Response to DO-242 Issue Papers 2 and 29

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Background

The current ADS-B MASPS (RTCA DO-242) requires that both barometric and geometric altitude be supplied in ADS-B state vector reports.

Issue paper 2 suggests eliminating altitude rate as a required state vector reporting element, and further suggests that a reasonable altitude rate could be derived by taking the first difference of the two most recent altitude reports. Issue paper 29 suggests that geometric altitude should not be a required data element in the state vector report.

Part of the basis for these two issue papers is that the modeling performed for DO-242 did not include process noise in the altitude trajectories of the aircraft. Issue paper 2 points out that altitude fluctuations will result in varying altitude rates. The logic in paper 2 suggests that since altitude rate varies rapidly there is no advantage in transmitting it.

We feel that vertical rate is essential for prediction of future aircraft state. Future state predictions, including vertical state, are required for nearly every application envisioned using ADS-B, including all conflict detection and resolution applications, and most cooperative separation management applications. We consider vertical rate to be of the utmost operational significance and necessary for inclusion in the ADS-B state vector report.

We recognize that vertical rate is subject to the effects of wind, turbulence, updrafts, and downdrafts. These situations do not preclude the use of vertical rate, given that potential noise in the information is taken into consideration by the applications processing that information.

Our expectation and experience is that vertical rate smoothed from successive position reports will be difficult to derive adequately (relative to the MASPS requirements), in that a significant lag resulting from any filtering on position reports is likely. We doubt that the difference of two successive position reports will be adequate relative to the MASPS requirements. The analysis described below provides an analytical basis for our views. Our experience is that sophisticated tracking techniques are required to derive vertical rate adequately from the receipt of successive position reports.

The MASPS, however, does not preclude implementations from deriving vertical rate on the receive side from successive position measurements. The MASPS does not specify message content. The MASPS states information content and accuracy degradation requirements for output reports. The MASPS does not specify the means by which those reports are to be derived. It is acceptable, therefore, for an implementation to derive vertical rate based on successive position reports, provided that the accuracy degradation is shown to be within the requirements of the MASPS. We strongly suggest, however, based on the attached analysis, that position only messages are likely to be inadequate in meeting operational requirements.

Analysis

To test the hypotheses of these two issue papers, I modified our Monte-Carlo simulation to include process noise in altitude and altitude rate. I consulted with Tony Warren of Boeing to come up with suitable parameters for our simulation model. The model used a damping ratio of 0.6, a time constant of 20 seconds, and a 95% containment value for altitude of 125 feet.

Experiments were run using a 3 second report update period with 95% probability of reporting. The scenario used is similar to that of DO-242 appendix J Figure J-14 with the addition of the process noise described above. Figure 1 below depicts a typical sample path used in the analysis. The results reported below are based on 500 Monte-Carlo iterations of the scenario. Each iteration of the scenario represents an obvious conflict, in fact, each is an NMAC.

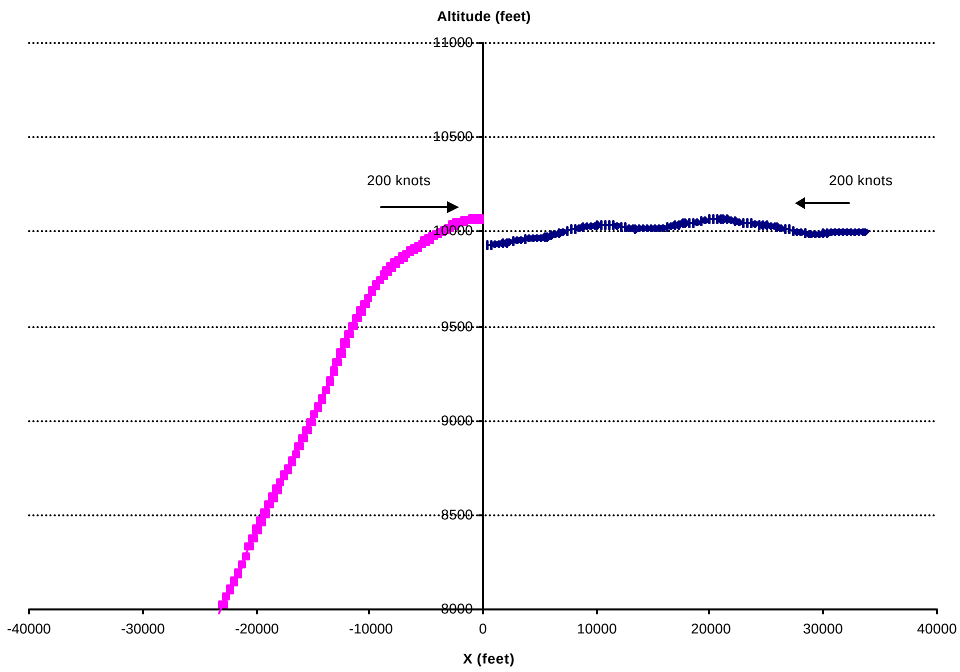

Figure 1: Altitude Conflict Scenario Sample Path

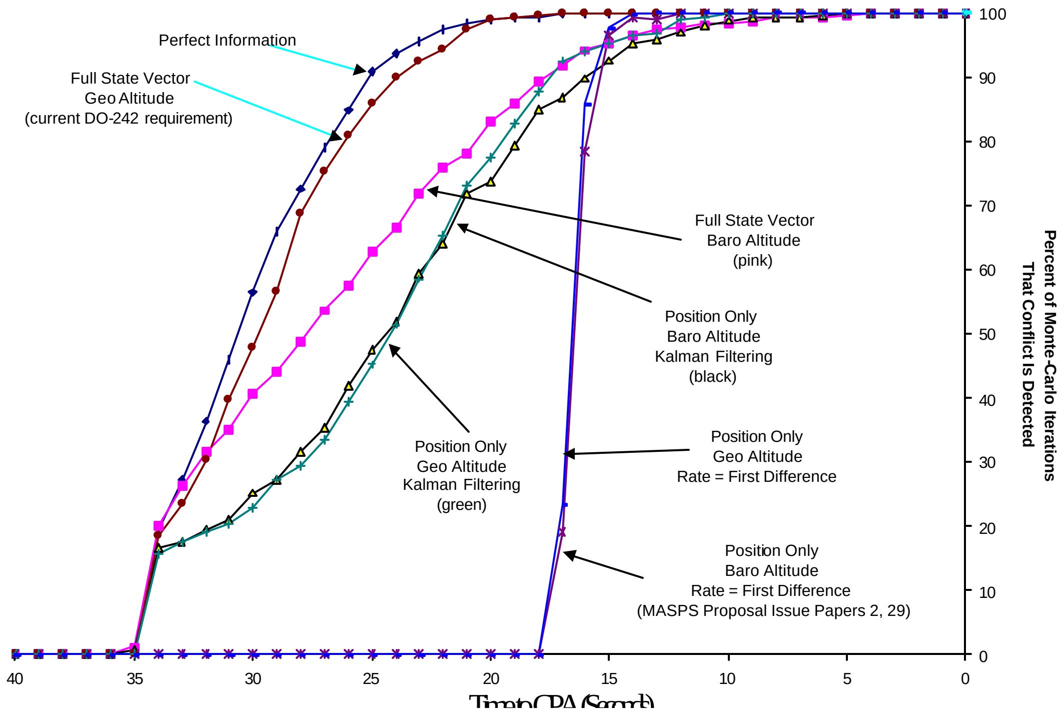

Figure 2: Monte Carlo Simulation Results

A simple conflict detection algorithm was employed that alerts when predicted vertical miss distance and predicted time to closest point of approach fall below threshold values. For these experiments, the threshold on vertical miss distance was 600 feet and the threshold on estimated time to closest point of approach was 35 seconds.

Figure 2 shows simulation results for several information and tracking alternatives. The figure depicts as a function of time to closest point of approach (abscissa) the percentage of Monte-Carlo iterations on which a conflict was detected (ordinate). Higher percentages earlier in the scenario represent better alerting performance.

The line in the figure labeled "perfect information" depicts results for an update rate of 1 report per second, both altitude and altitude rate being reported, and no error in the reported altitude information. The curve labeled "Full State Vector, Geo altitude" represents the current MASPS requirements for a 3 second update period with 95% probability of update, the MASPS tolerance for additional altitude errors, and reported geometric altitude based on GPS/WAAS accuracies.

Serious degradation of alerting times results with barometric altitude because of barometric altimetry errors. The model used for altimetry errors is consistent with that used in modeling TCAS. Even with full state vector information, barometric altitude results in significantly lower alert times than geometric altitude for this scenario.

Removing full state vector reports further reduces alerting performance. Two alternatives were examined using altitude-only reporting, rather than altitude plus altitude rate reporting. In the curves labeled "Kalman filtering," a Kalman filter was applied to smooth the reported altitude data. However, filter lags through the maneuver cause degradation in alerting performance.

Use of first differences to derive vertical rate is examined in the curves labeled "Position only, rate = first difference." These curves represent the performance of the proposals outlined in issue papers 2 and 29. These offer the worst performance observed in the study, and would result in significant degradation in alerting performance as compared with the current MASPS requirements.

Conclusions

The proposals outlined in issue papers 2 and 29 will result in significant degradation of alerting performance. It is recommended that these proposals be rejected. Instead, it is recommended that the information contained in this paper be integrated into appendix J.