, it may contribute latency, but that contribution is not attributed to ADS-B latency. Similarly, a data bus may be used to convey information from ADS-B to an application, and any resulting latency is not attributed to ADS-B.

- Report time error: Each ADS-B report includes timing information. Report time error is defined as the reported time minus the true time of the measurement. The time in the report is taken to be the time of the position measurement. If the times of applicability of the position and velocity are different and are not reported separately, then the application can use the single reported time for both, with a resulting report time error.

- Differential Delay: The difference in adjacent aircraft report times used by a third party surveillance application. Differential delay, relative to the output of a separate surveillance system e.g., radar, will also influence position registration error when the two outputs are combined.

3.3.3.2.2 Latency Requirements

For NAC_P less than 9, ADS-B latency of the reported information shall (R3.16) be less than 1.2 s with 95 percent confidence. For $NAC_P \geq 9$, ADS-B latency shall (R3.17) be less than 0.4 s with 95% confidence. The standard deviation of the report time error shall (R3.18) be less than 0.5 s (1 sigma). The mean report time error for position shall (R3.19) not exceed 0.5 s. The mean report time error for velocity shall (R3.20) not exceed 1.5 s. Differential delay errors should be considered and, if necessary, compensated for by the using application. ADS-B is not required to compensate for differential delays; however, all necessary information to perform such compensation is included in the ADS-B state vector report. Appendices G, J, and K provide a more detailed discussion of the different sources of latency, and provide the rationale for these numerical requirements.

3.4 ADS-B Messages And Reports

This section provides requirements and definition of ADS-B reports and the relationship between these reports and the received messages. The ADS-B output report definitions establish the standard contents and conditions for outputting data qualified for user applications. Exchange of broadcast messages and report assembly considerations are discussed in Paragraph 3.4.2. Report data elements are specified in Paragraphs 3.4.3 to 3.4.8 and standardized according to content, nomenclature, parameter type, applicable coordinate system, logical content, and operational conditions. Reports required for each Equipment Class and supporting message contents are defined in Paragraph TBD. Report contents and message requirements are based on the information requirements summarized in Table 2-2. These definitions provide the basis for:

- Independence between applications and broadcast link technologies
- Interoperability of applications utilizing different ADS-B technologies.

Specific digital formats are not defined since interface requirements will determine those details. Such interfaces may be internal processor buses or inter-system buses such as those described in ARINC, IEEE, and Mil 1553 standards. Additional information requirements may develop in the future and result in expansion to the report definitions specified in this document. ADS-B system designs should be sufficiently flexible to accommodate such future expansion.

3.4.1 Report Assembly Design Considerations

Three report types are defined as ADS-B outputs to applications. They provide flexibility in meeting delivery and performance requirements for the information needed to support the operations identified in Section 2. Report types, also shown in Figure 3-8, are:

- Surveillance State Vector Report (SV, paragraph 3.4.3);
- Mode-Status Report (MS, paragraph 3.4.4);
- Various On-Condition Reports (OC, paragraph 3.4.5) – a category that includes the following report types:
  - ♦ Air Referenced Velocity Report (ARV, paragraph 3.4.6),
  - ♦ Target State Report (TSR, paragraph 3.4.7),
  - ♦ Trajectory Change Report (TCR or TCR+0, TCR+1, etc., paragraph 3.4.8), and
  - ♦ Other On-Condition Reports, which may possibly be defined in future versions of this MASPS.

All interactive participants must receive messages and assemble reports specified for the respective equipage class (Table 3.3-2). All transmitting participants must ouput at least the minimum data for the SV and ~~partial~~ MS reports. The minimum requirements for exchanged information and report contents applicable for equipage classes are provided in Paragraph TBD.

3.4.2 ADS-B Message Exchange Technology Considerations in Report Assembly

ADS-B participants can vary both in the information exchanged and in the applications supported. ADS-B reports are assembled from received ADS-B messages. Message formats are defined in MOPS or equivalent specifications for each link technology chosen for ADS-B implementation. Reports are independent of the particular message format and network protocol. In some ADS-B broadcast exchange technologies the information may be conveyed as a single message, while others may utilize multiple messages which require assembly in the receiving subsystem to generate the ADS-B report. The report assembly function must be performed by the ADS-B subsystem prior to disseminating the report to the application.

Broadcast technologies vary in broadcast rate and probability of message reception. The receiving subsystem, therefore, must process messages compatibly with the message delivery performance to satisfy required performance as observed in the ADS-B report outputs. Also, data compression techniques may be used to reduce the number of transmitted bits in message exchange designs.

The messages shall (R3.29) be correlated, collated, uncompressed, re-partitioned, or otherwise manipulated as necessary to form the output reports specifically defined in Paragraphs 3.4.3 to 3.4.8 below. The message and report assembly processing capabiolity of the receiving subsystem shall (R3.30) support the total population of the participants within detection range provided by the specific data link technology.

Receiving subsystem designs must provide reports based on all decodable messages received, i.e., for each participant the report shall (R3.31) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is received from that participant. The Report Assembler function converts the received messages into the reports appropriate to the information conveyed from the transmitting participant. The applicable reports shall (R3.32) be made available to the applications on a continual basis in accordance with the local system interface requirements.

Each ADS-B report contains an address, for the purpose of enabling the receiver to associate the receptions into a single track. If the ADS-B design uses the ICAO 24-bit addres, then there shall (R3.33) be agreement between the address currently being used by the Mode S transponder and the reported ADS-B address, for aircraft with both transponder and ADS-B.

3.4.3 State Vector Report

Table 3.4.3 lists the report elements that comprise the state vector (SV) report. The SV report contains information about an aircraft or vehicle's current kinematic state. Measures of the state vector quality are contained in the NIC element of the SV report and in the NAC_P, NAC_V, NAC_{baro} and SIL elements of the Mode Status Report (paragraph 3.4.4 below).

Table 3.4.3: State Vector Report Definition.

	SV Elem. #	Contents [Resolution or # of bits]	Required from surface participants	Required from airborne participants	Reference Section	Notes
ID	1	Participant Address [24 bits]	•	•	2.1.2.3.1	
	2	Address Qualifier [4 bits]	•	•	2.1.2.3.2	1
TOA	3	Time Of Applicability [0.2 s]	•	•	2.1.2.1	
Geometric Position	4a	Latitude (WGS-84) [20 m or better]	•	•	3.4.3.4	2
	4b	Longitude (WGS-84) [20 m or better]	•	•		
	4c	Horizontal Position Valid [1 bit]	•	•	3.4.3.5	
	5a	Geometric Altitude [25 ft or 100 ft]	•		3.4.3.6	3
	5b	Geometric Altitude Valid [1 bit]	•		3.4.3.7	
Horizontal Velocity	6a	North Velocity while airborne [4 knots or better]	•		3.4.3.8	
	6b	East Velocity while airborne [4 knots or better]	•			
	6c	Airborne Horizontal Velocity Valid [1 bit]	•		3.4.3.9	
	7a	Ground Speed while on the surface [1 knot]		•	3.4.3.10	
	7b	Surface Ground Speed Valid [1 bit]		•	3.4.3.11	
Heading	8a	Heading while on the Surface [6° or better (6 bits)]		•	3.4.3.12	
	8b	Heading Valid [1 bit]		•	3.4.3.13	
Baro Altitude	9a	Pressure Altitude [25 ft or 100 ft]	•		3.4.3.14	3
	9b	Pressure Altitude Valid [1 bit]	•		3.4.3.15	
Vertical Rate	10a	Vertical Rate (Baro/Geo) [TBD]	•		3.4.3.16	
	10b	Vertical Rate Valid [1 bit]	•		3.4.3.17	
NIC	11	Navigation Integrity Category [4 bits]	•	•	3.4.3.19	
Report Mode	12	SV Report Mode [2 bits]			3.4.3.19	

Notes for Table 3.4.3:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits shown in the table for the Address Qualifier field is 4 only because experience in encoding that field the MOPS for particular ADS-B data links seems to indicate that 4 bits is sufficient for encoding this field.*

2. *A horizontal position resolution finer than 20 m will be required if NAC_P element of the MS report is TBD or greater.*

3. *Only one of the two altitude types (barometric pressure altitude and geometric altitude) need be reported at the full SV update rate. The other altitude type must be reported if it is available to the ADS-B transmitting subsystem, but may be reported at a lower update rate. (See subparagraph TBD.)*

ADS-B participants that are known to be on the surface shall (R3.xxx) transmit those State vector elements that are indicated with bullets ("•") in the "required from surface participants" column of Table 3.4.3. Likewise, participants that are known to be airborne shall (R3.xxx) transmit those SV elements that are indicated by bullets in the "required from airborne participants" column. Any transmitting ADS-B participant for which the air/ground state is uncertain shall (R3.xx) transmit all SV elements with bullets in either column. <<AI for Jim Maynard: Revise the language here and in subparagraph 3.4.3.1 below to have three states: "know that you're airborne," "know that you're on the surface," and "don't know whether airborne or on the surface." In the latter case, require that participants transmit the "airborne" SV elements, and recommend that they also transmit the "surface" SV elements. (It is only to those A/Vs that could be either airborne or on the ground that the third option would apply.)>>

3.4.3.1 Airborne/Surface State Determination

For purposes of determining whether to transmit the "required from airborne participants" or the "required from surface participants" report elements from Table 3.4.3 above, the following tests are to be applied:

1. If the transmitting ADS-B participant is *not* equipped with a means, such as a weight-on-wheels switch, to determine whether the participant is airborne or on the surface, then it shall (R3.xx) apply the test described in Table 3.4.3.1 (a) to determine whether to transmit the "required from airborne participants" or the "required from surface participants" report elements from Table 3.4.3.

2. If a transmitting ADS-B participant *is* equipped with a means, such as a weight-on-wheels switch, to determine automatically whether it is airborne or on the surface, then:

   a. If that automatic means indicates that the transmitting ADS-B participant is airborne, the participant shall (R3.xx) transmit messages to support the "required from airborne participants" SV report elements of Table 3.4.3.

   b. If that automatic means indicates that the transmitting ADS-B participant is on the surface, the additional test of Table 3.4.3.1 (b) shall (R3.xx) be performed to validate the "on-the-surface" condition.

Table 3.4.3.1 (a): Tests to Select "Airborne" or "Surface" State In The Absence Of Automatic Means To Determine That State.

	Conditions for Determining Air/Ground State				**Resulting Air/Ground State**
	Participant Category, C (subparagraph 2.1.2.4)		**Ground Speed (GS), Airspeed (AS), Radio Height (RH)**		
if	(C = Light Aircraft) **or** (C = Rotorcraft) **or** (C = Glider/Sailplane) or (C =Lighter-Than-Air) or (C = Unmanned Aerial Vehicle) (C = Ultralight / Hand glider / Paraglider) **or** (C - Parachutist / Skydiver) or C = Point Obstacle) **or** (C = Cluster obstacle) **or** (C = Line obstacle) **or** (Category information not available)			**then**	Select Airborne State
else if	(C = Surface Vehicle, emergency) **or** (C = Surface Vehicle, service)			**then**	Select Surface State
else if	(C = Small Aircraft) **or** (C = Large Aircraft) **or** (C = High-Wake-Vortex Large Aircraft) **or** (C = Heavy Aircraft) **or** (C = Highly Maneuverable Aircraft) **or** (C= Space / Trans-Atmospheric Vehicle)	**if**	(GS < 100 knots) **or** (AS < 100 knots) **or** (RH < 100 ft)	**then**	Select Surface State
		else		~~**else**~~	Select Airborne State

Notes for Table 3.4.3.1(a):

1. *Because of the unique operating capabilities of rotorcraft, i.e., hover, etc., an operational rotorcraft shall always report the "Airborne" state unless the "Ground" state is specifically declared in compliance with subparagraph "a" above.*

2. *Because of the unique operating capabilities of "Lighter-than-Air" vehicles, i.e., balloons, and operational "Lighter-than-Air" vehicle shall always report the "Airborne" State unless the "Ground" state is specifically declared in compliance with subparagraph "a" above.*

3. *Because of the fact that it is important for fixed ground or tethered obstructions to report altitude, such objects shall always report the "Airborne" State.*

Table 3.4.3.1(b): Test to Validate "On the Surface" Condition.

	Conditions for Determining Air/Ground State				Resulting Air/Ground State
	Participant Category, C (subparagraph 2.1.2.4)		**Ground Speed (GS), Airspeed (AS), Radio Height (RH)**		
if	(C = Small Aircraft) **or** (C = Large Aircraft) **or** (C = Large Aircraft) **or** (C = High-Wake-Vortex Large Aircraft) **or** (C = Heavy Aircraft) **or** (C = Highly Maneuverable Aircraft) **or** (C= Space / Trans-Atmospheric Vehicle)	**and**	(GS > 100 knots) **or** (AS > 100 knots) **or** (RH > 100 ft)	**then**	Select Airborne State
else					Select Surface State

3.4.3.2 State Vector Update Rate

Required SV report update rates, described by operating range, are given in Table 3-4(a) in subparagraph 3.3.3.1 above.

3.4.3.3 State Vector Time of Applicability

The time of applicability relative to local system time shall (R3.37) be updated with each State Vector report update. For other elements of the SV report, the report assembly function shall (R3.38) either provide updates when data is received or indicate "no data available" if no data are received in the preceding 10 second period.

3.4.3.4 Horizontal Position in SV Report

Horizontal position (subparagraph 2.1.2.6) shall (R3.xx) be reported as WGS-84 latitude and longitude. Horizontal position shall (R3.xx) be reported with the full range of possible latitudes (-90° to +90°) and longitudes (-180° to +180°).

Horizontal position shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_P field of the Mode-Status report (subparagraphs 2.1.2.14 and 3.4.4). Moreover, horizontal position shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal position error, σ_{hp}, listed in Table 3-4(a): 20 m for airborne participants, or σ_{hp} = 2.5 m for surface participants.

3.4.3.5 Horizontal Position Valid Field in SV Report

The Horizontal Position Valid field in the SV report shall (R3.xx-A) be set to ONE if a valid horizontal position is being provided in geometric position (latitude and longitude) fields of that report; otherwise, the Horizontal Position Valid field shall (R3.xx-B) be ZERO.

3.4.3.6 Geometric Altitude Field In SV Report

Geometric altitude shall (R3.xx) be reported with a range from -1,000 feet up to +100,000 feet. If the NAC_P code reported in the MS report (subparagraph 2.1.2.14) is 9 or greater, geometric altitude shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the vertical accuracy reported in the NAC_P field. Moreover, geometric altitude shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to vertical position error, σ_{vp}, listed in Table 3-4(a): σ_{vp} = 30 feet for airborne participants.

Note: A resolution of 100 feet or finer is sufficient not to compromise the one-sigma (one standard deviation) ADS-B contribution to vertical position error listed in Table 3-4(a). This is because the error introduced by rounding altitude to the nearest multiple of 100 feet has a uniform probability distribution, for which the standard deviation is 100 feet divided by the square root of 12, that is, about 28.9 feet.

3.4.3.7 Geometric Altitude Valid Field in SV Report

~~3.4.3.5~~3.4.3.8 Geometric Horizontal Velocity in SV Report

Geometric horizontal velocity is the horizontal component of the velocity of an A/V with respect to the earth (or with respect to an earth-fixed referenced system, such as the WGS-84 ellipsoid). The range of reported horizontal velocity shall (R2.22) accommodate speeds of up to 250 knots for surface participants and up to 4000 knots for airborne participants. Horizontal velocity shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the accuracy reported in the NAC_V field of the Mode-Status report. Moreover, horizontal velocity shall (R3.xx) be communicated and reported with a resolution sufficiently fine that it does not compromise the one-sigma maximum ADS-B contribution to horizontal velocity error, σ_{hv}, listed in Table 3-4(a): that is, 0.5 m/s (about 1 knot) for airborne participants with speeds of 600 knots or less, or 0.25 m/s (about 0.5 knot) for surface participants.

Note: The rounding of velocity to the nearest encoded representation may be modeled with a uniform probability distribution. As such, the standard deviation (one-sigma velocity error, s_{hv}) due to rounding to the nearest possible encoded representation is the weight of the LSB divided by the square root of 12. Thus, s_{hv} = 0.5 m/s (about 1 knot) for airborne participants implies a resolution of $res_{hv} = s_{hv} \cdot \sqrt{12}$ = 1.73 m/s (about 3.4 knots), so even a horizontal velocity resolution of 2 knots is sufficiently fine to meet the constraint imposed by Table 3-4(a) on airborne participants with speeds up to 600 knots. Likewise, a horizontal velocity resolution of 1 knot is sufficiently fine to satisfy the constraint imposed by Table 3-4(a) for surface participants.

3.4.3.9 Airborne Horizontal Velocity Valid Field in SV Report

The Airborne Horizontal Velocity Valid field in the SV report is a one-bit field which shall (R3.xx-A) be set to ONE if a valid horizontal geometric velocity is being provided in the “North Velocity while airborne” and “East velocity while airborne” fields of the SV report; otherwise, the “Airborne Horizontal Velocity Valid” field shall (R3.xx-B) be ZERO.

3.4.3.10 “Ground Speed While On the Surface” Field in SV Report

The ground speed (the magnitude of the geometric horizontal velocity) of an A/V that is known to be on the surface shall (R3.xx) be reported in the “ground speed while on the surface” field of the SV report. For A/Vs moving at ground speeds less than 70 knots, the ground speed shall (R3.xx) be communicated and reported with a resolution of 1 knot or finer. Moreover, the resolution with which the :ground speed while on the surface” field is communicated and reported shall be sufficiently fine so as not to compromise the accuracy of that speed as communicated in the NAC_V field of the MS report (subparagraph 2.1.2.15 below).

3.4.3.11 “Surface Ground Speed Valid” Field in SV Report

~~3.4.3.6~~3.4.3.12 "Heading While On the Surface" Field in SV Report

If the heading of an A/V is available to the ADS-B transmitting subsystem on that A/V, then that heading shall (R2.xx) be transmitted while that A/V is known to be on the surface.

Heading shall (R3.xx-A) be reported for the full range of possible headings (the full circle, from 0° to nearly 360°). The heading of surface participants shall (R3.xx-B) be communicated and reported with a resolution of 6 degrees of arc or finer.

Notes:

1. *If heading is encoded as a binary fraction of a circle, a resolution of 6° of arc or finer would require at least 6 binary bits.*

2. *The reference direction for heading (true north or magnetic north) is communicated in the Mode-Status report (paragraph 3.4.4).*

3. *For operations at some airports, heading may be required to enable proper orientation and depiction of an A/V by applications supporting those surface operations.*

Participants are not required to broadcast heading if their length code (part of the aircraft size code, section 2.1.2.5) is 0. However, ADS-B participants of length code 1 or above shall (R2.xx) transmit messages to support the heading element of the SV report when those participants are on the surface and have a source of heading available to the ADS-B transmitting subsystem.

3.4.3.13 "Heading Valid" Field in SV Report

The "heading valid" field in the SV report shall (R3.xx-A) be ONE if a valid heading is provided in the "heading while on the surface" field of the SV report; otherwise, it shall (R3.xx-B) be ZERO.

~~3.4.3.7~~3.4.3.14 Pressure Altitude Field in SV Report

Barometric pressure altitude shall (R2.18) be reported referenced to standard temperature and pressure (1013.25 hPa or mB, or 29.92 in Hg). Barometric pressure altitude shall (R3.xx) be reported over the range of -1,000 feet to +100,000 feet.

If a pressure altitude source with 25-foot or better resolution is available to the ADS-B transmitting subsystem, then pressure altitude from that source shall (R3.xx-A) be communicated and reported with 25-foot or finer resolution. Otherwise, if a pressure altitude source with 100-foot or better resolution is available, pressure altitude from that source shall (R3.xx-B) be communicated and reported with 100-foot or finer resolution.

Note: A field is reserved in the MS report ("BAQ" field, subparagraph 3.4.4.13) for future use in reporting the accuracy and resolution of the pressure altitude provided in the SV report.

3.4.3.15 "Pressure Altitude Valid" Field in SV Report

The "pressure altitude valid" field in the SV report is a one-bit field which shall (R3.xx-A) be ONE if valid information is provided in the "pressure altitude" field; otherwise, the "pressure altitude valid" field shall be ZERO.

~~3.4.3.8~~3.4.3.16 Vertical Rate Field in SV Report

The "vertical rate" field in the SV report is a TBD-bit field that contains the altitude rate (subparagraph 2.1.2.9.1) of an airborne ADS-B participant. This shall (R3.xx) be either the rate of change of pressure altitude or of geometric altitude, as specified by the "vertical rate type" element in the MS report.

3.4.3.17 "Vertical Rate Valid" Field in SV Report

The "vertical rate valid" field in the SV report is a one-bit field which shall (R3.xx-A) be ONE if valid information is provided in the "vertical rate" field; otherwise, the "vertical rate valid" field shall be ZERO.

3.4.3.18 Navigation Integrity Category (NIC) Field in SV Report

The NIC field in the SV report is a 4-vit field that shall (R3.xx) report the Navigation Integrity Category described in subparagraph 2.1.2.13 above.

3.4.3.19 Report Mode Field in SV Report

The "Report Mode" provides a positive indication when SV acquisition is complete and all applicable data sets and modal capabilities have been determined for the participant or that a default condition is determined by the Report Assembly function. The information for this SV element is not transmitted over the ADS-B data link, but is provided by the report assembly function at the receiving ADS-B participant. Table 3.4.3.18 lists the possible values for the SV Report Mode.

Table 3.4.3.19 : SV Report Mode Values.

Value	Meaning
0	Acquisition
1	Track
2	Default

<< We need text to describe the meanings of "acquisition," "track," and "default" SV report modes.>>

3.4.4 Mode Status Report

The mode-status (MS) report contains current operational information about the transmitting participant. This information includes participant type, mode specific parameters, status data needed for certain pairwise operations, and assessments of the integrity and accuracy of position and velocity elements of the SV report. These elements require lower update rates than the SV report. Specific requirements for a participant to supply data for and/or generate this report subgroup will vary according to the equipage class of each participant. Subsection 3.3.2 defines the required capabilities for each Equipage Class defined in Section 3.2.3. Equipage classes define the level of MS information to be exchanged from the source participant to support correct classification onboard the user system.

The Mode-Status report for each acquired participant contains the unique participant address for correlation purposes, static and operational mode information and Time of Applicability. Contents of the Mode-Status report are summarized in Table 3.4.4.

The static and operational mode data includes the following information:

- Capability Class (CC) Codes – used to indicate the capabilities of a transmitting ADS-B participant.
- Operational Mode (OM) Codes – used to indicate the current operating mode of a transmitting ADS-B participant.

For each participant the Mode-status report shall (R3.41) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant. For all applications other than Aid to Visual Acquisition the required MS report must be available to qualify for ADS-B operations.

~~The time of applicability relative to local system time shall (R3.42) be updated with every Mode-status report update.~~

Table 3.4.4: Mode-Status (MS) Report Definition.

	MS Elem. #	Contents [Resolution or # of bits]	Parameters That Trigger Fast Update Rate	Reference Section	Notes
ID	1	Participant Address [24 bits]		2.1.2.3.1	
	2	Address Qualifier [4 bits]		2.1.2.3.2	1
TOA	3	Time of Applicability [1 s resolution]		3.4.4.2	
ID, Continued	4a	Call sign [up to 8 alpha-numeric characters]		3.4.4.3	
	4b	Emitter Category [5 bits]		3.4.4.4	
	4c	A/V Length and Width Codes [4 bits]		3.4.4.5	2
Status	5a	Mode-Status Data Available [1 bit]		3.4.4.6	
	5b	Emergency/Priority Status [3 bits]	•	3.4.4.7	
CC, Capability Codes	6	Capability Class Codes [TBD bits]		3.4.4.8	
		6a: CDTI display capability [1 bit]		3.4.4.8.1	
		6b: TCAS installed and operational [1 bit]		3.4.4.8.2	
		6c: (Reserved for Service Level) [3 bits]		3.4.4.8.3	
		6d: TSR Capability Flag [3 bits]		3.4.4.8.53. 4.4.8.53.4. 4.8.4	
		6e: TCR Capability Level [2 bits]		3.4.4.8.63. 4.4.8.63.4. 4.8.5	
		(CC Codes reserved for future growth) [TBD bits]		3.4.4.8.73. 4.4.8.73.4. 4.8.6	
OM, Operational Mode	7	Operational Mode Parameters [TBD bits]		3.4.4.9	
		7a: ACAS/TCAS resolution advisory active [1 bit]	•	3.4.4.9.1	
		7b: Current TCR Cycle Number [2 bits]	•	3.4.4.9.2	
		7c: (Res. For TCR+0 Transition Flag) [1 bit]		3.4.4.9.3	
		7d: IDENT Switch Active [1 bit]	•	3.4.4.9.4	
		7e: Using ATC services [1 bit]	•	3.4.4.9.5	
		(Reserved for future growth) [TBD bits]		3.4.4.9.6	
SV Quality	8a	Nav. Acc. Category for Position (NAC_P) [4 bits]	•	3.4.4.10	
	8b	Nav Acc. Category for Velocity (NAC_V) [2 bits]	•	3.4.4.11	
	8c	Surveillance Integrity Level (SIL) [2 bits]	•	3.4.4.12	
	8d	(Res. For BAQ, Barometric Altitude Quality) [2 bits]		3.4.4.13	
	8e	NIC_{baro} - Altitude Cross Checking Flag [1 bit]		3.4.4.14	
Data Reference	9a	True/Magnetic Heading [1 bit]		3.4.4.15	
	9b	Airspeed Type (IAS/TAS/Mach) [2 bits]	?	3.4.4.16	
	9c	Vertical Rate Type (Baro./Geo.) [1 bit]	?	3.4.4.17	
Other		Flight Mode Specific Data [TBD bits]		3.4.4.18	3

Notes for Table 3.4.4:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. For example, address qualifier bits might be needed to distinguish reports about TIS-B targets from reports about ADS-B targets. . The number of bits shown in the table for the Address Qualifier field is 4 only because experience in encoding that field the MOPS for particular ADS-B data links seems to indicate that 4 bits is sufficient for encoding this field.*

2. *The aircraft size code only has to be transmitted by aircraft above a certain size, and only while those aircraft are on the ground. (See section 2.1.2.5 for details.)*

3. *Flight mode specific data will be defined in a lower level of documentation and be included through a later revision to the MASPS. <<We promise to go on to Rev B!>> Examples are: touchdown speed and pair-wise operational capabilities.*

3.4.4.1 Mode-Status Update Rate

<<Insert text here or reference Table 3-4(a)'s requirements on the update rate for the data in MS reports. This text must state that it's only unfavourable changes of the NAC or BAQ elements that trigger the faster update rate changes. >>

The report assembly function shall (R3.43-A) provide update when received. For those elements indicated in Table 3.4.4 as "parameters that trigger fast update rate" , the report assembly function shall (R3.43-B) indicate "no data available" if no update is received in the preceding 24 second period.

Note: The 24-second period before which "no data is available" was chosen as being twice the nominal update interval for MS data, as indicated in Table 3-4(a) above.

3.4.4.2 Time of Applicability (TOA) Field in MS Report

The time of applicability relative to local system time shall (R3.42) be updated with every Mode-status report update.

3.4.4.3 Call Sign Field in MS Report

An ADS-B participant's call sign (subparagraph 2.1.2.2) is conveyed in the Call Sign field of the MS report. The call sign shall (R3.xx) consist of up to 8 alphanumeric characters. The characters of the call sign shall (R3.xx) consist only of the capital letters A-Z, the decimal digits 0-9, and – as trailing pad characters only – the "space" character.

3.4.4.4 Emitter Category Field in MS Report

An ADS-B participant's emitter category code (subparagraph 2.1.2.4) is conveyed in the Participant Category field of the MS report. The particular encoding of the emitter category is not specified in this MASPS, being left for lower level specification documents, such as the MOPS for a particular ADS-B data link. Provision in the encoding shall (R3.xx) be made for at least [24] distinct emitter categories, including the particular categories listed in subparagraph 2.1.2.4 above.

3.4.4.5 A/V Length and Width Codes in MS Report

The "A/V length and width codes" field in the MS field is a 4-bit field that describes the amount of space that an aircraft or ground vehicle occupies. The aircraft length and width codes shall (R3.xx) be as described in Table 3.4.4.5 below. The aircraft size code is a four-bit code, in which the 3 most significant bits (the length code) classify the aircraft into one of eight length categories, and the least significant bit (the width code) classifies the aircraft into a "narrow" or "wide" subcategory.

Each aircraft shall (R3.xx) be assigned the smallest length and width codes for which its overall length and wingspan qualify it.

Note: For example, consider a powered glider with overall length of 25 m and wingspan of 50 m. Normally, an aircraft of that length would be in length category 0. But since the wingspan exceeds 33 m, it will not fit within even the "wide" subcategory of length category 0. Such an aircraft would be assigned length category 3 and width category 1, meaning "length less than 54 m and wingspan less than 52 m."

Each aircraft ADS-B participant for which the length code is 1 or more (length greater than or equal to 30 m or wingspan greater than 33 m) shall (R3.xx) transmit its aircraft size code while it is on the surface. For this purpose, the determination of when an aircraft is on the surface shall (R3.xx) be as described in subparagraph 3.4.3.1.

Table 3.4.4.5: Aircraft Size (Length and Width) Codes.

Length Code (3 MSBs)			Width (Wingspan) Code (LSB)	
dec.	**binary**	**Length Category**	**Narrow (LSB = 0)**	**Wide (LSB = 1)**
0	0 0 0	L < 30 m	W < 16.5 m	16.5 m ≤ W < 33 m
1	0 0 1	L < 38 m	W < 30.5 m	30.5 m ≤ W < 38 m
2	0 1 0	L < 46 m	W < 38 m	38 m ≤ W < 48 m
3	0 1 1	L < 54 m	W < 42 m	42 m ≤ W < 52 m
4	1 0 0	L < 62 m	W < 51.5 m	51.5 m ≤ W < 65 m
5	1 0 1	L < 70 m	W < 66.5 m	66.5 m ≤ W < 74 m
6	1 1 0	L < 78 m	W < 69.5 m	69.5 m ≤ W < 80 m
7	1 1 1	L ≥ 78 m	W < 84 m	W ≥ 84 m

3.4.4.6 Mode-Status Data Available Field in MS Report

<<Text TBD>>

3.4.4.7 Emergency/Priority Status Field in MS Report

The emergency/priority status field in the MS report is a 3-bit field which shall (R3.xx) be encoded as indicated in Table 3.4.4.7.

Table 3.4.4.7: Emergency/Priority Status Encoding.

Coding	Meaning
0	No emergency / not reported
1	General emergency
2	Lifeguard / medical emergency
3	Minimum fuel emergency
4	No communications
5	Unlawful interference
6	Downed Aircraft
7	(Reserved for future definition)

3.4.4.8 Capability Class (CC) Codes Field in MS Report

A transmitting ADS-B participant broadcasts capability class (CC) codes (subparagraph 2.1.2.11) so as to indicate capabilities that may be of interest to other ADS-B participants. The subfields of the CC codes field are described in the following subparagraphs.

3.4.4.8.1 CDTI Traffic Display Capability

The CC code for "CDTI based traffic display capability" shall be set to ONE if the transmitting aircraft has the capability of displaying nearby traffic on a Cockpit Display of Traffic Information (CDTI). Otherwise, this CC code shall be ZERO.

3.4.4.8.2 TCAS/ACAS Installed and Operational

The CC code for "TCAS/ACAS installed and operational" shall be set to ONE if the transmitting aircraft is fitted with a TCAS (ACAS) computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts. Otherwise, this CC code shall be ZERO.

3.4.4.8.3 Service Level of Transmitting A/V

At least three bits (eight possible encodings) shall be reserved in the capability class codes for the "service level" of the transmitting ADS-B participant. ADS-B equipment conforming to the current version of this MASPS (DO-242A) shall (R2.xx) set the Service Level capability code to ZERO.

Note: *The service levels other than ZERO will be defined in a later version of this MASPS.*

3.4.4.8.4 ARV Capability Flag

<<Text TBD, to be provided by Richard Barhydt>>

3.4.4.8.5 TSR Capability Flag

<<Text TBD, to be provided by Richard Barhydt>>

3.4.4.8.6 TCR Capability Level Field in MS Report

The TCR Capability Level is a two-bit field that shall be encoded as in Table 3.4.4.8.6.

Table 3.4.4.8.6: TCR Capability Levels.

TCR Capability Level	Meaning
0	No capability for Trajectory Change Reports
1	Capability of sending information for TCR+0 only.
2	Capability of sending information for multiple TCRs.
3	(Reserved for future use.)

3.4.4.8.7 Other Capability Codes

Other capability codes are expected to be defined in later versions of this MASPS.

3.4.4.9 Operational Mode (OM) Parameters in MS Report

Operational Mode (OM) codes are used to indicate the current operational modes of transmitting ADS-B participants. Specific operational mode codes are described in subparagraphs 3.4.4.9.1 to 3.4.4.9.6 below.

~~3.4.4.6.1~~3.4.4.9.1 TCAS/ACAS Resolution Advisory Active Flag

A transmitting ADS-B participant shall (R2.xx) set the TCAS/ACAS Resolution Advisory Active Flag to ONE in the messages that it transmits to support the MS report so long as a TCAS (ACAS) resolution advisory is in effect. At all other times, the transmitting ADS-B participant shall set the TCAS/ACAS Resolution Advisory Active Flag to ZERO.

~~3.4.4.6.2~~3.4.4.9.2 TCR Cycle Number OM Code

<<Text to be provided by Tony Warren>>

~~3.4.4.6.3~~3.4.4.9.3 (Reserved for TCR+0 Transition Flag)

<<Text to be provided by Tony Warren>>

~~3.4.4.6.4~~3.4.4.9.4 "IDENT Switch Active" Flag

The "IDENT Switch Active" Flag is a one-bit OM code that is activated by an IDENT switch. Initially, the "IDENT switch active" OM code shall (R2.xx-A) be ZERO. Upon activation of the IDENT switch, this flag shall (R2.xx-B) be set to ONE for a period of 18 ± 1 seconds; thereafter, it shall (R2.xx-C) be reset to ZERO.

Note: If an aircraft is equipped with ATC transponder (Mode A, Mode C, or Mode S transponder), it is likely that the aircraft's transponder control panel would be connected to the ADS-B transmitting equipment, so that the IDENT switch for the transponder also controls the "IDENT Switch Active" OM code in ADS-B messages.

~~3.4.4.6.5~~3.4.4.9.5 "Using ATC Services" Flag

The "Using ATC Services" flag is a one-bit OM code. When set to ONE, this code shall (R3.xx) indicate that the transmitting ADS-B participant is being provided with ATC services; when not receiving ATC services, a transmitting ADS-B participant should set this OM code to ZERO.

Note: This MASPS does not specify the means by which the "Using ATC Services" flag is set. That is left to lower-level documents, such as the MOPS for a particular ADS-B data link.

~~3.4.4.6.6~~3.4.4.9.6 Other Operational Mode Codes

Other operational mode (OM) codes are expected to be defined in later versions of this MASPS.

3.4.4.10 Navigation Accuracy Category for Position (NAC_P) Field in MS Report

The Navigation Accuracy Category for Position (NAC_P, subparagraph 2.1.2.14) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use. The NAC_P field in the MS report is a 4-bit field which shall (R3.xx) be encoded as described in Table 2.1.2.15 in subparagraph 2.1.2.14 above.

3.4.4.11 Navigation Accuracy Category for Velocity (NAC_V) Field in MS Report

3.4.4.12 Surveillance Integrity Level (SIL) Field in MS Report

The SIL field in the MS report is a 2-bit field which shall (R3.xx) be coded as described in Table 2.1.2.16 in subparagraph 2.1.2.16 above.

3.4.4.13 "Reserved for BAQ" Field in MS Report

The "Reserved for Barometric Altitude Quality" field in the MS report is a 2-bit field which shall (R3.xx) be ZERO for equipment that conforms to this version (DO-242A) of the ADS-B MASPS.

Note: A possible future encoding of the BAQ field is described in subparagraph 2.1.2.17 in Section 2 above.

3.4.4.14 NIC_{baro} Field in MS Report

The NIC_{baro} field in the MS report is a one-bit flag that indicates whether or not the barometric pressure altitude provided in the State Vector Report has been cross-checked against another source of pressure altitude. A transmitting ADS-B participant shall set NIC_{baro} to ONE in the messages that it sends to support the MS report only if there is more than one source of barometric pressure altitude data and cross-checking of one altitude source against the other is performed so as to clear the "barometric altitude valid" flag in the SV report if the two altitude sources do not agree. Otherwise, it shall set this flag to ZERO.

3.4.4.15 True/Magnetic Heading Flag in MS Report

The True/Magnetic Heading Flag in the Mode-Status report is a one-bit field which shall (R3.xx) be ZERO to indicate that heading is reported referenced to true north, or ONE to indicate that heading is reported referenced to magnetic north.

3.4.4.16 Airspeed Type Field in MS Report

The Airspeed Type field in the MS report is a 2-bit field which shall (R3.xx) be encoded as specified in Table 3.4.4.16.

Table 3.4.4.16: Airspeed Type Encoding

Airspeed Type	Meaning
0	Airspeed Type Field Not Valid
1	True Airspeed (TAS)
2	Indicated Airspeed (IAS)
3	Mach

3.4.4.17 Vertical Rate Type Field in MS Report

The Primary Vertical Rate Type field in the MS report is a one-bit flag which shall (R3.xx) be ZERO to indicate that the vertical rate field in the SV report 3.4.3.16 holds the rate of change of barometric pressure altitude, or ONE to indicate that the vertical rate field holds the rate of change of geometric altitude.

3.4.4.18 Flight Mode Specific Data Field in MS Report

<<Text TBD>>

3.4.5 On-Condition Reports

The following sections (3.4.6 to 3.4.8) describe various On Condition (OC) reports. The OC reports are those for which messages are not transmitted all the time, but only when certain conditions are satisfied. Several OC report types are currently defined, as follows:

ARV: Air Referenced Velocity Report (section 3.4.6).

TSR: Target State Report (section 3.4.7).

TCR, TCR+1, TCR+2, TCR+3: Trajectory Change Reports (section 3.4.8). This may be for either the current trajectory change point towards which the aircraft is being controlled (the TCP), or for subsequent trajectory change points (TCP+1, TCP+2, TCP+3).

Other OC reports may be defined in future versions of this MASPS. Examples of such reports are to be found in Appendix M.

3.4.6 Air Referenced Velocity (ARV) Report

The Air Referenced Velocity (ARV) report contains velocity information that is not required from all airborne ADS-B transmitting participants, and that may not be required at the same update rate as the position and velocity elements in the SV report. Table 3.4.6 lists the elements of the ARV Report.

Table 3.4.6: Air Referenced Velocity (ARV) Report Definition.

	ARV Elem. #	Contents [Resolution or # of bits]		Reference Section	Notes
ID	1	Participant Address	[24 bits]	2.1.2.3.1	
	2	Address Qualifier	[4 bits]	2.1.2.3.2	1
TOA	3	Time of Applicability	[1 s resolution]	2.1.2.1	
Airspeed	4a	Airspeed	[1 knot or 4 knots]	3.4.6.3	2
	4b	Airspeed Valid	[1 bit]	3.4.6.4	
Heading	5a	Heading while airborne-	[1 degree]	3.4.6.5	3
	5b	Heading Valid	[1 bit]	3.4.6.6	

Notes for Table 3.4.6:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. The number of bits shown in the table for the Address Qualifier field is 4 only because experience in encoding that field in MOPS for particular ADS-B data links seems to indicate that 4 bits is sufficient.*

2. *The airspeed reference (IAS or TAS) is given in the MS report. Indicated airspeed (IAS) is defined as the speed indicated on the pilot's airspeed indicator. True airspeed (TAS) is defined as the speed of the A/V relative to the air mass.*

3. *The heading reference direction (true north or magnetic north) is given in the MS report.*

3.4.6.1 Condition for transmitting ARV report elements.

An airborne ADS-B participant of equipage class A1, A2 or A3 shall (R3.xx) transmit messages to support the ARV report when a period of TBD seconds has elapsed without the receipt of ground-referenced velocity information from the own-ship navigation equipment.

Notes:

1. *Airspeed and heading can be used by surveillance systems as a temporary replacement for ground-referenced velocity (N-S and E-W velocity, or alternately ground speed and ground track angle). The condition stated above for transmitting ARV report information is based on that use of the ARV information.*

2. *Additional uses of the ARV report are anticipated for future applications such as in-trail spacing, separation assurance when the transmitting aircraft is being controlled to an air-referenced heading, and for precision turns. For example, ARV report information allows wind conditions encountered by the transmitting aircraft to be derived. Current heading also provides a consistent reference when the aircraft is being controlled to a target heading. Such anticipated uses for ARV information are described in Appendix TBD.*

3. *Such additional uses will be associated with additional conditions for transmitting messages to support the ARV report. It is anticipated that when the requirements for such future applications are better understood, that additional conditions for transmitting the ARV report information may be included in a future revision of this MASPS.*

3.4.6.2 Update Interval for ARV report elements.

When the condition of subparagraph 3.4.6.1 is met, messages to support the ARV report shall be transmitted at a rate sufficient that the ARV report is updated at the same rate as the SV report.

3.4.6.3 "Airspeed" Field in ARV Report

Reported airspeed ranges shall (R3.xx) be 0-4000 knots airborne. Airspeeds of 600 knots or less shall (R3.xx) be reported with a resolution of 1 knot or finer. Airspeeds between 600 and 4000 knots shall (R3.xx) be reported with a resolution of 4 knots or finer.

3.4.6.4 "Airspeed Valid" Field in ARV Report

The "airspeed valid" field in the ARV report is a one-bit flag that shall (R3.xx) be ONE if valid airspeed data is being reported in the "Airspeed" field, or ZERO if valid airspeed data is not available.

3.4.6.5 "Heading While Airborne" Field in ARV Report

An aircraft's heading (subparagraph 2.1.2.10) is reported as the angle measured clockwise from the reference direction (magnetic north or true north) to the direction in which the aircraft's nose is pointing. If an ADS-B participant broadcasts messages to support ARV reports, and heading is available to the transmitting ADS-B subsystem, then it shall (R2.xx) provide heading in those messages. Reported heading range shall (R3.xx) cover a full circle, from 0 degrees to (almost) 360 degrees. The heading field in ARV reports shall (R3.xx) be communicated and reported with a resolution at least as fine as 1 degree of arc.

Note: The reference direction for heading (true north or magnetic north) is reported in the Mode-Status) report (paragraph 3.4.4 above).

3.4.6.6 "Heading Valid" Field in ARV Report

The "heading valid" field in the ARV report shall (R3.xx) be ONE if the "heading while airborne" field contains valid heading information, or ZERO if that field does not contain valid heading information.

3.4.7 Target State Report (TSR)

-The Target State Report (TSR) contains information about the current heading or altitude towards which the aircraft is being controlled. Table 3.4.7 lists the elements of this report.

Table 3.4.7: Target State Report (TSR) Definition.

	TSR Elem. #	Contents	[Resolution or # of bits]	Reference Section	Notes
ID	1	Participant Address	[24 bits]	2.1.2.3.1	
	2	Address Qualifier	[4 bits]	2.1.2.3.2	1
TOA	3	Time of Applicability	[1 s resolution]	2.1.2.1	
Target Heading or Track Angle	4a	Horizontal Data Available	[1 bit]		
	4b	Target Heading or Track Angle	[1 degree]	3.4.7.2.1.1 3.4.7.2.1.2	
	4c	Heading/Track Indicator	[1 bit]	3.4.7.3.1	
	4c	(Reserved for Heading/Track Capability)	[1 bit]	<<Richard to provide text>>	
	4d	Target Source Indicator (Horizontal)	[2 bits]	3.4.7.2.1.3	
	4e	Mode Indicator (Horizontal)	[1 bit]	3.4.7.2.1.4	
	4f	(Reserved for Horizontal Validity Flag)	[1 bit]		
Target Altitude	5a	Vertical Data Available	[1 bit]	3.4.7.4.5	
	5b	Target Altitude	[100 ft resolution]	3.4.7.4.6	
	5c	Target Altitude Type	[1 bit]	3.4.7.4.7	
	5d	Target Altitude Capability	[2 bits]	<<Richard to provide text>>	
	5e	Vertical Target Source Indicator	[2 bits]	3.4.7.4.8	
	5f	Vertical Mode Indicator-	[1 bit]	3.4.7.4.9	
	5g	(Reserved for Vertical Conformance)	[1 bit]		
Reserved		(Reserved for future growth)	[2 bits]		

Notes for Table 3.4.7:

1. *The minimum number of bits required by this MASPS for the Address Qualifier field is just one bit. However, when ADS-B is implemented on a particular data link, more than one bit may be required for the address qualifier if that data link supports other services in addition to the ADS-B service. For example, address qualifier bits might be needed to distinguish reports about TIS-B targets from reports about ADS-B targets. The number of bits shown in the table for the Address Qualifier field is 4 only because experience in encoding that field the MOPS for particular ADS-B data links seems to indicate that 4 bits is sufficient for encoding this field.*

3.4.7.1 Conditions for Transmitting TSR Information

An airborne ADS-B participant of equipage class A2 or A3 shall (R3.xx) transmit messages to support the OC-TSR report when the flight director or autopilot is engaged consistent with the axis of the target being sent. The class A2 or A3 participant shall (R3.xx) transmit these messages when either of the following conditions is met:

a. Target altitude is available from the automation system, or

b. Target heading or target track is available from the automation system.

3.4.7.2 Update Interval for TSR Information

The air-to-air update interval for TSR information shall (R3.xx) be as specified in Table 3.4.7.2 for a 95% probability of successful update at the specified ranges.

Table 3.4.7.2: TSR Update IntervalAs A Function of Range Between Aircraft.

	R £ 20 NM (95% Probability of Reception)	**20 NM < R £ 40 NM** (95% Probability of Reception)
Following Target State Changes	≤ 12 s	≤ 12 s
Nominal	≤ 12 s	max(12 s, 0.45 × R)

Note: In the above table, the formula, "max (12 s, 0.45 ´ R)" means the larger of (a) 12 seconds, or (b) 0.45 seconds per nautical mile times the range in nautical miles.

3.4.7.2.1 Short Term Horizontal Intent

Short term horizontal intent is conveyed in the Target State Report (TSR) and includes the following report elements:

- Target Heading (subparagraph 3.4.7.2.1.1) or Target Track (subparagraph 3.4.7.2.1.2)
- Target Heading / Target Track Indicator (subparagraph)
- Horizontal Target Source Indicator (subparagraph 3.4.7.2.1.3)
- Horizontal Mode Indicator (subparagraph 3.4.7.2.1.4)

3.4.7.2.1.1 Target Heading << move to section 3>>

Target heading is the aircraft's intended heading after turn completion or its current intended heading if in straight flight. Target heading shall (R2.xx) be provided with a range of 0 to 359 degrees <<possible rewording here?>> and shall (R2.xx) have a resolution of one degree. Target heading is only provided if the aircraft is being controlled to an air reference heading angle.

3.4.7.2.1.2 Target Track Angle

Target track angle is the aircraft's intended track angle over the ground after turn completion or its current intended track angle if in straight flight. Target track shall (R2.xx) be provided with a range of 0 to 359 degrees <<possible rewording>> and shall (R2.xx) have a resolution one degree of arc or smaller. Target track is only provided if the aircraft is being controlled to a ground referenced track angle.

3.4.7.2.1.3 Horizontal Target Source Indicator << move to section 3>>

The Horizontal Target Source Indicator in the Target State Report provides the source of target heading or track angle information. The ADS-B system shall (R2.xx) support the following three options:

- FMS or RNAV system (indicates track angle specified by leg type);
- Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU);
- Maintaining current heading or track angle (e.g., autopilot mode select).

3.4.7.2.1.4 Horizontal Mode Indicator << move to section 3>>

The Horizontal Mode Indicator element of the Target State Report reflects the aircraft's state relative to the target heading or track angle. The ADS-B system shall (R2.xx) support the following two options:

- Acquiring target heading or track angle.
- Capturing or maintaining target heading or track angle.

3.4.7.3 Horizontal Data Elements in TSR Report

3.4.7.3.1 Horizontal Data Available

The Horizontal Data Available flag for the target heading, TSR element #9, shall be ONE to indicate that data in the target heading or track angle field (element #4) is valid, or ZERO otherwise.

3.4.7.3.2 Heading/Track Indicator

The orientation type (heading or track angle) is conveyed in the Heading/Track Indicator. This field shall be ZERO to indicate that the "Target Heading or Track Angle" field conveys target heading, or ONE to indicate that it conveys target track angle. The reference direction (true north or magnetic north) is conveyed in the MS report.

3.4.7.3.3 Reserved for Target Heading/Track Capability

A bit is reserved to indicate whether or not the aircraft has the capability to provide the horizontal guidance target. In this "revision A" version of the MASPS, this bit shall (R3.xx) be ZERO.

3.4.7.3.4 Horizontal Target Source Indicator

The Horizontal Target Source indicator is a two-bit field that indicates the source of the Target Heading/Track Angle information. <<Need text to define the values of this field.>>

3.4.7.3.5 Horizontal Mode Indicator

The Horizontal Mode Indicator is a one-bit flag that …. <<Need text to define the values of this field.>>

3.4.7.4 Vertical Data Elements in Target State Report Target Altitude

Target Altitude is the aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude. Target altitude shall (R2.xx) be represented as the operational altitude recognized by the transmitting aircraft's guidance system. In order to ensure a consistent reference for target altitude, all aircraft must follow standard conventions by using barometric corrected altitude (altimeter set to local setting) below the transition level and pressure altitude (altimeter set to 29.92 in Hg or 1013.25 hPa) above the transition level. Target altitude shall (R2.xx) be provided with a range of 1,000 feet up to 100,000 feet and shall (R2.xx) have a resolution of 100 feet.

Note: The 100-foot resolution for target altitude was chosen because that is the resolution supported by the Mode Control Panel (MCP) or Flight Control Unit (FCU) equipment in use on commercial aircraft. Since target altitude can only be input in multiples of 100 feet, there is no need for a finer resolution for the encoding of target altitude. This MASPS requirement does not, of course, dictate how target altitude will be encoded on a particular ADS-B data link.

3.4.7.4.1 Target Altitude Type

The target altitude type is used to determine whether the target altitude is represented as a pressure altitude or a barometric corrected altitude. Target altitude type shall (R2.xx) indicate whether the target altitude is above or below the transition level.

3.4.7.4.2 Target Altitude Capability

Alternate values of target altitude may be provided by aircraft unable to support the general definition of target altitude. The target altitude capability describes the value occupying the target altitude field. The ADS-B system shall (R2.xx) support 3 levels of target altitude capability:

- Holding altitude or autopilot control panel selected altitude.
- Holding altitude, autopilot control panel selected altitude, or FMS/RNAV cruise altitude.
- Holding altitude, autopilot control panel selected altitude, or any FMS/RNAV level-off altitude.

3.4.7.4.3 Vertical Target Source Indicator

The Vertical Target Source Indicator in the Target State Report provides the source of target altitude information. The ADS-B system shall (R2.xx) support the folloing three options:

- FMS or RNAV system.
- Autopilot control panel, such as Mode Control Panel (MCP) or Flight Control Unit (FCU).
- Holding Altitude.

3.4.7.4.4 Vertical Mode Indicator

The Vertical Mode Indicator reflects the aircraft's position relative to the target altitude. The ADS-B system shall (R2.xx) support the following two options:

- Acquiring Target Altitude
- Capturing or Maintaining Target Altitude

3.4.7.4.5 Vertical Data Available

Vertical Data Available is a one-bit field in the Target State Report. This field shall (R3.xx) be ONE if Target Altitude data is available and valid; otherwise, it shall be ZERO.

3.4.7.4.6 Target Altitude

Target altitude is the aircraft's next intended level flight altitude if in a climb or descent or its current intended altitude if commanded to hold altitude. Target altitude shall (R3.xx) be represented as the operational altitude recognized by the transmitting aircraft's guidance system. In order to ensure a consistent reference for target altitude, all aircraft must follow standard conventions by using barometric corrected altitude (altimeter set to local setting) below the transition level and pressure altitude (altimeter set to 29.92 in Hg, or 1013.25 hPa) above the transition level. Target altitude shall (R3.xx) be provided with a range from -1000 ft to +100,000 feet and shall (R3.xx) have a resolution of 100 feet.

3.4.7.4.7 Target Altitude Type

The Target Altitude Type field is a one-bit field in the Target State Report that is reserved for future use to indicate whether the target altitude is represented as a pressure altitude or as a barometric corrected altitude.

Notes:

1. *It is expected that a future version of this MASPS target altitude type information to be conveyed in messages that support the TSR report.*

2. *It is expected that, when target altitude type information is required, this field will be ZERO to indicate pressure altitude or flight level (target altitude above the transition level), or ONE to indicate baro corrected altitude (target altitude below the transition level.*

3.4.7.4.8 Vertical Target Source Indicator

The Vertical Target Source Indicator field in the TSR indicates the source of target altitude information. The ADS-B system shall (R3.xx) support the following three options:

3.4.7.4.9 Vertical Mode Indicator

<< Need text>>

3.4.8 Trajectory Change Reports (TCR, TCR+1, etc.)

Table 3.4.8 shows the overall structure for Trajectory Change Reports (TCRs). The structure shown here is intended to accommodate up to four trajectory change points, and to provide for additional fields as more types and subtypes of TCR reports are developed for later versions of this MASPS.

Table 3.4.8: Trajectory Change Report (TCR) Definition.

	TCR Elem. #	Contents [Notes]	[Resolution or # of Bit	Needed Only For TCR+0 Reports	Reference Section	Notes
ID	1	Participant Address	[24 bits]		2.1.2.3.1	
	2	Address Qualifier	[4 bits]		2.1.2.3.2	
TOA	3	Time of Applicability	[1 s resolution]		2.1.2.1	
TCR #	4	TCR Sequence Number-	[2 bits]		3.4.8.3	1
TCR Version	5a	TCR Cycle Number	[2 bits]		3.4.8.4	
	5b	(Reserved for TCR+0 Transition Flag)	[1 bit]	•	3.4.8.5	
TTG	6	Time To Go	[1 s resolution]		3.4.8.6	
Horizontal TCP Information	7a	Horizontal Data Available	[1 bit]		3.4.8.7.1	
	7b	Horizontal TCP Type	[4 bits]		3.4.8.7.2	2
	7c	TCP Latitude	[0.1 NM]		3.4.8.7.3	3
	7d	TCP Longitude	[0.1 NM]		3.4.8.7.4	3
	7e	Turn Radius	[0.1 NM]		3.4.8.7.5	3
	7f	Track to TCP	[1 degree]		3.4.8.7.6	
	7g	Track from TCP	[1 degree]		3.4.8.7.7	
	7h	(Reserved for Horizontal Conformance)	[1 bit]	•	3.4.8.7.8	
	7i	Command/Planned (Horizontal)	[1 bit]		3.4.8.7.9	
Vertical TCP Information	8a	Data Available (Vertical)	[1 bit]		3.4.8.8.1	
	8b	Vertical TCP Type	[4 bits]		3.4.8.8.2	
	8c	TCP Altitude	[100 ft resolution]		3.4.8.8.3	
	8d	TCP Altitude Type	[1 bit]		3.4.8.8.4	
	8e	Reserved for Altitude Constraint Type	[2 bits]		3.4.8.8.5	
	8f	(Res. for Able/Unable Altitude Constraint)	[1 bit]	•	3.4.8.8.6	
	8g	(Res. For Vertical Conformance)	[1 bit]	•	3.4.8.8.7	
	8h	Command/Planned (Vertical)	[1 bit]		3.4.8.8.8	

Notes for Table 3.4.8:

1. *(note)*

2. *(note)*

3. *Finer resolution than 0.1 NM may be required for future precision approach/departure applications. It is expected that new TCP types will be defined for applications with finer resolution requirements.*

3.4.8.1 Conditions for Transmitting TCR Information

<<Text TBD >>

3.4.8.2 Update Interval for TCR Information

<<Text TBD>>

3.4.8.3 TCR Number ("N" in "TCR+N")

The TCR number is a sequence number for the set of Trajectory Change Reports that describe a target's current intent; it is "N" in the expresseion "TCR+N". The current TCR ("TCR+0") is a trajectory change report that describes the next point (Trajectory Change Point, TCP) at which the aircraft's trajectory will change. "TCR+1" is a Trajectory Change Report that describes the next trajectory change after the one described in the TCR+0 report. And so on.

The TCR Number field in the TCR data structure shall (R3.xx) contain a value in the range from 0 to 3, as defined in Table 3.4.8.3.

Table 3.4.8.3: TCR Number Definition.

TCR Number	Meaning
0	The TCR report describes the current trajectory change (TCP) towards which the aircraft is being directed.
1	The TCR+1 report describes the next TCP after the current TCP.
2	The TCR+2 report describes the next TCP after the TCP described in the TCR+1 report.
3	The TCR+3 report describes the next TCP after the TCP described in the TCR+2 report.

3.4.8.4 TCR Cycle Number

The TCR Cycle Number indicates a current "version number" for the numbering of the TCR reports.

Each TCR report (subparagraph 3.4.8 above) includes both a TCR number (the "N" in "TCR+N") and a TCR cycle number for the current numbering of the TCR reports. When a TCR report is inserted into or deleted from the list of current TCRs, or the trajectory change point described in the current TCR+0 report is reached, the TCR cycle number is incremented.

The TCR Cycle Number shall (R2.xx) be a number in the range from 0 to 3 that is incremented (modulo 4) each time the numbering of TCR reports changes. That is, the TCR cycle number is incremented from 0 to 1, then from 1 to 2, then from 2 to 3, and then from 3 back to 0.

3.4.8.5 TCR+0 Transition Flag

The TCR+0 transition flag is used to indicate when a transmitting ADS-B participant has just reached the current TCP (described in the TCR+0 report) so that the numbering of TCR reports (the TCR numbers, the "N" in "TCR+N") has changed.

Normally, this flag should be ZERO. When the transmitting ADS-B participant reaches the trajectory change point described in the current TCR+0 report, it shall (R2.xx) set the transition flag to ONE for a period of TBD seconds in the messages it transmits to support the MS report. After the TBD second interval has expired, the transmitting participant shall reset the transition flag to ZERO.

[AI 9-12] Tony Warren will provide updates for this text.

3.4.8.6 Time To Go (TTG) Field in TCR Reports

~~3.4.8.6~~

3.4.8.7 Horizontal TCP Information

3.4.8.7.1 Horizontal Data Available

3.4.8.7.2 Horizontal TCP Type

3.6 ADS-B Functional Level Requirements

3.6.1 Required Message Generation Function

3.6.2 Required Message Exchange Function

3.6.3 Required Message Exchange Function