Appendix H
Future Air-Referenced Velocity (ARV) Broadcast Conditions

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H Background

In this version of these MASPS (RTCA DO-3xx), there are no conditions that require the transmission of air-referenced velocity data (heading and airspeed). There is optional transmission of ARV data in the event of loss of ground velocity to maintain tracks when ground data is lost. However, there are other future applications discussed in this MASPS and currently being developed that could make good use of ARV reports. Among those applications:

- Collision Avoidance and Separation Assurance and Sequencing: ARV data can be used to improve accuracy of conflict detection, prevention, and resolution routines when the transmitting aircraft is being controlled to either an air-referenced or a ground referenced velocity.
- For Interval Management and other future spacing applications, ARV data enables near real-time wind estimation and provides improved situation awareness for trailing aircraft.
- ARV data, allowing wind direction and speed estimates, provides improved real-time information for Ground ATC automation functions and supports improved weather monitoring.

There may also be a future application that could use ARV data to maintain or even acquire tracks when ground data is lost.

H.2 Applications Benefited by ARV data

H.2.1 Collision Avoidance and Separation Assurance and Sequencing

H.2.1.1 Operational Scenarios

ADS-B receiving aircraft or ground stations can use ARV along with the ground track and ground speed (available through the state vector) to approximate wind information encountered by a transmitting aircraft. Consideration of winds should improve the performance of conflict detection, prevention, and resolution routines in cases where the transmitting aircraft is flown in a heading-referenced flight mode, or when the predicted flight path encounters changes in along-track winds. Operational examples include heading select and heading hold modes often used while being vectored by air traffic control or deviating around hazardous weather. Figure H-1 shows the effect of wind on an aircraft's ground track when turning from a northerly to westerly heading in the presence of a 30-knot wind from the south. The ground track is extended for two minutes after turn completion. The target heading after turn completion is provided in the Target State report when the turn is initiated. Throughout the scenario, the aircraft flies at a constant true airspeed of 250 knots and maintains a constant bank angle corresponding to a standard rate turn (360 degrees in four minutes). For comparison, the no-wind ground track is also shown.

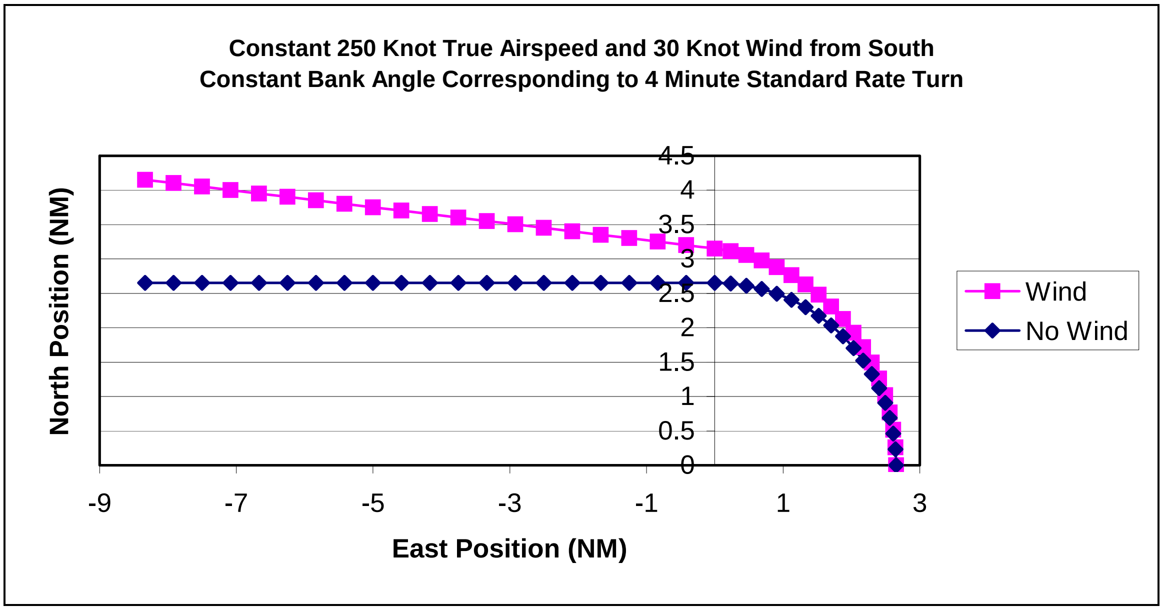

Figure H-1 **Wind Effects on Heading-Referenced Flight Modes**

In the wind condition, the aircraft completes the turn a half-mile north of the no-wind case. After flying in the crosswind for two minutes, the aircraft has drifted an additional mile to the north. The combination of these wind errors could affect the accuracy of predicted conflicts. Although this example assumes a simplified constant bank angle turn ~~(see Figure J-4 for example of aircraft bank angle variance in a turn)~~, the wind effects are apparent nonetheless.

Consider a second example of two aircraft engaged in an air-air separation assurance application. In Figure H-2, an aircraft operating in a heading hold mode is flying 3000 feet below another aircraft flying a defined ground track angle. The lower aircraft begins a constant 1500 ft/min climb and encounters a left crosswind that is 30 knots greater at the higher aircraft's altitude. This scenario is designed to represent the common occurrence of changing wind conditions with altitude. Each aircraft can combine the other aircraft's air and ground-referenced velocity vectors to approximate the wind encountered by that aircraft. Assuming each aircraft knows its own wind conditions, the wind differential encountered by the climbing aircraft can be approximated by a ramp function. Figure H-2 shows the ground track of the climbing aircraft in the presence of the ramp wind. The crosswind causes the climbing aircraft to drift a half-mile during the climb. If the climbing aircraft in this example were to encounter a changing headwind or tailwind component, the availability of ARV information would also enable a more accurate location and time prediction of the point in which it climbs through the other aircraft's altitude.

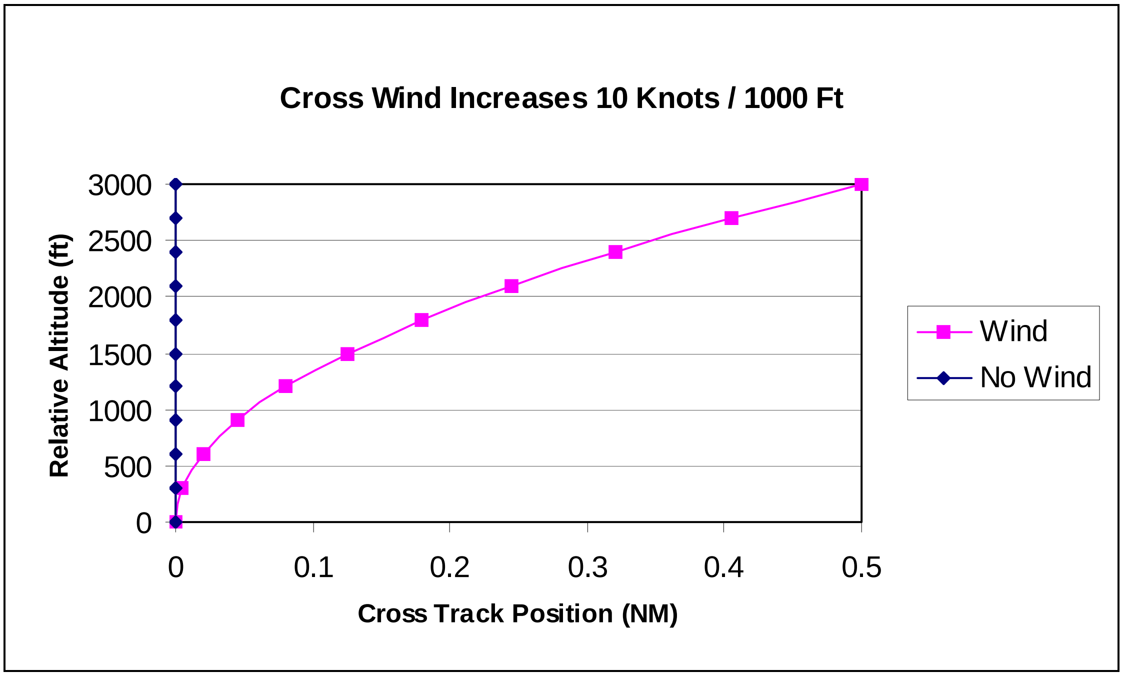

Figure H-2 Drift Due to Ramp Cross Wind

ARV broadcast while operating in comparable scenarios may be beneficial. Certain addressed datalink systems allow some aircraft to provide ground stations with current wind conditions [1]. Under this concept, ground-based command and control systems process incoming wind data and make them available to participating aircraft. However, ADS-B may enable more current and localized wind approximation for aircraft engaged in paired applications. ARV information is expected to be particularly beneficial when aircraft are operating in heading-referenced flight modes. It may also lead to improved predictions for fly-by turn segments. In normal conditions, winds do not affect aircraft predictions when flying straight and level ground-referenced legs.

Controllers may also benefit from ARV information when providing radar vectors and speed commands to sequence aircraft in the terminal area. Due to the inability of some aircraft to determine ground track and ground speed, controllers issue these commands in the form of magnetic heading and indicated airspeed. Controllers must anticipate the heading and airspeed targets needed in order to produce the desired ground track. This process often requires the controller to verify current heading and airspeed over the radio. After issuing vectors and speed commands, controllers have no direct way to ensure compliance. Direct broadcast of ARV information would enable more accurate control and would likely make this process easier [2].

H.2.1.2 Possible ARV Broadcast Conditions

In order to improve the accuracy of conflict detection, prevention, and resolution routines, ~~the following ARV broadcast conditions may be needed:~~

~~1.~~ARV information should be broadcast at a rate sufficient to derive wind estimates for the ADS-B transmitting aircraft~~ whenever TS messages are broadcast with target heading as the active guidance source for the transmitting aircraft.~~

1. ~~ARV information should be broadcast at a rate sufficient to derive wind estimates for the ADS-B transmitting aircraft whenever TC messages are broadcast indicating a Fly-by or Radius to Fix turn maneuver of greater than TBD degrees and time to go to the TCP of less than two minutes.~~

In order to support air traffic control use of radar vectors and speed commands, the following ARV broadcast condition may be needed:

~~3.~~ARV information should be broadcast at a rate consistent with that for ADS-B state vectors when engaged in identified terminal operations such as approach transition, as indicated by an appropriate ADS-B air-ground service level or as identified by other means such as pilot input. The ARV information should continue to be broadcast until an appropriate signal or condition occurs that signifies that the information is no longer needed (such as arrival at the Outer Marker).

H.2.2 ~~In-trail~~ Spacing Applications

H.2.2.1 Operational Scenario

~~In-trail spacing approaches~~Spacing applications may also benefit from ARV information. Accurate wind information, potentially derived from ARV, is essential for establishing proper spacing intervals. Current airspeed information could also enhance situation awareness for trailing aircraft. One proposed ~~in-trail~~ spacing concept attempts to achieve a constant threshold-crossing interval for a stream of landing traffic. Prior to reaching the final approach fix, the trailing aircraft is required to maintain a specified time spacing behind the lead aircraft, consistent with safety. The time spacing is based on the difference in final approach speeds between the lead and trailing aircraft after passing the final approach fix (when the aircraft is configured for landing) and the current wind conditions

ARV information notifies the trailing aircraft to speed changes initiated by the lead aircraft. These speed changes could be part of ATC clearances or associated with unplanned speed reductions (e.g., for required arrival timing). Situation awareness resulting from ARV information should enable trailing aircraft flight crews to take necessary actions to prevent separation loss.

ARV broadcasts enable wind estimation. Wind affects the amount of time in which the differences in final approach speeds act to close or stretch the gap between aircraft after passing the final approach fix. For example, a strong headwind would leave more time for a faster trailing aircraft to close the gap between a slower lead aircraft. Inaccurate wind information will lead to greater variability in threshold crossing time, thereby reducing efficiency.

H.2.2.2 Possible ARV Broadcast Condition

In order to support in-trail spacing applications and to provide appropriate situation awareness information to aircraft in an arrival stream, the following ARV broadcast condition may be needed:

> ARV information should be broadcast at a rate consistent with that for ADS-B state vectors when engaged in certain in-trail separation applications as indicated by an appropriate ADS-B service level or by other means such as pilot input. The ARV information should continue to be broadcast until an appropriate signal or condition occurs that signifies the end of the separation application.

H.2.2.3 Air Referenced Velocity Acquisition, Update Interval and Acquisition Range

Air referenced velocity (ARV) proposed update periods and acquisition range requirements are summarized in Table H.2.2.3a. These requirements are specified in terms of acquisition range and required update interval to be achieved by at least 95% of the observable user population (radio line of sight) supporting ARV on-condition reports within the specified acquisition range or time interval.

Note: *For the remainder of the user population that has not been acquired at the specified acquisition range, it is expected that those ADS-B participants will be acquired at the minimum ranges needed for safety applications. It is anticipated that certain of these safety applications that are applicable in en route and potentially certain terminal airspace, may require that 99% of the airborne ADS-B equipped target aircraft in the surrounding airspace are acquired at least 2 minutes in advance of a predicted time for closest point of approach. This assumes that the target aircraft will have been transmitting ADS-B for some minutes prior to the needed acquisition time and are within line-on-sight of the receiving aircraft.*

Table H.2.2.3a Summary of Air Referenced Velocity Report Acquisition Range and Update Interval Requirements

Operational Domain →	**Terminal, En Route, and Oceanic / Remote Non-Radar ↓**			
Applicable Range →	**R ≤ 10 NM**	**10 NM < R ≤ 20 NM**	**20 NM < R ≤ 40 NM**	**40 NM < R ≤ 90 NM**
Equipage Class →	A1 required	A1 required	A2 required	A3 required
ARV Acquisition Range	NA (see note)	20 NM	40 NM	90 NM
ARV Nominal Update Period (95%) when ground referenced velocity data not available	5 s	7 s	12 s	12 s

Note for Table H.2.2.3a:

This row is meant to specify the minimum acquisition ranges for all class A equipage classes. Since A1, A2, and A3 equipment all have minimum acquisition ranges greater than 0 NM, no requirement is specified in this cell.

The following update rates apply when an ARV report is required:

a. The ARV report's nominal update interval should be 5 seconds for A1, A2, and A3 equipment at ranges of 10 NM and closer.
b. The ARV report's nominal update interval should be 7 seconds for A1, A2, and A3 equipment at ranges greater than 10 NM and less than or equal to 20 NM.
c. The ARV report's nominal update interval should be 12 seconds for A2 equipment at ranges greater than 20 NM and less than or equal to 40 NM.

d. The ARV report's nominal update interval should be 12 seconds for A3 equipment at ranges greater than 40 NM and less than or equal to 90 NM.

The ARV report acquisition range in the forward direction should be:

a. 20 NM for equipage class A1,
b. 40 NM for equipage class A2, and
c. 90 NM for equipage class A3.

The acquisition range requirements in directions other than forward should be consistent with those stated in Note 3 of Table 3.2.1.4.3.1.1a.

For air-to-air use of ARV to potentially support spacing applications, the received update rates for wind speed and direction broadcasts are a 15 second 95% update interval for lead-trail aircraft distances less than 10 NM, and a 30 second 95% update interval for nearby aircraft less than 20 NM away.

H.3 Summary

ARV information is likely to be most beneficial to equipped aircraft engaged in certain applications, such as those described above. Further application usages of ARV broadcasts may be identified in future MASPS revisions. Periodic low-rate ARV broadcast may also enable coarse wind predictions that can be used to improve back-up surveillance necessitated by the loss of ground track or ground speed information. Further research done on potential benefits of ARV information and the required update rates and conditions needed to achieve those benefits could lead to ARV reporting requirements in future MASPS.

References

[1] "Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (AUTOMET)," RTCA, DO-252, Washington, 2000.

[2] Rose, A., "The Airborne Impact of Mode S Enhanced Surveillance and Down-linked Aircraft Parameters," Eurocontrol, SUR3.82.ST03.2150, Nov. 1999, p. 24.

With the wind vector derivation described in APPENDIX B, nominal broadcast of ARV data may be compatible with that needed for air-ground MET broadcasts. The recommended broadcast of MET data in RTCA DO-252, for example, varies from 3 minutes nominal update rate at cruise altitude to between 20 and 60 seconds for climbs and descents from the TMA to cruise altitude. In descents to TMA airspace, 40 second updates at 95% probability are recommended for general MET applications. However, at lower altitudes, within about 2000 meters above ground level (AGL), weather conditions can change more rapidly with altitude as an aircraft transitions the planetary boundary layer of the atmosphere. Consequently, a compromise value of 30 seconds is proposed for 95% update interval of received ARV data for computing wind vector for arrival management, (Section 6 below). For air-to-air wake vortex applications, the received update rates for wind speed and direction broadcasts are a 15 second 95% update interval for lead-trail aircraft distances less than 10 NM, and a 30 second 95% update interval for nearby aircraft less than 20 NM away (see columns 3 and 4, Table 5-1). In the first case, a 4 to 1 ratio is assumed for transmit rate to receive rate resulting in a minimum transmit interval of 15 / 4 = 3.75 seconds. The 30 second requirement for distances less than 20 NM yields the same 3.75 second minimum transmit interval for ADS-B IN wake vortex applications, since the transmit rate to receive rate is assumed to be 8 to 1 for air-to-air ranges between 10 NM and 20 NM. The proposed interleaving of ARV and ground vector broadcasts described herein could potentially meet these data requirements. An analysis for the arrival management applications based on ADS-B IN reception of