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Space-based ADS-B for GPS-independent position validation

Aircraft operators, Air Navigation Service Providers (ANSP), air traffic control organizations, and others rely heavily on data and associated systems to safely and efficiently operate and navigate aircraft throughout the airspace. From takeoff to touchdown and beyond, positional data is critical. But what happens when the systems fail? What if the GPS data is somehow compromised?

Aireon has developed a proof-of-concept multilateration solution that allows for independent position determination of ADS-B-equipped aircraft. This solution will allow Aireon to continue tracking aircraft even when they are unable to broadcast their GPS position using only their transmitted 24-bit aircraft address and the time of reception at the Aireon Hosted Payloads onboard the Iridium satellites.

This is done through a Satellite Wide Area Multilateration (SWAM) application that uses Time Difference of Arrival (TDOA) measurements from simultaneous detection of ADS-B transmissions on multiple payloads. This solution leverages traditional multilateration techniques used by terrestrial systems but applied via satellite. This is possible due to both the Iridium constellation, with its significant overlapping satellite coverage, and Iridium's ability to accurately track the position and timing of each satellite (on the order of hundreds of nanoseconds), which is shared with Aireon.

The significance of this application is that it will give Aireon another method of delivering aircraft positions to Air Navigation Service Providers (ANSP) around the world that is not dependent on GPS, effectively mitigating a potential mode of failure in ADS-B transponders. By combining both the reported and derived positions of the aircraft, Aireon can provide a robust solution that allows for improved monitoring of aircraft around the globe.

Multilateration uses TDOA measurements where a single transmission is detected on multiple receivers. If at least three receivers detect a single transmission, the TDOA measurements allow for determination of the two-dimensional position (no altitude determination); with four receivers the full three-dimensional position can be found. Additional receivers can be used to improve the fidelity of the solution with each independent pair of satellites providing more information on the location of the aircraft. The Iridium constellation is made up of many polar orbits that converge at the north and south poles which provide greater satellite overlap the closer an aircraft is to the poles; this allows for constant overlapping coverage above 43° and below -43° latitude. These areas show the greatest promise for Aireon's multilateration solution, but it can function worldwide.

Aireon has already begun leveraging these capabilities to create an ADS-B position validation solution that can estimate if a reported aircraft position is accurate, but not determine the truth position itself. This validation solution uses similar techniques as a full-blown multilateration solution, such as TDOA measurements, but is only being used to flag suspect position reports.

ADS-B is dependent on GPS to deliver an aircraft's position, any issues with the onboard GPS equipment or external GPS interference can cause an ADS-B equipped aircraft to be unable to transmit their position. Even in the absence of GPS, ADS-B transponders continue to transmit allowing these of messages to be used for multilateration. GPS interference is an emerging safety risk with hotspots identified in the Middle East where a significant number of ADS-B equipped aircraft lose their GPS position.

Aireon's prototype multilateration solution has been evaluated using Aireon's own operational ADS-B data to check its performance in the real-world. Using data captured from around Iqaluit, Canada, the performance shows a position accuracy of 557 meters, 95th percentile (see **figure 1**). Further work is envisioned to improve this accuracy through improvements to the algorithm and smoothing techniques. The data also shows that the proof-of-concept meets the necessary 8s update interval for Enroute air traffic separation. These are promising metrics for an initial evaluation and should improve as the solution is further developed.

Aireon is also exploring the benefits of combining space-based ADS-B with terrestrial ADS-B to improve the number of receivers available to contribute to the multilateration solution. This should benefit areas where there is existing ADS-B ground stations and a desire to expand the network to support multilateration. By leveraging space-based ADS-B, the existing ADS-B ground stations can be combined with Aireon's data to achieve the required receiver overlap and create a full Wide Area Multilateration (WAM) solution without the significant cost of building out more terrestrial infrastructure. An added benefit of this approach is that the geometry of having receivers above and below the aircraft enhances the accuracy of the altitude determination.

Deployment of the Satellite Wide Area Multilateration solution is on Aireon's roadmap to be ready in 2027.

FIGURE 1
The chart depicts the probability distribution of the MLAT error in meters, highlighting the median (yellow), mean (green), and 95th percentile (purple) errors. The distribution is highly skewed toward the lower values, thereby indicating good performance of the proof-of-concept algorithm.