Addendum to Issue Paper Number 2
Tony Warren, May 21, 2001

Recent simulations conducted by Jonathan Hammer were performed to examine the effect of including high quality altitude rate data (augmented GPS geometric altitude and altitude rate), low quality altitude rate data (baro altitude and altitude rate), and derived altitude and altitude rate data given 3 second updated altitude only data on a vertical conflict alerting problem. The simulation results showed that detection alert times were much better with altitude rate data than without, and that use of high-quality geometric altitude and altitude rate data was significantly better than use of lower quality baro altitude and altitude rate data.

Discussion of these results within the Ad Hoc MASPS working group led to the conclusion that there is value to retaining altitude rate data in the revised ADS-B MASPS. However, two questions were brought up in the discussion which warrant further study:

(1) Is it necessary for all aircraft including basic VFR aircraft to transmit altitude rate data if the quality of such data is poor, and such aircraft are unlikely to participate in the kind of conflict alerting scenarios envisioned in the reference simulations?

This question is not addressed in this addendum, but may be addressed in a new issue paper dealing with class codes, i.e. it may be necessary for ADS-B aircraft to transmit some means of specifying functional capability, in addition to NIC / NAC state vector integrity and accuracy codes, to differentiate those aircraft which need to support ADS-B applications using high quality altitude rate data.

(2) Is it necessary to broadcast both geometric and baro altitude rate if both (or multiple) sources are available, i.e. why not broadcast the best source of altitude rate data for the purpose of short term altitude prediction and conflict alerting?

The main issue with this idea is that it is not clear whether one can substitute geometric altitude rate for baro rate or visa versa. However, it can be shown that the two quantities can be directly related to one another by the following equation, valid for non-standard atmosphere conditions (Burrows, Ref [1]):

h_dot = (Tk / Tstd)* hp_dot

Where h_dot denotes geometric altitude rate
hp_dot denotes pressure altitude rate
Tk denotes actual temperature relative to absolute zero
Tstd denotes standard temperature at pressure altitude hp.

Now the addendum author submits that it is feasible to relate one version of altitude rate to the other with acceptable percent accuracy using the above equation, except in rare circumstances, and for limited altitude ranges, i.e. for temperature inversions near the earth boundary layer (typically extending no more than 3000 ft AGL). In most cases of interest, the receiving aircraft can use delta-ISA (temperature difference from standard temperature) onboard the receiving aircraft as a means of approximating Tk for the transmitting source aircraft, i.e.

Tk ~ Tstd(hp) + delta_ISA

Thus it is possible in most cases of interest to directly relate geometric altitude rate to baro altitude rate given one transmitted altitude rate and an estimate of delta_ISA. Even when the above approximation is not valid, the error due to non-standard temperature profile rarely exceeds 10%, which is small compared to the short term variations in vertical rate on climb (which can be up to 1000 ft/min according to recent NASA Ames studies).

Consequently, given the above simulation results, we recommend consideration of the following alternative to deletion of altitude rate data:

<u>Alternative Proposal</u>: Change the ADS-B MASPS to require broadcast of the best source of altitude rate, and the type of altitude rate provided, e.g. geometric or baro based altitude rate. In the case of aircraft having only one source of data, they would broadcast that source when available. Otherwise, such aircraft would determine which data source was most accurate and appropriate for short term altitude predictions and broadcast that data source. This proposal would reduce the state vector from supporting two altitude rate quantities to one, conserving message bandwidth for other potential uses.

Reference:
[1] J.W. Burrows and A. Chakravarty, “Time Controlled Aircraft Guidance in Uncertain Winds and Temperatures,” American Control Conference, pp.191-197, 1984.