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RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #9

Proposed Approach for 1090 MHz Extended Squitter to Accommodate New Requirements for Intent Information

Prepared by Ron Jones, FAA, ASD-140

Summary

The proposed changes to the ADS-B MASPS for the broadcast of intent information will need to be finalized for the ballot version of DO-242A in March 2002. Two key areas for which the requirements need further investigation is the rate at which the receiving application requires updates of TSRs, TCR and TCR+1 reports. The other is what is the minimum set of parameters required for each report type. This paper includes proposals for how 1090 MHz Extended Squitter avionics could support the revised requirements for intent reporting. Also attached is a copy of a draft working paper for Working Group 6 that makes proposals for the update rate requirements for reports of intent information and recommends an approach for specifying the minimum set of data parameters.

Reference: RTCA Paper #377-01/SC-186-184, Proposed ADS-B MASPS Revisions: Intent Information Broadcast, Version 3.0, December 2001

Attachment: Draft working paper for SC-186/WG6

1. Background

The referenced paper that was produced by WG6 and presented to SC-186 plenary in December 2001, included in section 10, under "Minimum Intent Report Requirements" a section on "Transmission Update Requirements." While for a given ADS-B link, the associated MOPS will need to define the transmission rates for each of the various ADS-B reports, the ADS-B MASPS must remain independent of the ADS-B link technologies. Therefore, the MASPS requirement must be expressed in terms of the effective update rate requirement as viewed by the receiving system. Since the application that is using the intent information to support an operational capability is on the aircraft that is receiving the ADS-B reports, this is consistent with the MASPS stating the requirements in terms of the effective received update rate. This is the approach that was taken with the update rate requirements in the current DO-242.

The attachment to this working paper is a draft of a paper that is being prepared for submission to WG6 at it next meeting. It proposes specific update rate requirements for the three types of intent reports being defined with DO-242A (TSR, TCR and TCR+1). Note that these proposed changes to the MASPS have not yet been presented to WG6 and are thus subject to change.

The following material proposes changes for DO-260A that are aligned with the proposal being offered to WG6 for the MASPS requirements associated with intent report update rates.

2. Discussion

If the proposed intent reporting as per the attached paper is accepted by WG6 and incorporated into DO-242A then DO-260A will include compatible provisions for the broadcast of intent information. The following material is presented assuming the proposed intent reporting rates are accepted for the ADS-B MASPS. The proposed MASPS requirements are summarized in Table 1 below.

TABLE 1

Air-to-Air Target Range (nmi.)	TSR Update Rate @ 95 percentile	TCR Update Rate @ 95 Percentile			TCR+1 Update Rate @ 95 Percentile		
		TTG $\leq$ 150 seconds	150<TTG$\leq$900 seconds	TTG>900 seconds	TTG $\leq$ 300 seconds	300 < TTG $\leq$ 900 seconds	TTG > 900 seconds
$\leq$ 20	12 seconds	12 sec.	24 sec.	NA	24 sec.	60 sec.	NA
>20 & $\leq$ 40	24 seconds	24 sec.	48 sec.	NA	48 sec	90 sec.	NA
>40 & $\leq$ 90	48 seconds	48 sec.	96 sec.	NA	96 sec.	120 sec.	NA
>90	not specified	not specified.	not specified	NA	not specified	not specified	NA

Note that TTG is "time-to-go" to the start of the maneuver.

The current DO-260 broadcast rate requirements for intent information are:

TABLE 2

DO-260 TCP requirements	TCP rate	TCP+1 rate	**Total Rate (squitters/sec)**
broadcast interval	1.700	1.700	
broadcast squitters/sec.	0.588	0.588	**1.176**

The proposal in the referenced RTCA working paper #377-01/SC-186-184 proposed three types of intent reports (TSR, TCR and TCR+1). It appears that a TSR could be broadcast within a single squitter, but TCR and TCR+1 each include more data elements than could be accommodated in a single squitter. If the truly essential information for a TCR could be included in a single squitter then a second squitter (extension to TCR or TCR+1) would be used to broadcast the remaining, perhaps optional, information.

One constraint of accommodating TSR, TCR and TCR+1 within 1090 MHz. Extended Squitter MOPS should be to keep the total squitter rate to approximately the same as currently defined for TCP and TCP+1. As shown above, this amounts to approximately 1.2 squitters per second for the broadcast of intent information. Keeping with this limitation on the total broadcast rate the following table proposes a reception rates at 95% probability for each TSR, TCR and TCR+1. As suggested in the reference working paper #377-01/SC-186-184 the transmission rate can be reduced when the "time-to-go" to the start of the maneuver exceeds 2.5 minutes. Also the transmission rate for TCR+1 need not generally be as high as for TCR. Table 3 below proposes the maximum transmission rates (i.e., for the minimum Time-to-Go cases) for each type of squitter carrying intent information.

TABLE 3

Proposed DO-260A req.	TSR	TCR basic	TCR exten.*	TCR+1 basic	TCR+1 ext.*	**Total Rate**
broadcast interval (sec.)	2.500	2.500	7.500	5.000	15.000	
broadcast squitters/sec.	0.400	0.400	0.133	0.200	0.067	**1.200**

* *This assumes that TCR and TCR+1 extension messages would include optional or less dynamic information than that included in the basic TCR and TCR+1 messages thus allowing for a reduced broadcast rate. Also if it proves possible to combine all of the TCR extension and TCR+1 extension data into a single squitter then this squitter could be broadcast at a 5 second interval while keeping the total rate at 1.2 squitters per second.*

The consequence of applying the above squitter transmission rates and of also satisfying the proposed MASPS requirements for received intent update rates would be a need to achieve the individual squitter reception probabilities shown in Table 4 below.

TABLE 4

a-a range	------- Required per Squitter Reception Probability ---------		
	TSR	TCR basic	TCR+1 basic
20 nmi.	0.464	0.464	0.464
40 nmi.	0.268	0.268	0.268
90 nmi.	0.144	0.144	0.144

The probabilities shown in Table 4 above are for 95% probability of reception of each type of squitter individually based on the formula: $P_{squitter} = 1 - (0.05)^{1/N}$. Where $P_{squitter}$ is the probability of individual squitter reception and N is the number of squitter transmissions within the required update interval. However, if we apply the 95% probability of reception requirement to the reception of either the combination of TSR and TCR basic -or- TSR, TCR basic and TCR+1 basic then the required reception performance increases to the values indicated in Table 5 below.

TABLE 5

Required per Squitter Reception Probability for Combined Overall 95% Reception Probability		
a-a Range	TSR and TCR	TSR, TCR and TCR+1
20 nmi.	0.535	0.572
40 nmi.	0.318	0.346
90 nmi.	0.174	0.191

The required reception probabilities under this above scenario would be somewhat higher at ranges up to 40 nmi. as compared to the reception probability necessary to satisfy the original TCP reception requirements of DO-242. However, the required reception probability would be less for ranges beyond 40 nmi.

Additional sophistication could be incorporated to temporarily increase the broadcast rate for TSR or TCR information for a short time after any significant change in the information. One approach could be to use the squitters normally used for TCR+1 to serve as additional TSR or TCR broadcasts. If this were done for just the first 12 seconds following a change in the information of a TSR or TCR, thus replacing two or three TCR+1 squitters with the changed TSR or TCR report, the effective transmission rate for the changed TSR or TCR report would increase from 0.4 squitters per second to 0.6 squitters per second for the first 12 second interval. When considered over the first 24 second interval the rate would be 0.50 squitters/second and over the first 48 second interval the rate would be 0.45 squitters per second. This would result in the required probability of individual squitter reception decreasing to the values shown below in Table 6 (at 95% probability of reception within the required update interval) as compared to the higher reception probabilities indicated in Table 4 above.

TABLE 6

a-a range	Required per Squitter Reception Probability	
	TSR	TCR basic
20 nmi.	0.340	0.340
40 nmi.	0.221	0.221
90 nmi.	0.130	0.130

Thus this approach would offer a considerable advantage in performance when changes to TSR or TCR occur but would degrade the effective update for TCR+1 information for a brief period. In the case where both TSR and TCR have changed then TSR would take precedence and it would be broadcast at the increased update rate.

3. Proposal

WG3 is invited to review and endorse the proposal in the attached draft working paper for WG6 as being representative of the most realistic requirements for intent reporting for which future editions of the 1090 Extended Squitter MOPS could support. As an alternative to defining TSR, TCR and TCR+1 in DO-242a, WG3 may wish to consider recommending to WG6 that only TSR be defined for now and leave the definition of the requirements for TCR and TCR+1 for a longer-term update to the MASPS. This would allow time for the validation of the postulated applications that might use such information.

If this proposal is accepted by WG3, then WG3 is invited undertake coordination with WG6 to confirm the requirements for intent reporting and to progress the intent reporting provisions in DO-260A along the lines suggested in the Section 2 above.

ATTACHMENT

DRAFT WORKING PAPER FOR WG6

“ADS-B MASPS Requirements for Intent Information”

Version 2.2, Jan. 2, 2002

RTCA SC-186
Work Group 6

ADS-B MASPS Requirements for Intent Information

Prepared by Ron Jones, FAA, ASD-140

Summary

The proposed changes to the ADS-B MASPS for the broadcast of intent information will need to be finalized for the ballot version of DO-242A in March 2002. Two key areas for which the requirements need further investigation is the rate at which the receiving application requires updates of TSRs, TCR and TCR+1 reports. The other is what is the minimum set of parameters required for each report type. This paper makes proposals for the update rate requirements for this reports of intent information and recommends an approach for specifying the minimum set of data parameters.

Reference: RTCA Paper #377-01/SC-186-184, Proposed ADS-B MASPS Revisions: Intent Information Broadcast, Version 3.0, December 2001

1. Background

The referenced paper that was produced by WG6 and presented to SC-186 plenary in December 2001, included in section 10, under "Minimum Intent Report Requirements" a section on "Transmission Update Requirements." While for a given ADS-B, the associated MOPS will need to define the transmission rates for each of the various ADS-B reports, the ADS-B MASPS must remain independent of the ADS-B link technologies. Therefore, the MASPS requirement must be expressed in terms of the effective update rate requirement as viewed by the receiving system. Since the application that is using the intent information to support an operational capability is on the aircraft that is receiving the ADS-B reports, this is consistent with the MASPS stating the requirements in terms of the effective received update rate. This is the approach that was taken with the update rate requirements in the current DO-242.

First we need to review how DO-242 specified the update requirements for Mode Status Reports, which contains the TCP information. Currently the Mode Status Report requirements are defined by:

Table 2-2 indicates that intent information is only required to support the following applications defined by DO-242:

Separation Assurance and Sequencing

Flight Path Deconfliction Planning

ATS Surveillance

Note that Separation Assurance and Sequencing only requires TCP and not TCP+1.

Table 3-4 includes the requirements for the Mode Status Report and the update rate is indirectly specified with note 8 to that table. Note 8 states: "*The delay for MS or OC report updates after a MS or OC state change should be no more than the coast interval associated with the state vector report (with 95% confidence).*" Also in Table 3-4, the coast interval is defined to be the same value (in seconds) as the 99% confidence state vector update interval. The net result from this is that any change in intent must be received, with 95% confidence, within a time period that is equal to twice the 95% confidence state vector update interval. The following table presents the current Mode State Report update rate requirement, at 95% confidence, as a function of air-to-air range as required by DO-242. Note that the referenced RTCA Paper #377-01/SC-186-184 incorrectly states the update rate requirements for TCP.

Max. Air-to-air Range	Application	Mode Status Report Update Rate at 95th Percentile
20 nmi.	Separation Assurance and Sequencing	14 seconds
40 nmi.	Separation Assurance and Sequencing	24 seconds
90 nmi.	Flight Path Deconfliction Planning	24 seconds

Since the designs, simulations, and studies for the capabilities and the characteristics of the 1090 MHz Extended Squitter and UAT ADS-B links have been based on the intent reporting requirements of the existing ADS-B MASPS (as shown above), WG6 would be well advised to carefully consider the negative impact that the changes in intent reporting requirements could have on the associated link characteristics. Specifically, any significant increase in the update rate requirements and especially the amount of intent information that must be conveyed per unit of time could have a significant impact on the ADS-B link capacity as well as the associated MOPS requirements. Therefore, WG6 must be careful to not over-specify the requirements for either the minimum required parameters included in the intent reports or the rate at which the updates must be successfully received. Also as discussed at the December 2001 SC-186 Plenary, the air-to-ground aspects of intent reporting are a significant aspect that must be further defined as certain intent information may be more significant to ground-based applications.

The new proposed approach for conveying intent information via ADS-B would require at least 3 separate reports (TSR, TCR and TCR+1), instead of the previous two (i.e., TCP and TCP+1). Also the TCR and TCR+1 reports include substantially more parameters than the old TCP reports. Given the very real capacity limitations of the current 1090 MHz Extended Squitter and UAT designs to support delivery of intent information, DO-242A will need to identify which of the TSR, TCR and TCR+1 data elements which truly represent the minimum requirement vs. those elements that while useful, could be considered optional. For example, if we specify a certain set of parameters as being the minimum requirement for a TCR then if the data is not available for any one of those parameters, then the ADS-B message(s) associated with TCR should not be broadcast (i.e., minimum requirement really means this is the minimum requirement for broadcasting TCR information). Furthermore, DO-242A will need to define not just the required update rates for TSR, TCR and TCR+1, but will need to specify how the required update rates will vary depending on the time-to-go to the occurrence of the event being reported (by the transmitting aircraft) and the air-to-air range from the target aircraft (as seen by the receiving aircraft).

2. Proposal

2.1 Update Rate Requirements

The following table is presented as a strawman proposal for the update rate requirements for intent information. The term “TTG” in the following table is the time-to-go until the event being reported begins (e.g., time until aircraft begins turn or begins climb). With this proposal, only information associated TCR and TCR+1 events occurring within the next 15 minutes would be broadcast while TSR associated data would continually be broadcast, if the onboard data for the minimum set of required parameters are available.

Air-to-Air Target Range (nmi.)	TSR Update Rate @ 95 percentile	TCR Update Rate @ 95 Percentile			TCR+1 Update Rate @ 95 Percentile		
		TTG ≤ 150 seconds	150<TTG≤900 seconds	TTG>900 seconds	TTG ≤ 300 seconds	300 < TTG ≤ 900 seconds	TTG > 900 seconds
≤ 20	12 seconds	12 sec.	24 sec.	NA	24 sec.	60 sec.	NA
>20 & ≤ 40	24 seconds	24 sec.	48 sec.	NA	48 sec	90 sec.	NA
>40 & ≤ 90	48 seconds	48 sec.	96 sec.	NA	96 sec.	120 sec.	NA
>90	not specified	not specified.	not specified	NA	not specified	not specified	NA

The above table could be added to DO-242A as a supplement to Table 3-4 (perhaps as Table 3-4a) with a note in Table 3-4 (modifying the current note 8) pointing to this supplemental table.

The need for an additional table to express the requirements for air-to-ground delivery of intent information also needs to be explored for DO-242a.

For a given ADS-B link the MOPS will need to specify a transmission rate for the ADS-B messages associated with the TSR, TCR and TCR+1 reports. The specified transmission rates will need to result in an effective received update rate consistent with the requirements of the above table. Thus the required transmission rates will be link specific. Specifying the update rate requirements in the manner proposed in the above table would allow nearby aircraft to receive relatively rapid updates (e.g., 12 second rate) while the more distant aircraft would only be required to receive the updates at a lower rate. This is appropriate since knowing the changes in the intent of target aircraft will be most important for nearby aircraft and less important for distant aircraft. This approach also matches the characteristics inherent in all of the ADS-B links where the reception probability will decrease (thus increasing the time between the successful reception of updates) as the target range increases.

2.2 Minimum Requirements for Report Content

It is proposed that WG6 accept the following criteria for determining which data parameters represent the minimum required for TSR, TCR and TCR=1 reports. The criteria would be that no TSR, TCR or TCR+1 report would be generated (and thus no corresponding ADS-B message would need to have been broadcast) unless valid data for all of the required parameters is available onboard the transmitting aircraft. All of the other parameters defined by the MASPS would be considered optional and if during the development of the ADS-B link MOPS requirements it is determined that there is insufficient link capacity to accommodate all of the optional parameters, then a given ADS-B link may elect to not support the broadcast of one or more of the optional parameters. With this approach it would be appropriate for WG6 to provide guidance to the ADS-B link MOPS developers indicating which of the optional parameters are considered the most useful vs. those of only marginal utility.