RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #15

Proposed Revisions to DO-260 Appendix H: Report Assembly Guidance

Presented by: Ron Jones

SUMMARY
This Working Paper proposes changes to the original DO-260 Appendix H with changes required to State Vector, Mode Status and On-Condition Reports as they have been modified Revision 1 of the ADS-B MASPS (DO-242A).

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Appendix H

Report Assembly Guidance

<<DRAFT VERSION 2 with Ron Jones Proposed Updates>>

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H Report Assembly Guidance

H.1 Scope and Purpose

This Appendix is provided as a guide to the implementation of the report assembly function in an ADS-B receiving subsystem. The actual *requirements* on the report assembly function are to be found in Section 2 of this MOPS, particularly subsections §2.2.8 and §2.2.10. This appendix is provided as a narrative guide to those requirements and to how they might be met.

H.2 Data Flow Into and Out Of the Report Assembly Function

See Figure H-1, which is a copy of Figure 2-15 from Section 2 of this document. The report assembly function takes ADS-B messages after they have been received and corrected for possible bit errors by the Message Input Processing. From these messages it composes ADS-B reports and delivers those reports to the report output storage buffer, from which they can be retrieved by the user application. The actual interface between the report output storage buffer and the ADS-B user application is beyond the scope of this MOPS.

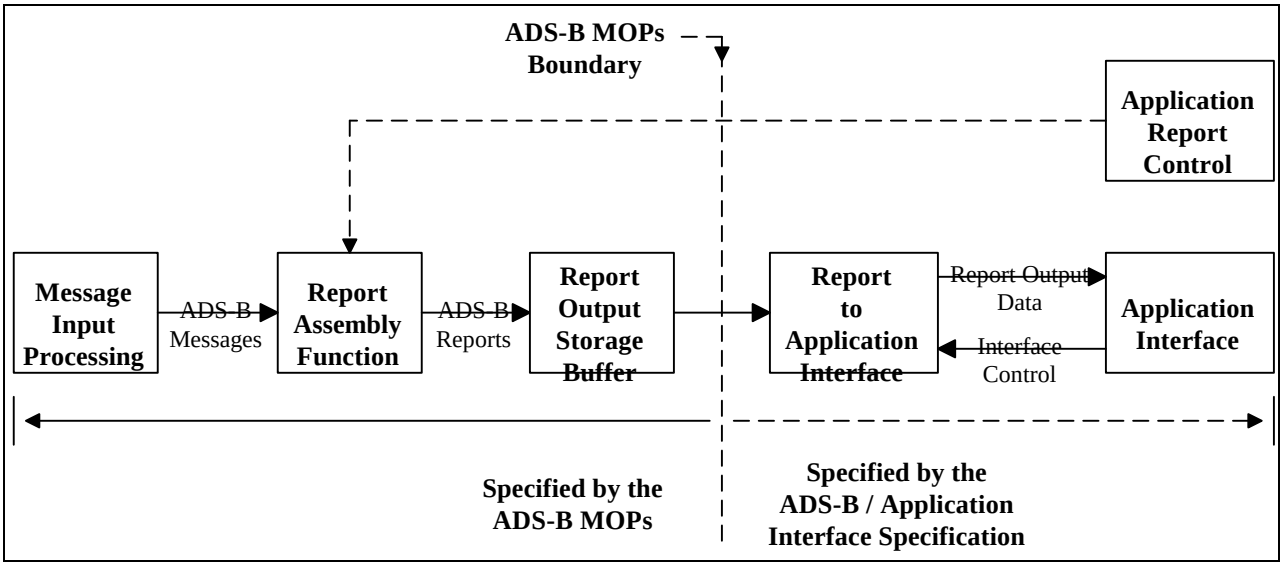

Figure H-1: ADS-B Message and Report General Data Flow.

H.2.1 Optional Report Control Interface

The dashed-line arrow in Figure H-1 represents an optional Report Control Interface by which an application may configure the output of the Report Assembly Function for its particular needs. The requirements on this optional interface have not been specified in this document. This interface, if present, might be used in the following ways.

a. The Report Control Interface could let the application specify for which ADS-B participants it desires to receive reports, and for which participants it does not require reports. For instance, an application might specify, via the Report Control

Interface, that it does not require reports for aircraft that are more than 50 nautical miles away from the own-ship. Again, the application might use the Report Control Interface to specify that it does not require reports concerning targets that are above (or below) a specified altitude.

~~c.~~b. The Report Control Interface could let the application specify, for specific targets, which report data elements are required and which may be omitted. For example, a Paired Approach application (as in RTCA DO-242A, §D.1.14) would require more information about the target with which the own-ship is paired for the approach than the a concurrently running Aid To Visual Acquisition application would require for other nearby ADS-B participants.

H.2.2 Type 1 and Type 2 Report Assembly Functions

The concept of Type 1 and Type 2 Report Assembly Functions, as described in §2.2.6, subparagraphs "b" and "c," is similar to, but not quite the same as, that of the optional report control interface.

- A Type 2 Report Assembly Function has the full functionality. That is, it is capable of meeting all Report Assembly Function requirements. If a Report Control Interface is provided, then the user application may use that interface to throttle back the Report Assembly Function, causing it to provide fewer report elements for some or all of the targets.

- A Type 1 Report Assembly Function has reduced functionality customized for a particular set of user applications. Although ~~T~~the outputs of a Type 1 Report Assembly Function are ~~like~~ similar to those of a Type 2 function with a Report Control Interface, in the case of the Type 1 function ~~that has~~it has already been ~~optimized~~ statically pre-configured ~~(by means of a Report Control Interface)~~ to meet the specific needs of a particular user application or set of applications.

H.2.3 TIS-B Report Assembly Function

The requirements for the generation of TIS-B reports are provided in §2.2.17.4.6. These MOPS do not specify the reporting format for TIS-B reports. However, the information content is specified by §2.2.17.4.6. The generation of TIS-B reports is substantially less complex than ADS-B report generation since in the former case the report elements, except for position and time of applicability, are directly mapped from the TIS-B message contents. The remainder of this Appendix deals only with the ADS-B report generation function.

H.3 Messages and Reports

H.3.1 ADS-B Messages (Input Data for Report Assembly)

Table H-1 lists the types of ADS-B messages that may be received ~~and the more important subfields in those messages that are~~ and used when assembling ADS-B reports.

Table H-1: 1090 MHz ADS-B Message Types

Message Type	Reference Section
ADS-B Airborne Position	2.2.3.2.3
ADS-B Surface Position	2.2.3.2.4
ADS-B Aircraft Identification and Type	2.2.3.2.5
ADS-B Airborne Velocity Message	2.2.3.2.6
Target State and Status	2.2.3.2.7.1
Aircraft Operational Status	2.2.3.2.7.2
Aircraft Status	2.2.3.2.7.8

Message Type	Message Subfield	Reference Sections
Airborne Position (§2.2.3.2.3)	AA, Address Announced	§2.2.3.2.1.1.1
	Message Type Code	§2.2.3.2.3.1
	Altitude	§2.2.3.2.3.4
	Encoded Latitude	§2.2.3.2.3.7
	Encoded Longitude	§2.2.3.2.3.7
	Time of Reception (See note 1.)	
Surface Position (§2.2.3.2.4)	AA, Address Announced	§2.2.3.2.1.1.1
	Message Type Code	§2.2.3.2.4.1
	Movement	§2.2.3.2.4.2
	Ground Track Angle	§2.2.3.2.4.4
	Encoded Latitude	§2.2.3.2.4.7
	Encoded Longitude	§2.2.3.2.4.8
	Time of Reception (See note 1.)	
Aircraft ID and Type (§2.2.3.2.5)	AA, Address Announced	§2.2.3.2.1.1.1
	Message Type Code	§2.2.3.2.5.1
	ADS-B Emitter Category	§2.2.3.2.5.2
	Character	§2.2.3.2.5.3
Airborne Velocity (§2.2.3.2.6)	AA, Address Announced	§2.2.3.2.1.1.1
	NUC-R Subfield	§2.2.3.2.6.1.5
	E/W Direction and E/W Velocity	§2.2.3.2.6.1.6 and §2.2.3.2.6.1.7
	N/S Direction and N/S Velocity	§2.2.3.2.6.1.8 and §2.2.3.2.6.1.9
	Vertical Rate Subfields	§2.2.3.2.6.1.10 to §2.2.3.2.6.1.12
	Turn Indicator Subfield	§2.2.3.2.6.1.13
	Difference From Barometric Altitude	§2.2.3.2.6.1.14 and §2.2.3.2.6.1.15
	Time of Reception (See note 1.)	
Aircraft Trajectory Intent (§2.2.3.2.7.1 and §A.1.4.9)	AA, Address Announced	§2.2.3.2.1.1.1
	Current or Next (TCP or TCP+1)	§2.2.3.2.7.1.2
	Trajectory Point/Leg Type	§2.2.3.2.7.1.2
	TCP/TCP+1 Data Valid	§2.2.3.2.7.1.3 & §A.1.4.9.4
	TCP/TCP+1 Format	§A.1.4.9.5
	TCP/TCP+1 Altitude	§A.1.4.9.6
	TCP/TCP+1 Latitude	§A.1.4.9.7
	TCP/TCP+1 Longitude	§A.1.4.9.8
	TCP/TCP+1 Time To Go (TTG)	§A.1.4.9.9
	Time of Reception (See note 1.)	
Aircraft Operational Status	Capability Classes(CC)	§2.2.3.2.7.3.3
	Operational Modes (OM)	§2.2.3.2.7.3.4

~~***Note:*** *A message's time of applicability is not actually conveyed as a subfield within the message, but is taken as the time of reception of that message.*~~

H.3.2 ADS-B Reports (Data Delivered By Report Assembly Function)

H.3.2.1 SV Reports

Table H-2 lists the fields in State Vector Reports and the sources of the data in those fields.

The SV report contains three different times of applicability: TOA-P, TOA-V, and TOA-R. The third column of the table indicates for each SV report element, which of these three times of applicability is the TOA for that report element. In a minimum system, in which the Report Assembly Function outputs SV reports only when a position or velocity message is received, TOA-R, the time of applicability of the SV report, would always be either TOA-P or TOA-V, the time of applicability of the position or velocity message which triggered the outputting of that report. In a more-than-minimum system that outputs SV reports at additional times, the TOA of the report, TOA-R, may differ from either TOA-P or TOA-V. For aircraft/vehicles on the airport surface, both position and velocity related information are conveyed within the surface position messages. Therefore the TOA for the state vector report elements associated with both position and velocity information are listed in Table H-2 as TOA-P.

Table H-2: SV Report Data

Item #	S/V Report Subfield	TOA	Obtained From
0a	Report Type	TOA R	Report Assembly Function
0b	Report Structure	TOA R	Report Assembly Function
0c	Validity Flags	TOA R	Report Assembly Function
1	Participant Address	TOA R	All message types AA subfield
2	Address Qualifier	TOA R	Aircraft Identification and Type Message and for all message types received from non-transponder devices (i.e.., DF=18) the CF subfield
3	Report Time of Applicability (Position and Velocity) (see note 4)		Provided by Report Assembly Function
4	Encoded Latitude (WGS-84)	TOA P	Airborne Position Message or Surface Position Message
5	Encoded Longitude (WGS-84)	TOA P	Airborne Position Message or Surface Position Message
6	Altitude, Geometric (see note 1) (WGS-84)	TOA R	Computed by Report Assembly Function
7	North / South Velocity	TOA V	Airborne Velocity Message
8	East / West Velocity	TOA V	Airborne Velocity Message
9	Ground Speed while on the Surface	TOA P	Surface Position Message
10	Heading while on the Surface	TOA P	Surface Position Message
11	Altitude, Barometric (Pressure Altitude)	TOA P	Airborne Position Message
12	Vertical Rate, Geometric/Barometric (WGS-84)	TOA V	Airborne Velocity Message
13	Navigation Integrity Category (NIC)	TOA P	Airborne Position Message or Surface Position Message
14	Estimated Latitude (WGS-84)	TOA R	Estimate Computed by Report Assembly Function
15	Estimated Longitude (WGS-84)	TOA R	Estimate Computed by Report Assembly Function
16	Estimated North/South Velocity	TOA R	Estimate Computed by Report Assembly Function
17	Estimated East/West Velocity	TOA R	Estimate Computed by Report Assembly Function
18	Surveillance Status/Discretes (see note 3)	TOA R	Airborne Position and Airborne Velocity Messages
19	Report Mode	TOA R	Report Assembly Function

~~Item #~~	~~SV Report Subfield~~	~~TOA~~	~~Obtained From~~
~~0a~~	~~Report Type~~	~~TOA R~~	~~Report Assembly Function~~
~~0b~~	~~Report Structure~~	~~TOA R~~	~~Report Assembly Function~~
~~0c~~	~~Report Subfield Validity Flags~~	~~TOA R~~	~~Report Assembly Function~~
~~1~~	~~Participant Address~~	~~TOA R~~	~~All Message Types – AA Field~~
~~2~~	~~Latitude~~	~~TOA P~~	~~Airborne Position Message *or* Surface Position Message~~
~~3~~	~~Longitude~~	~~TOA P~~	~~Airborne Position Message *or* Surface Position Message~~
~~4~~	~~Geometric Altitude (See note 1.)~~	~~TOA R~~	~~Computed by Report Assembly Function~~
~~5~~	~~NUC-P~~	~~TOA P~~	~~Airborne Position Message *or* Surface Position Message~~
~~6~~	~~NUC-R~~	~~TOA V~~	~~Airborne Velocity Message~~
~~8~~	~~North/South Velocity~~	~~TOA V~~	~~Airborne Velocity Message~~
~~9~~	~~East/West Velocity~~	~~TOA V~~	~~Airborne Velocity Message~~
~~10~~	~~Vertical Rate, Geometric~~	~~TOA V~~	~~Airborne Velocity Message~~
~~11~~	~~Barometric Pressure Altitude~~	~~TOA P~~	~~Airborne Position Message~~

Item #	SV Report Subfield	TOA	Obtained From
12	Barometric Altitude Rate	TOA-V	Airborne Velocity Message
13a	True Airspeed (See note 2.)	TOA-V	Airborne Velocity Message
13b	Indicated Airspeed (See note 2.)	TOA-V	Airborne Velocity Message
14	Ground Speed	TOA-P	Surface Position Message
15	Ground Track Angle	TOA-P	Surface Position Message
16	Magnetic Heading (See note 2.)	TOA-V	Airborne Velocity Message
17	Turn Indication	TOA-V	Airborne Velocity Message
18	TOA-P, Position Time of Applicability	-	Airborne Position Message *or* Surface Position Message
19	TOA-V, Velocity Time of Applicability	-	Airborne Velocity Message
20	Estimated Latitude	TOA-R	Estimated by Report Assembly Function
21	Estimated Longitude	TOA-R	Estimated by Report Assembly Function
22	Estimated N/S Velocity	TOA-R	Estimated by Report Assembly Function
23	Estimated E/W Velocity	TOA-R	Estimated by Report Assembly Function
24	TOA-R, Report Time of Applicability	-	Provided by Report Assembly Function
25	Surveillance Status Discretes	TOA-P	Airborne Position Message
26	Report Mode	TOA-R	Report Assembly Function

Notes:

1. *The Geometric Altitude must be computed by the Report Assembly Function, using the barometric pressure altitude from the Airborne Position Message and the difference between barometric and geometric altitudes from the Airborne Velocity Message. §H.4.3 below describes one acceptable computation method.*

2. *The Airspeed and Magnetic Heading values are only available from airborne participants that are not providing information about their velocities over the ground. Normally, an airborne participant would emit "subtype 1" or "subtype 2" airborne position messages, which do provide the N/S and E/W components of its velocity over the ground. But if velocity over the ground were not available, an airborne participant could emit "subtype 3" or "subtype 4" velocity messages, that contain airspeed and heading fields.*

3. *The Surviellance Status/Discretes includes elements mapped from both the Airborne Position and the Airborne Velocity messages. See §2.2.8.1.21 for details.*

4. *The "Report Time of Applicability" field, as defined in §2.2.8.1.4, contains three separate data sub-elements for reporting the Time of Applicability for: TOA-R for the estimated position and estimate velocity information; TOA-P the position information; and TOA—V for the velocity information.*

~~3~~5. *For details of the fields in SV reports, see §2.2.8.1 of this document and subsections of that section.*

H.3.2.2 MS Reports

Table H-3 lists the fields in Mode Status Reports and the sources of the data in those fields.

Table H-3: MS Report Data

Item #	MS Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
0c	Validity Flags	Report Assembly Function
1	Participant Address	All Message Types AA Field
2	Address Qualifier	Aircraft Identification and Type Message and for Operational Status messages received from non-transponder devices (i.e.., DF=18) the CF subfield
3	Time of Applicability	Report Assembly Function
4	ADS-B Version	Operational Status Message
5a	Call Sign	Aircraft Identification and Type Message
5b	Emitter Category	Aircraft Identification and Type Message
5c	A/V Length and Width Codes	Operational Status Message
6	Emergency/Priority Status	Aircraft Status Message – Subtype 1
7	Capability Codes	Operational Status Message –and- Target State and Status Message
8	Operational Mode	Operational Status Message –and- Target State and Status Message
9a	SV Quality - NACp	Operational Status Message –or- Target State and Status Message
9b	SV Quality - NACv	Airborne Velocity Message
9c	SV Quality – SIL	Operational Status Message –or- Target State and Status Message
9d	SV Quality – BAQ (reserved)	N/A
9e	SV Quality – NICbaro	Operational Status Message –or- Target State and Status Message
10a	Track/Heading and HRD	Operational Status Message
10b	Vertical Rate Type	Airborne Velocity Message
11	Other (Reserved)	N/A

~~Item #~~	~~Report Subfield~~	~~Obtained From~~
~~0a~~	~~Report Type~~	~~Report Assembly Function~~
~~0b~~	~~Report Structure~~	~~Report Assembly Function~~
~~0c~~	~~Report Subfield Validity Flags~~	~~Report Assembly Function~~
~~1~~	~~Participant Address~~	~~All Message Types – AA Field~~
~~2~~	~~Call Sign~~	~~Aircraft ID and Type Message~~
~~3~~	~~Participant Category~~	~~Aircraft ID and Type Message~~
~~4~~	~~Emergency/Priority Status~~	~~Aircraft Status Message~~
~~5~~	~~TCP Latitude~~	~~Aircraft Trajectory Intent (TCP) Message~~
~~6~~	~~TCP Longitude~~	~~Aircraft Trajectory Intent (TCP) Message~~
~~7~~	~~TCP Altitude~~	~~Aircraft Trajectory Intent (TCP) Message~~
~~8~~	~~TCP Time To Go~~	~~Aircraft Trajectory Intent (TCP) Message~~
~~9~~	~~Operational Mode Specific Data~~	~~Aircraft Operational Status Message~~
~~10~~	~~Flight Mode Specific Data~~	~~Aircraft Operational Status Message~~
~~11~~	~~Paired Address~~	~~Aircraft Operational Status Message~~
~~12~~	~~Current Trajectory Point/Leg Type~~	~~Aircraft Trajectory Intent (TCP) Message~~
~~13~~	~~Report Time of Applicability~~	~~Report Assembly Function~~

Notes:

1. *Certain message parameters are conveyed within both the Operational Status Message and also within the Target State and Status Message. In this case the Mode Status Report will use the most recently received message that contains the required data element (i.e., source will be either the*

Operational Status Message OR the Target State an Status Message. In the case of the Capability Codes and Operational Mode parameters, the Target State and Status Message conveys only a subset of the codes conveyed by the Operational Status Message. For this case the Mode Status Report will report the codes always using data from the Operational Status Message for those codes only reported in this message type. For the case where the same codes are conveyed in both message types, then the most recently received message will be used for Report Assembly. Thus when both message types are being received a combination of data extracted from the Operational Status Message AND the Target State and Status Message may be required to fully report the most current Capability Codes and Operational Status.

2. *For details of the fields in MS reports, see §2.2.8.2 of this document and subsections of that section.*

H.3.2.3 ~~TCP+1~~Target State Reports

Table H-4 lists the fields in ~~TCP+1~~Target State Reports and the sources of the data in those fields.

Table H-4: ~~TCP+1~~Target State Report Data

Item #	TS Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
1	Participant Address	Report Assembly Function
2	Address Qualifier	All Message Types AA Field
3	Report Time of Applicability	Aircraft Identification and Type Message and for Target State and Status messages received from non-transponder devices (i.e.., DF=18) the CF subfield
4a	Horizontal Intent: Horizontal Data Available & Horizontal Target Source Indicator	Target State and Status Message
4b	Horizontal Intent: Target Heading or Track Angle	Target State and Status Message
4c	Horizontal Intent: Target Heading/Track Indicator	Target State and Status Message
4d	Horizontal Intent: Reserved for Heading/Track Capability	N/A
4e	Horizontal Intent: Horizontal Mode Indicator	Target State and Status Message
4f	Horizontal Intent: Reserved for Horizontal Conformance	N/A
5a	Vertical Intent: Vertical Data Available & Vertical Target Source Indicator	Target State and Status Message
5b	Vertical Intent: Target Altitude	Target State and Status Message
5c	Vertical Intent: Target Altitude Type	Target State and Status Message
5d	Vertical Intent: Target Altitude Capability	Target State and Status Message
5e	Vertical Intent: Vertical Mode Indicator	Target State and Status Message
5f	Vertical Intent: Reserved for Vertical Conformance	N/A

~~Item #~~	~~Report Subfield~~	~~Obtained From~~
~~0a~~	~~Report Type~~	~~Report Assembly Function~~
~~0b~~	~~Report Structure~~	~~Report Assembly Function~~
~~0c~~	~~Report Subfield Validity Flags~~	~~Report Assembly Function~~
~~1~~	~~Participant Address~~	~~All Message Types AA Field~~
~~2~~	~~TCP+1 Latitude~~	~~Aircraft Trajectory Intent (TCP+1) Message~~
~~3~~	~~TCP+1 Longitude~~	~~Aircraft Trajectory Intent (TCP+1) Message~~
~~4~~	~~TCP+1 Altitude~~	~~Aircraft Trajectory Intent (TCP+1) Message~~
~~5~~	~~TCP+1 Time To Go~~	~~Aircraft Trajectory Intent (TCP+1) Message~~
~~6~~	~~Next Trajectory Point/Leg Type~~	~~Aircraft Trajectory Intent (TCP+1) Message~~
~~7~~	~~Report Time of Applicability~~	~~Report Assembly Function~~

Note: *For details of the fields in ~~TCP+1~~Target State ~~r~~Reports, see §2.2.8.3.1 of this document and subsections of that section.*

H.3.2.4 Air Reference Velocity (ARV) Reports

Table H-5 lists the fields in Air Referenced Velocity Reports and the sources of the data in those fields.

Table H-5: Air Referenced Velocity Report Data

Item #	TS Report Subfield	Obtained From
0a	Report Type	Report Assembly Function
0b	Report Structure	Report Assembly Function
0c	Validity Flags	
1	Participant Address	Report Assembly Function
2	Address Qualifier	Airborne Velocity Message Subtype 3 or 4 AA Field
3	Report Time of Applicability	Airborne Velocity Message Subtype 3 or 4
4a	Airspeed	Airborne Velocity Message Subtype 3 or 4
4b	Airspeed Type	Airborne Velocity Message Subtype 3
5	Heading While Airborne	Airborne Velocity Message Subtype 3

Note: *For details of the fields in Air Referenced Velocity Reports, see §2.2.8.3.2 of this document and subsections of that section.*

H.4 Estimating Report Field Values

Notice from Table H-2 in §H.3.2.1 above that not all of the information required in the fields of a State Vector (SV) Report is received in the same type of message. Indeed, some SV report elements, such the Geometric Altitude, can only be computed by combining information from more than one type of 1090 MHz ADS-B message.

Notice also that "estimated latitude," "estimated longitude," "estimated N/S velocity," and "estimated E/W velocity" fields, SV report items #~~20~~ 14 to #~~23~~17, all have TOA-R as their times of applicability. These fields together present an estimate of the horizontal position and horizontal velocity that is time-registered to the same time of applicability.

The report assembly function must estimate the values of the horizontal position (latitude and longitude) SV report elements at TOA-R, the time of applicability of the report, based on the data received in position and velocity messages that are received at different times. At the option of the implementor, the SV report may also contain estimated horizontal velocity fields that are applicable at TOA-R. This estimation may be implemented in a variety of ways, such as by alpha-beta filters, alpha-beta-gamma filters, Kalman filters, or linear extrapolation. The following subparagraphs discuss the estimation of some of the SV field elements in a little more detail.

H.4.1 Estimating Horizontal Position (Latitude and Longitude)

SV Report elements #~~20~~ 14 and #~~21~~15, "Estimated Latitude" and "Estimated Longitude", contain the position of the ADS-B participant at the time of applicability of the SV report (TOA-R, a sub-element of SV item #~~24~~3). For an airborne participant, the

report assembly function must estimate the horizontal position of that participant at the time of applicability of the report (TOA-R) based on the values it has received in airborne position and airborne velocity messages from that participant.

As Figure H-2 illustrates, at most latitudes – everywhere except in very close proximity to the N or S pole – the change in latitude, Df, and the change in longitude, $\Delta\lambda$, due to the own-ship moving for a short time *Dt* with East-West velocity component *dx/dt* and North-South velocity component *dy/dt* may be approximated by the formulas

$$\Delta x = \frac{dx}{dt}\Delta t = R \cdot \Delta l \cdot \cos f$$

$$\Delta y = \frac{dy}{dt}\Delta t = R \cdot \Delta f$$

where R is the radius of the sphere used to represent the earth and latitude, f, and longitude, l, are expressed in radians.

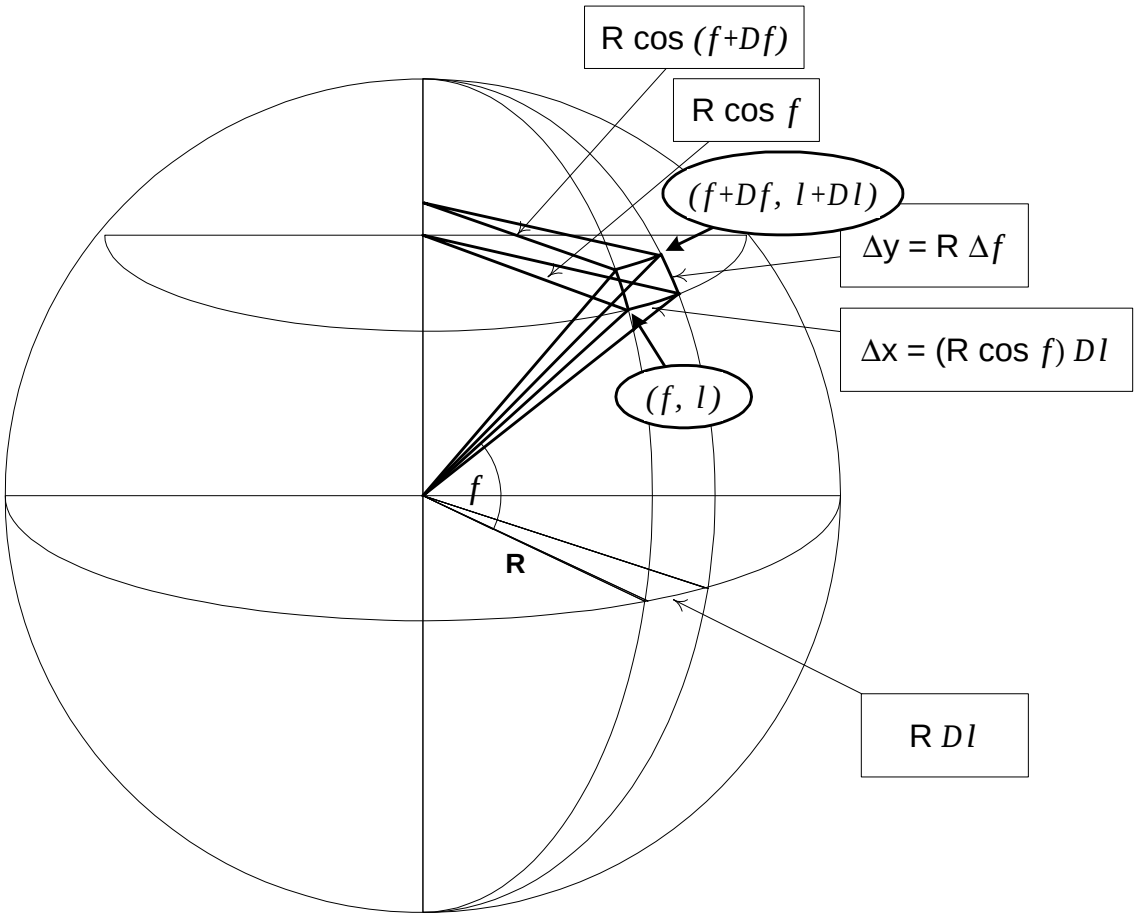

Figure H-2: Expressing a Small Change in Latitude and Longitude (f, l) As a Change in Local Cartesian Coordinates (x,y).

If the radius R of the sphere used to represent the earth is chosen so that one minute of arc on a meridian – one minute of latitude – is one nautical mile, and the velocities V_{NS}

and V_{EW} are expressed in knots (nautical miles per hour), and the changes in latitude and in longitude are expressed in degrees, then the formulas become

$$\Delta Latitude_{\deg rees} = \frac{V_{NS} \cdot \Delta t_{\sec onds}}{3600}$$

$$\Delta Longitude_{\deg rees} = \frac{V_{EW} \cdot \Delta t_{\sec onds}}{3600 \cdot \cos(Latitude)}$$

This approximation is adequate for extrapolating the position of an ADS-B participant forward in time over an interval *Dt* of a few seconds.

For the case when the target position is very close to the North or South pole, however, where the cosine of the latitude approaches zero, the above approximation is inadequate. Figure H-3 shows the situation for an ADS-B participant that is in close proximity to the pole. As the figure shows, for such a situation the latitude-longitude graticule is no longer adequately represented by a rectangular grid. If ADS-B receiving equipment is to be used in aircraft that travels over the poles, the position-extrapolation algorithm used in that equipment should be designed to handle the situation shown in Figure H-3. Implementers should take particular care when the (North or South) own-ship latitude exceeds 89 degrees.

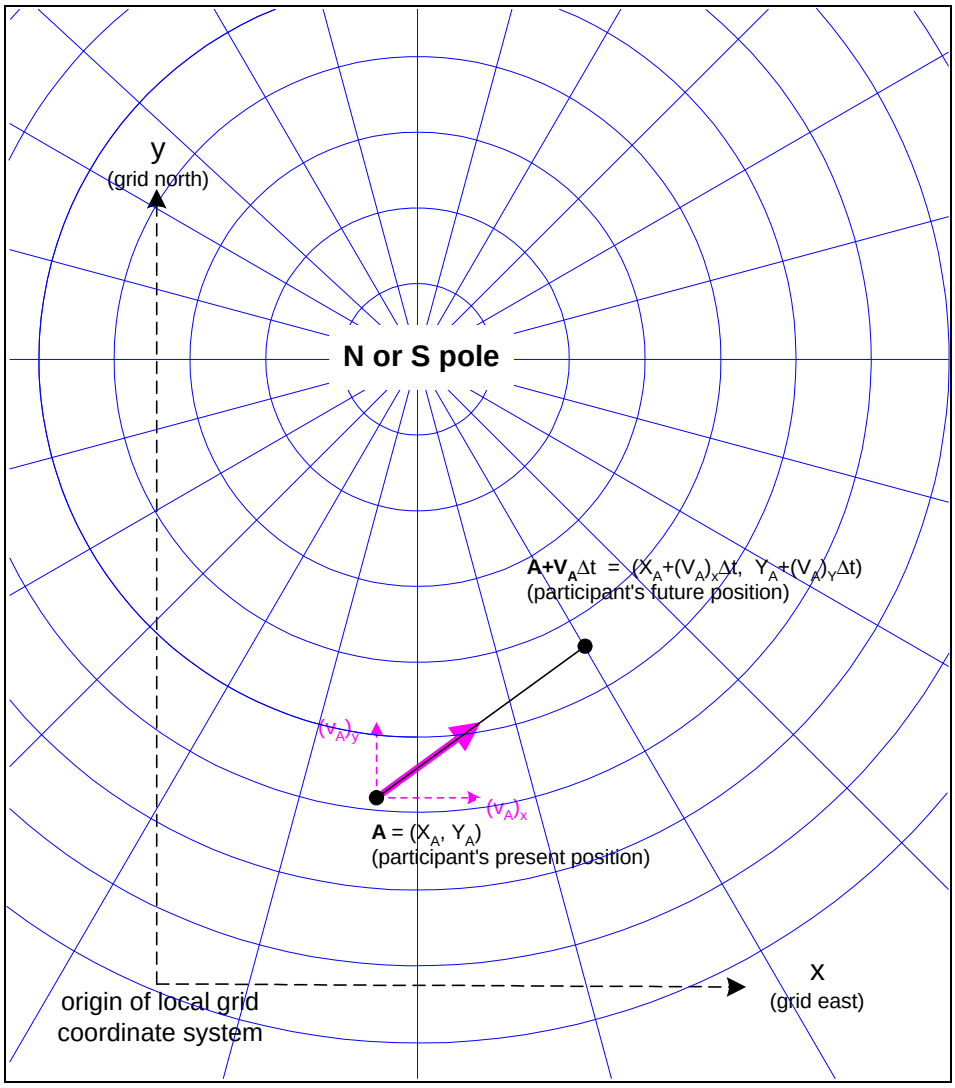

Figure H-3: Non-Rectangular Latitude/Longitude Graticule Near the Poles.

H.4.2 Estimating Horizontal Velocity

State Vector report elements #~~8~~ 7 and #~~9~~8, "North/South Velocity" and "East/West Velocity," contain the horizontal velocity of an airborne ADS-B participant as received in the most recent airborne velocity message from that participant. The time of applicability of these report elements is the time of applicability of that most recent airborne velocity message (TOA-V, a sub-element of SV item #~~19~~3), so no estimation or extrapolation is required.

Likewise, SV report elements #~~14~~ 9 and #~~15~~10, "Ground Speed" and "~~Ground Track Angle~~Heading While on the Surface" contain the horizontal velocity of a surface ADS-B participant as received in the "movement" and "~~ground track~~Heading" fields of the most recent surface position message from that participant. The time of applicability of these report elements is the time of applicability of that surface position message (TOA-P, a sub-element of SV item #~~18~~3), so no estimation or extrapolation is required; the E/W and N/S south components of the "estimated velocity" are merely computed by converting

the velocity from polar form (ground speed and ~~track angle~~heading) to rectangular form (E~~.~~/W and N/S velocity).

However, SV report elements #~~22~~ 16 and #~~23~~17, "Estimated North/South Velocity" and "Estimated East/West Velocity" contain the participant's horizontal velocity at time TOA-R, the time of applicability of the SV report, which may not be the same as the time of applicability of the most recent velocity message. These report elements are optional at the discretion of the implementor (see §2.2.8.1.~~24~~ 19 and §2.2.8.1.~~25~~20). If these report elements are provided, the estimation may be done in a variety of ways, including linear extrapolation, alpha-beta or alpha-beta-gamma filters, and Kalman filters. Appendix K discusses the results of simulation studies for some of these methods.

H.4.3 Computing Geometric Altitude (Height Above WGS-84 Ellipsoid)

If an airborne position message from a particular ADS-B participant has Type Code 20, 21, or 22, then the "altitude" field in that message contains the geometric altitude (height above WGS-84 ellipsoid) for that participant at the time of applicability of that message. But SV report element #~~4~~6, "geometric altitude" is the altitude at TOA-R, the time of applicability of the SV report, not the time of applicability of the airborne position message. The ADS-B Report Assembly Function must compute the geometric altitude, h, at the time of applicability of the report, t_R = *TOA-R*. This could be done by linear extrapolation, by an alpha-beta filter, alpha-beta-gamma-filter, or Kalman filter.

Most airborne position messages, however, will have type codes in the range from 9 to 18, indicating that their "altitude" fields contain barometric pressure altitude, H_P, rather than the geometric altitude, h. It is still possible for the report assembly function to estimate a value for SV element #~~4~~6, geometric altitude, at the time of applicability of the SV report, t_R = *TOA-R*. One way to do this would be by linear extrapolation, using

- $H_P(t_P)$, the pressure altitude from the most recently received airborne position message,
- $Diff(t_V)$, the difference of geometric altitude from pressure altitude, from the most recently received airborne velocity message, and
- dH_P/dt or dh/dt, the vertical rate from the most recently received airborne velocity message.

Let:

$H_P(t_P)$ = barometric pressure altitude from the most recent airborne position message, for which the time of applicability is t_P = *TOA-P*,

$Diff(t) = h(t) - H_P(t)$ = difference between geometric altitude, h, and barometric pressure altitude, H_P, as a function of time, t, and

$h(t_R)$ = geometric altitude, h, at the time of validity, t_R = *TOA-R*, of the SV report

Then $h(t_R)$, the geometric altitude at the time of applicability of the SV report, could be estimated as follows:

$$h(t_R) = H_P(t_R) + Diff(t_R)$$
$$= H_P(t_P) + (t_R - t_P) \cdot \frac{dH_p}{dt} + Diff(t_V) + (t_R - t_V) \cdot \frac{d}{dt}(h - H_P)$$

If the rate of change of the difference, $Diff = h - H_P$, is small, it might be ignored, so that the final term in the above formula, "$(t_R\text{-}t_V)\cdot d(h\text{-}H_P)/dt$" is omitted. It would probably be appropriate, however, to track $Diff = (h\text{-}H_P)$ as received in successive airborne velocity messages. The tracking filter, which might be an alpha-beta filter, an alpha-beta-gamma filter, or a Kalman filter, could then provide an estimate of the rate of change, $d(h\text{-}H_P)/dt$.

H.5 Tracking ADS-B Participants

The ADS-B Report Assembly Function must assemble reports giving the status of multiple ADS-B participants. With respect to each such participant, the report assembly function transitions between several states, as specified in §2.2.10.

When the first message from a participant is received, the report assembly function enters "Initialization State" with respect to that participant. It assigns a block of memory to hold messages from that participant.

When both "even" and "odd" airborne position or surface position messages have been received from the participant, so that an unambiguous decoding of the participant's CPR-encoded position into latitude and longitude can be performed, the report assembly function enters "Acquisition State" with respect to that participant and begins to output SV (state vector) reports for that participant into the Report Output Storage Buffer. The "Report Mode" field in those reports (SV item #~~26~~19) is set to indicate "Acquisition Mode."

When both an unambiguously decoded position and a velocity have been received for the participant, the report assembly function enters "Track State" for that participant, and begins to output SV reports in which the "Report Mode" field is set to "Track."

H.6 Track Acquisition and Coast Considerations

State vector update intervals of 3 (three) seconds are required (1 second desired) by the ADS-B MASPS for short range surveillance applications. Long range airspace deconfliction applications, on the other hand, can be supported by state vector update intervals ~~as long as~~of 12 seconds or longer dependent on range. Track files must be initiated and maintained on all ADS-B participants of interest to the supported applications, while the different applications are likely to have different target acquisition and track maintenance needs.

Recognizing this, this document requires the ADS-B Report Assembly Function to retain information on an ADS-B system participant for ~~up to 250~~at least 200 seconds when the Report Assembly Function is in "Acquisition" or "Track" state with respect to that participant. The information provided in the State Vector reports (i.e., separate times of applicability for velocity, position, and estimated (i.e. time-registered) position and velocity information), combined with the fact that ADS-B reports are not required to be generated for an ADS-B participant unless a new ADS-B message has been received from that participant, gives the following characteristics to a minimum system:

- Information may be associated with and retained for an ADS-B participant longer than required for the particular applications serviced by the ADS-B receiving subsystem.
- The ADS-B application has the information required for it to make all necessary determinations on coasting, dropping, etc., of an ADS-B system participant.
- Acquisition/reacquisition time for ADS-B system participants is reduced.

ADS-B implementations which output ADS-B reports for a system participant without receiving a new ADS-B message from that participant contain a separate time of applicability for the extrapolated state vector information. By comparing the various times of applicability in the SV report, the application will be able to determine the risk of error in the extrapolated ADS-B report.