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GPS interference and spoofing in the Baltics

Air Navigation Service Providers (ANSP) and aircraft operators rely on the integrity of the GPS signal to navigate the aircraft to its destination. Increasingly, however, the integrity of the GPS signal has become a target for interference — via nefarious actions like spoofing or jamming, or non-intentional actions like malfunctioning avionics. This trend has prompted many in the aviation industry to seek creative, technological redundancies to the GPS signal to ensure the aircraft is able to continue operating safely in the event of an interference.

Using its one-of-kind, space-based automatic surveillance broadcast (ADS-B) data, 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.

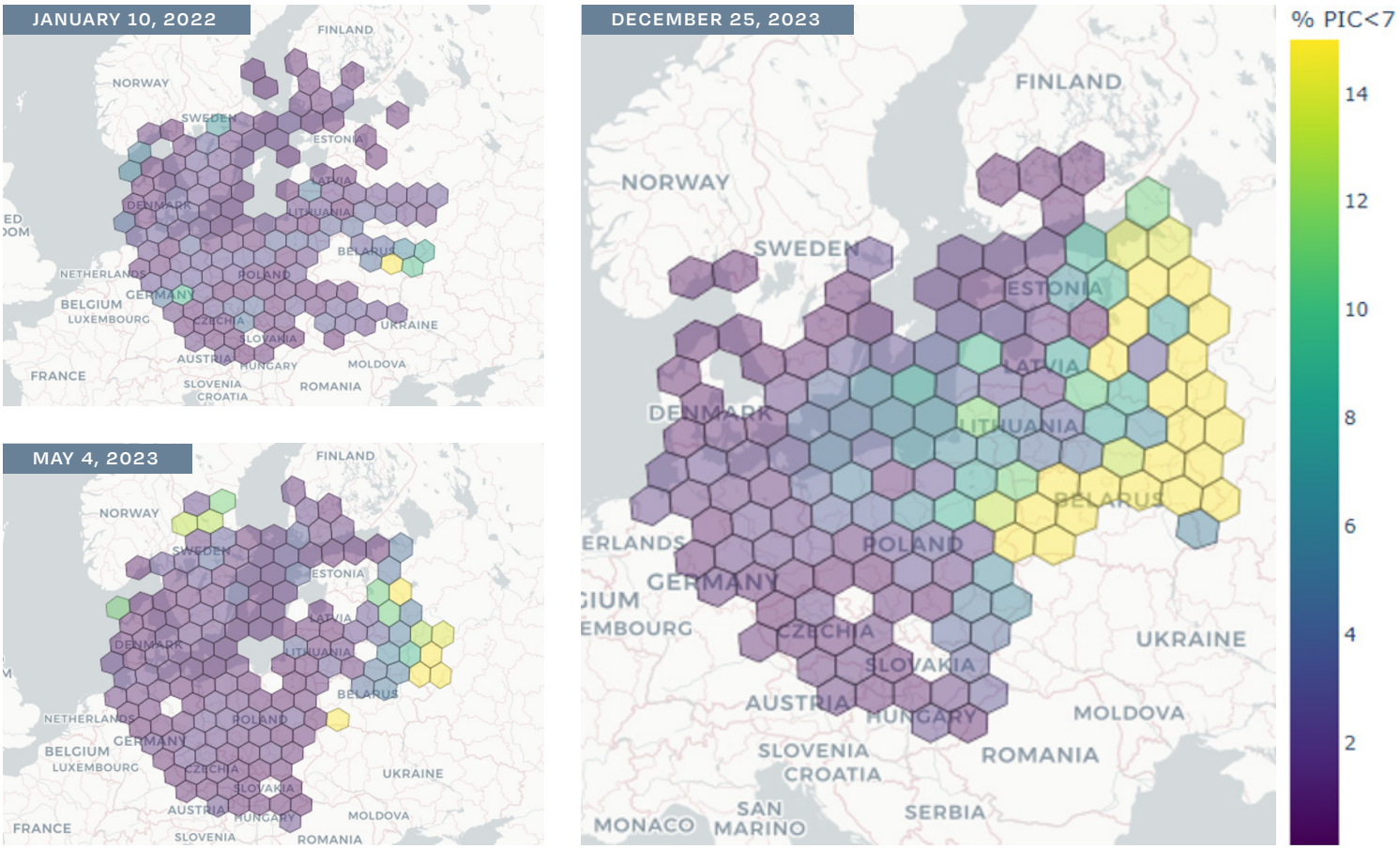
This is done through a Satellite Wide Area Multilateration (SWAM) application that uses Time Difference of Arrival (TDOA) measurements from simultaneous detection of ADS-B transmissions on multiple payloads.

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.

GPS interference in the Baltics

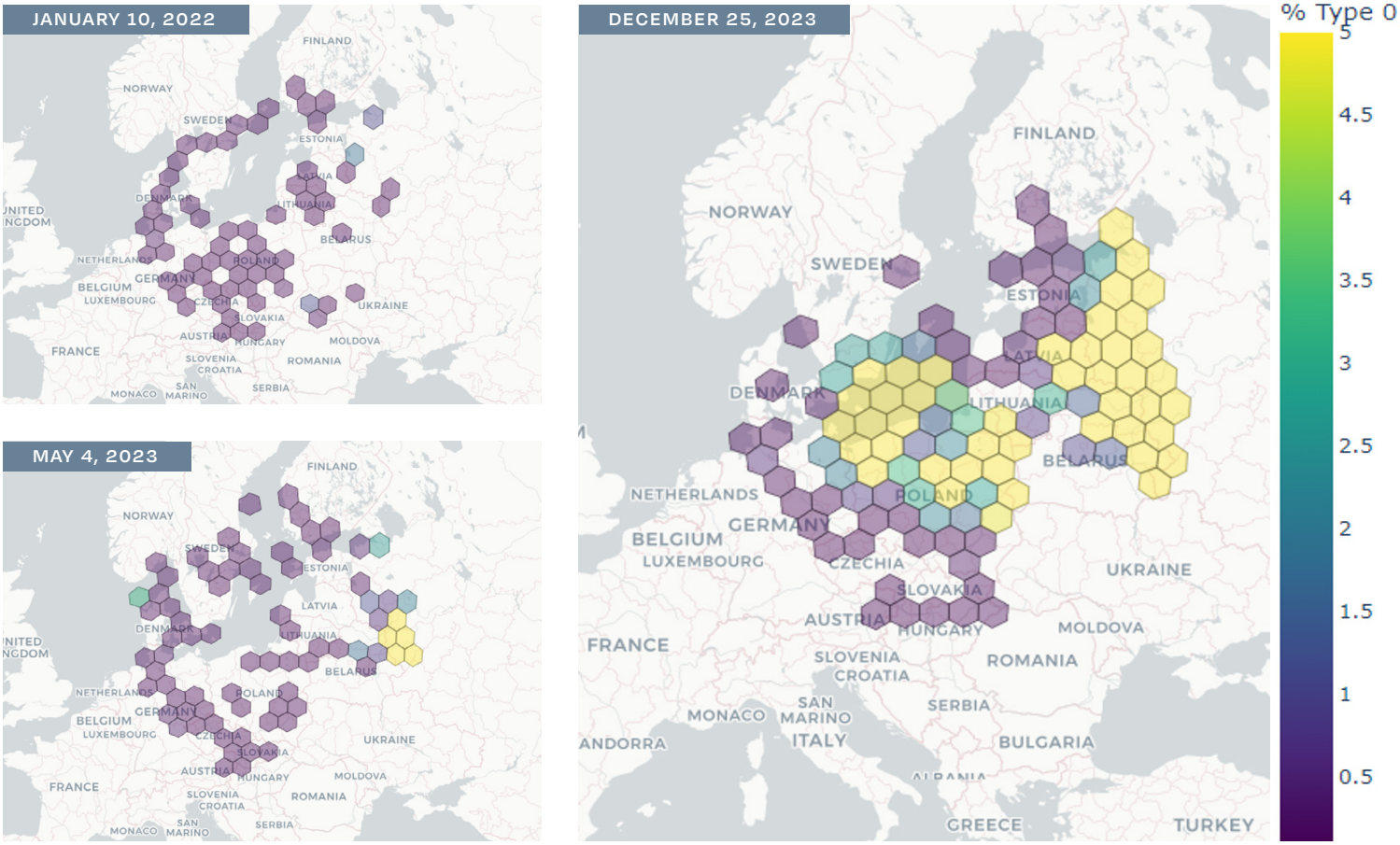
One such example illustrated in the Aireon data of GPS interference occurred between Dec. 25 and 26 with aircraft flying in the Baltic and Russian airspace. Using a variety of validation methods, Aireon determined, based on the aircraft with low reported position integrity category (PIC) values (which correlates with aircraft having large radii of horizontal position uncertainty from its GPS), it is clear that a significant number of aircraft were experiencing interference with GPS, with peak of 18% of aircraft having low PICs observed around 14:40 UTC as shown in Figure 1 (e.g. PIC of zero means > 20 NM position uncertainty whereas PIC of 15 is being used in the figure to represent all "good" integrity bound values < 0.5 NM).

FIGURE 1
Aircraft with Low PIC values Highlighted (indicating poor GPS quality).



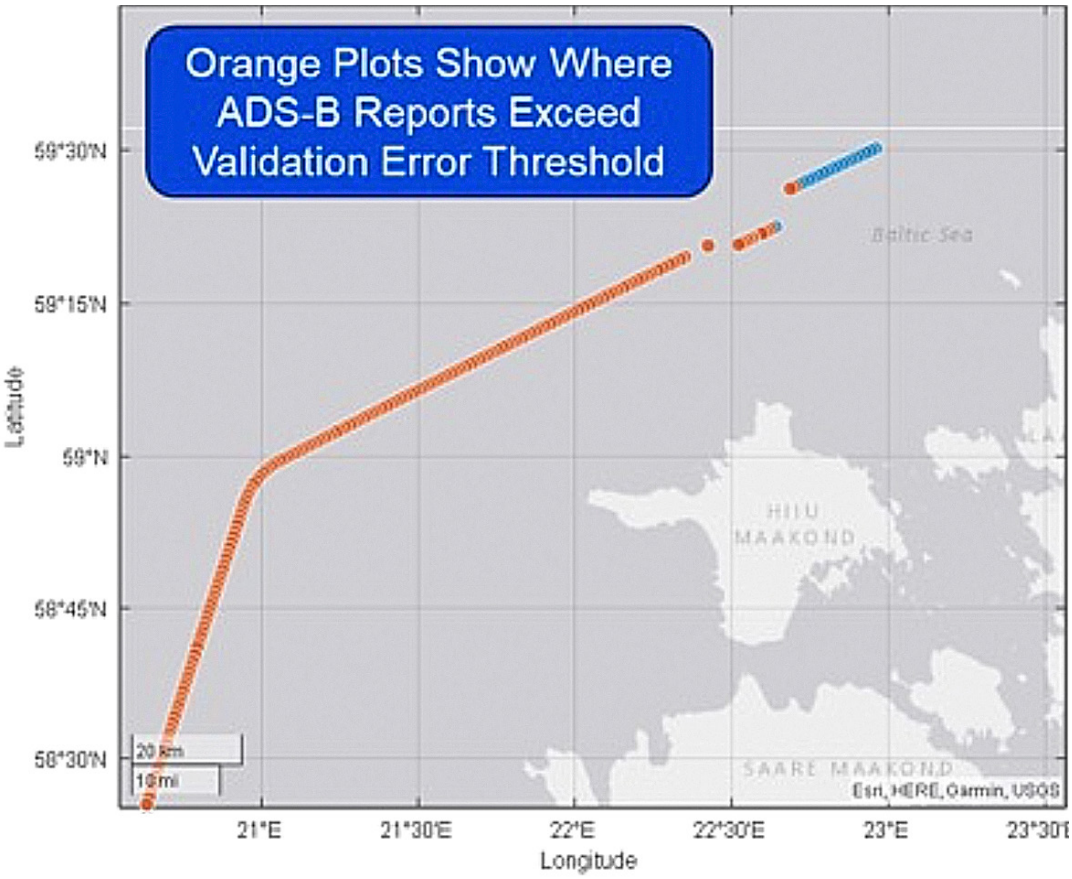
Another signature of interference was mapped by assessing ADS-B messages with a Field Type Code (FTC, which is a field within the message that communicates the message type) of zero (see Figure 2). This is a condition where the latitude and longitude from aircraft's GPS is unknown to the ADS-B transmitter (and often to the cockpit's GPS navigation system). Aireon records these messages for anomaly investigation even though they are discarded by most ADS-B ground systems.

FIGURE 2
Areas where high counts of ADS-B FTC0 messages were observed.



There were several cases of GPS interference in the Baltics during that timeframe that caused large position errors in the ADS-B reports (example shown in Figure 3). Many of these cases were flagged by Aireon's Independent Position Validation (IPV) algorithm that sets a field in the ADS-B reports informing users that the reported position has deviated by a significant amount from Aireon's reference track (derived from TDOA and kinematics).

FIGURE 3
Example of an ADS-B track with reported position that starts as valid (blue) followed by GPS interference inducing position errors large enough to be flagged by Aireon's IPV algorithm (orange).



However, the company continues to evaluate updates to these algorithms to innovate in the field of aircraft surveillance, tracking, analytics, and assurance. The team adapted the reference track algorithm to more aggressively continue to calculate estimated positions even in the absence of some of the expected data items such as ADS-B reported velocity (which dropped out for many tracks as they lost GPS lock). Since the Baltics are in a high latitude, this provides the Aireon system with at least 2 and in many cases 3+ overlapping satellites continuously.

For example, as illustrated in Figure 4, a flight from London/Heathrow to Changsha in China appears to have experienced GPS spoofing in its ADS-B messages. The Boeing 787-9 Dreamliner reported its position via the GPS signal as illustrated by the blue lines and dots. The reported position showed a number of gaps and disparate locations, suggesting significant interference with the GPS signal. The orange line in the bottom chart of Figure 4 is based on the Aireon analysis, showing where the aircraft actually was, far from the reported position.

FIGURE 4
Example of an ADS-B track (Dec. 25–26, 2023) showing signs of GPS spoofing (top map) with Aireon's updated reference track plot showing the likely true position of the aircraft throughout its flight (bottom map).

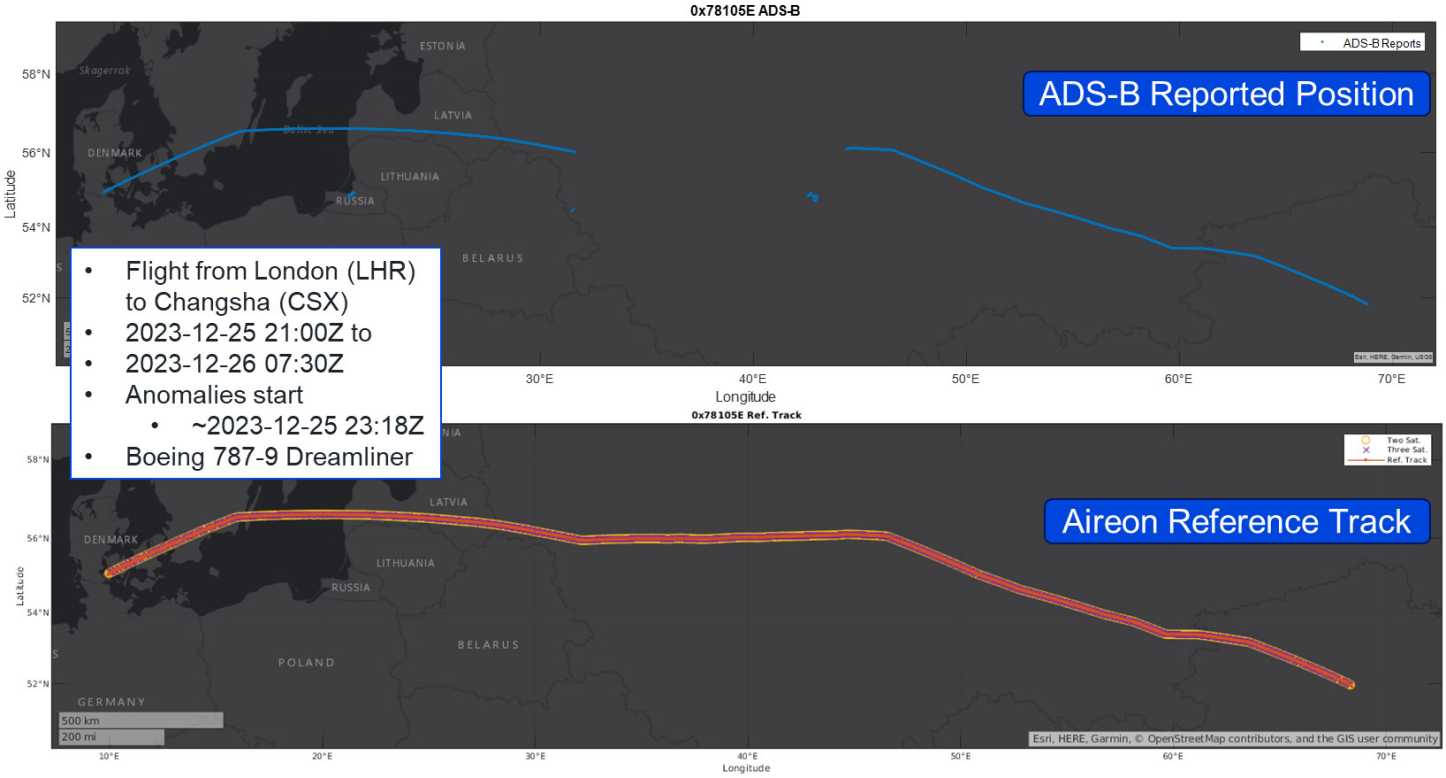


FIGURE 5
This image shows the probably inference of the GPS signal on the aircraft. The blue circles illustrate the aircraft reported ADS-B positions. The yellow x's are locations where Aireon had two satellites detect a single ADS-B message, and the magenta squares are where Aireon had three or more satellites detect a single ADS-B message. The green dots & line are the reference track final output which you can see runs along with all the multi-satellite detections.

Next steps

The problem of GPS interference — whether intention or unintentional — is likely to remain for quite some time. The critical need for the aviation industry is to develop redundant, back-up solutions in order to continue to operate the aircraft. The need to develop real-time tools for operations is critical.

Aireon is developing new data products and is refining its data analytics tools to provide resources for its customers with the goal of improving safety and situational awareness.