

To: ADS-B MASPS Ad Hoc Working Group
From: Ann Drumm, MIT Lincoln Laboratory
Subject: Proposed ADS-B Transmission of TCAS RA Information

As the principal developer of the original TCAS air-to-air coordination logic, I am writing to express concern about the proposed ADS-B transmission of TCAS RA information. My understanding is that the concept for ADS-B use of this information is not yet mature, and my feeling is that there are many ways in which the misuse of this information could cause a serious loss of separation/loss of safety for both aircraft in an ADS-B/TCAS encounter.

There are a few general thoughts I wanted to share:

(1) In an ideal situation, the TCAS coordination process is straight-forward: one aircraft selects a vertical sense (up or down) and communicates this sense to the second aircraft, which then selects the opposite sense. The process can become significantly more complicated if the two aircraft select a sense at the same time.

The duration of the time window within which a simultaneous sense selection can occur depends on the time delay between one aircraft's sense selection and the successful transmission of this sense to the other aircraft. In order to minimize this time window, and thus minimize the probability of simultaneous sense selection, coordination interrogations are transmitted immediately after the sense selection is made and coordination communication is required to be very robust. Coordination interrogations (always full power) are transmitted each second, with required retransmission up to 12 times per second if necessary in order to accomplish successful transmission. With a broadcast link, there is less certainty about accomplishing a successful transmission and thus a higher probability of simultaneous sense selection.

(2) In the TCAS safety studies, based on the TCAS encounter data, it was estimated that in approximately 10% of the encounters, the two aircraft would independently select incompatible (same sense) vertical maneuvers. Thus, in the case of a simultaneous sense selection, we can expect that approximately 10% of the time, the two aircraft will select incompatible maneuvers. If this happens in TCAS-TCAS encounters, within one second intent information is exchanged in both directions between the aircraft, and the aircraft Mode S addresses are used as a tie-breaker to resolve the incompatibility. (The aircraft with the higher Mode S address reverses its sense.) This reversal happens almost instantly, allowing the pilot essentially the full maneuver response time.

With a broadcast link (and without a mechanism for tie-breaking?), the fear is that the two aircraft could maneuver incompatibly until one or both determined via their surveillance tracking that the situation had worsened. TCAS would then reverse the sense of its original maneuver. These "geometric reversals" are expected to be extremely rare events. Countries that do monitoring of RA events specifically look for RA reversals. Geometric reversals are considered potentially confusing and disruptive to the

pilot, and they can occur late enough in the encounter that available pilot response time is lessened, sometimes considerably.

A still more serious situation would occur in the above case if BOTH aircraft determined that a sense reversal was warranted and both aircraft reversed to the opposite (but still incompatible) sense. What is to prevent this from occurring? Would there be time to resolve the incompatibility? In simulation testing of early versions of the coordination logic, cases occurred in which both aircraft “porpoised,” each changing from one vertical sense to the other multiple times, until time ran out and a collision occurred. Care must be taken that this cannot occur in an ADS-B/TCAS encounter. The lack of precise control of the transmission timing and the lack of a two-way link makes ADS-B use of TCAS RA data for coordination purposes worrisome.

(3) In some of the email traffic in the CDR subgroup, the statement was made that (from a TCAS point of view) a TCAS encounter against an ADS-B intruder should be no different from a TCAS encounter against an unequipped intruder. This is true only if the ADS-B intruder does not maneuver. In determining which vertical sense to select against an intruder, TCAS models the intruder’s flight path from its present position to the closest point of approach (CPA), assuming unchanged range rate and altitude rate. TCAS then models both upward and downward sense maneuvers for own aircraft and determines which sense provides the better vertical separation at CPA. Any maneuver by the ADS-B aircraft can thwart the sense selection by TCAS.

I have not seen proposals for ADS-B use of TCAS RA data. The above items are simply quick thoughts about issues that I think should be considered carefully. Experience with TCAS coordination suggests that subtle timing changes can produce vastly different outcomes in the coordination process. My concern is that if the TCAS RA information is broadcast, some use might be made of this information that would be considered benign – only to discover after implementation that it causes unexpected and unsafe aircraft interactions.