International Civil Aviation Organization

Twenty Eighth Meeting of the Communications/ Navigation and Surveillance Sub-group (CNS SG/28) of APANPIRG

Bangkok, Thailand, 01-05 July 2024

Agenda Item 6: Navigation

6.3 GNSS Interference and Mitigating Measures

RAISING INDUSTRY AWARENESS OF GNSS INTERFERENCE AND SEEKING INDUSTRY COOPERATION

(Presented by AIREON)

SUMMARY

This paper reviews the importance of industry cooperation to ensure that deliberate interference with GNSS is reduced to the extent possible, while reviewing existing regulatory actions and proposed mitigating frameworks

1. INTRODUCTION

1.1 GNSS has become a core infrastructure for aviation, serving important roles globally and all stages of flight, allowing applications to reduce aircraft separations, efficient approaches to arrivals, accurate tracking for air traffic management, TCAS collision avoidance, among many other critical services.

1.2 Significant efforts have been done by ICAO, ANSPs, and Industry Organizations such as IATA, IFALPA among other, raising concerns while working on regulatory frameworks, coordination initiatives, among others. However, during the last years elevated levels of GNSS RFI have been increasingly occurring in various regions, including spoofing and jamming.

1.3 With this paper, Aireon intent to raise awareness, while calling for collaborative actions, monitoring efforts, and industry cooperation to detect, mitigate and finding strategies to ensure reliability in GNSS and Positioning, Navigation, and Time (PTN) services in aviation.

2. DISCUSSION

GNSS provides required navigation and timing performance for flight operations, activities and procedures around the world. Global Positioning System (GPS) and Galileo infrastructures might be subjected to interference, which can be natural (such as weather related) or intentional (e.g., jamming and spoofing). During the last years, spoofing and jamming incidences have been reported by airlines

and ANSPs, causing a direct impact to the integrity of Positioning, Navigation, and Timing (PNT) services across several regions. While 'Jamming' blocks a signal, 'spoofing' refers to sending false information to the receiver on board the aircraft. Higher numbers of pilot and automated reports have been raised (in occasions related with zones of geopolitical conflict).

Monitoring and mitigation measures against GNSS RFI has become a critical risk management activity for airlines with few pragmatic options currently available to guarantee operational integrity, considering increasing levels of deliberate RFI, jamming, and spoofing.

2.1 International regulatory actions and activities:

During the recent years, ICAO, EASA, IATA, among others have contributed to raising awareness towards on detecting, reporting and mitigating GNSS Interferences.

In 2019, at the 40th Session of the Assembly some papers were introduced, emphasizing the need for a strong CNS systems resilience and to mitigate interference to GNSS. The Assembly agreed with the proposals and recommended that the Council act with urgency on measures aimed at elimination of harmful interference. In 2022, the 41st Session of the Assembly called for actions to strengthen CNS systems resilience and mitigate interference to GNSS. Paper A41-WP/97 presented/co-sponsored by over 100 States called for further action to mitigate GNSS and strengthen CNS system resilience's.

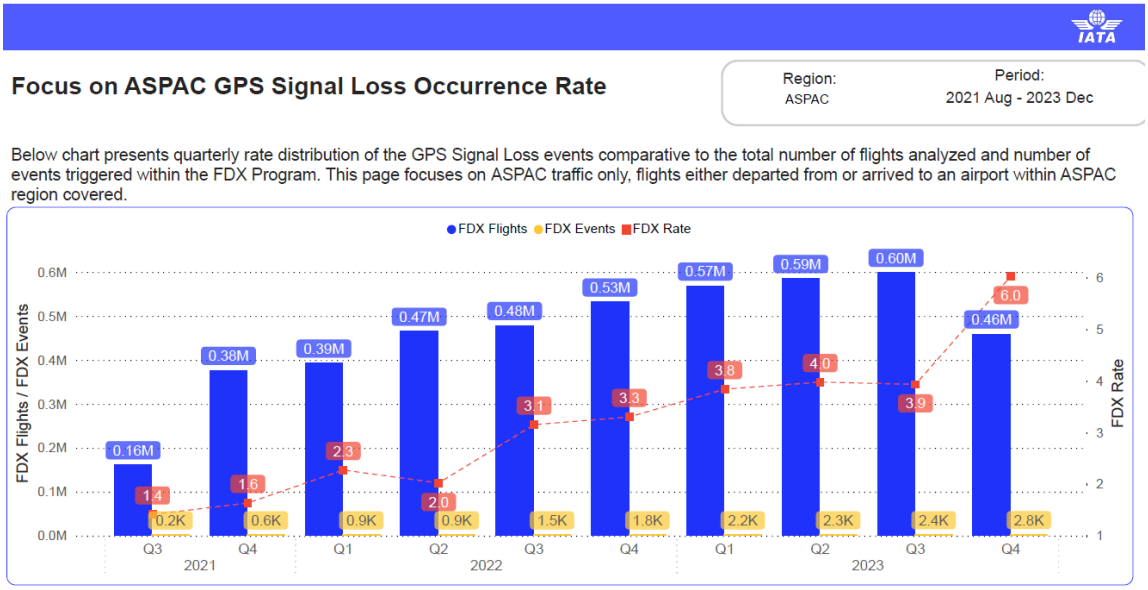
In January 2024, EASA (European Aviation Safety Agency) and IATA carried out a workshop, in which they shared information on reported GNSS RFI events and potential mitigation measures. Some of the conclusions included the stating that interferences with satellite-based services can pose significant challenges to aviation safety. Mitigating these risks requires short-, medium- and long term measures, beginning with the sharing of incident information and remedies. Measures agreed by the workshop to make PNT services provided by GNSS more resilient, including the need of reporting and sharing of GNSS interference event data, and collaborative efforts among aviation stakeholders.

The urgency of the matter was also highlighted by ICAO Secretary General, Mr. Salazar, on 30th April 2024 ICAO State Letter Ref.: E 3/5-24/54 "Aviation safety concerns regarding interference to the Global Navigation Satellite System (GNSS)", highlighting the critical operational issues associated with GNSS interference, and to foster discussions on the management of GNSS vulnerabilities and potential mitigation measures.

2.2 Regional context in Asia.

Eighth Meeting of the Spectrum Review Working Group (SRWG/8) of APANPIRG was held in ICAO APAC Regional Office from 5 to 7 March 2024. The meeting adopted the example forms for GNSS Interference Reporting to States through Decision SRWG/8/5 GNSS Interference Reporting Form for APAC. This GNNS Reporting form, including samples, were circulated by State Letter Ref.: T 8/5.10 – AP052/24(CNS) on 23 April 2024, signed by Regional Director Tao Ma.

In this same event IATA presented an analysis on the GPS Signal Loss occurrences during the period August 2021 to December 2023 using the data provided by airlines subscribed to FDX Program. IATA presented a rate distribution of the GPS Signal Loss events comparative to the total number of flights analysed and number of events triggered within the FDX Program. ASPAC traffic chart presents an increase of GPS Signal Loss occurrences, from Q3 2021 (1.4% of occurrences) to Q4 2023 (6.0% of occurrences).



IATA ASPAC Quarterly Traffic Vs GPS Signal Loss Events

In addition, IATA presented a list of the number of GPS Signal event happening by FIR in ASPAC, comparing events from 2021 to 2023. The table below displays the significant increase of events year to year (in order: Yangon, Delhi, Lahore, Kuala Lumpur, Incheon, Karachi, Dhaka, Mumbai, Chennai)

TOP15 FIR per event count per year

FIR	2021	2022	2023	Total
VYYF	2	378	3483	**3863**
VIDF	61	171	758	**990**
OPLR	78	116	638	**832**
WMFC	12	169	204	**385**
RKRR	11	103	136	**250**
OPKR	33	75	141	**249**
VGFR	4	197	16	**217**
VABF	26	66	124	**216**
VOMF	26	64	101	**191**
VVHN	2	72	73	**147**
WSJC	8	106	20	**134**
WAAF	7	57	67	**131**
VECF	1	43	85	**129**
WIIF	7	48	27	**82**
RJJJ	21	17	40	**78**
Total	**299**	**1682**	**5913**	**7894**

IATA ASPAC GPS Signal Loss Events by FIR – 2021 to 2023

During the Ninth Meeting of the Surveillance Implementation Coordination Group (SURICG/9) held in Bangkok, Thailand, 07 - 10 May 2024, Secretariat presented WP/04 “ICAO Recommendations and Guidance on GNSS Vulnerability”. The Meeting discussed new improvements in ADS-B avionics, which will transmit the GNSS interference status to a ground station, and pointing out that Aireon space-based ADS-B payload can mitigate the situation through a satellite-based MLAT solution.

A white paper and several cases of study has been prepared by Aireon, and some of them will be presented by Aireon following this paper in this meeting (Attachment 1).

2.3 Conclusion

GNSS RFI poses a major challenge for the aviation sector. To address these issues effectively, cooperation among regulatory bodies, industry players, and international organizations is crucial. Through the development of comprehensive strategies, GNSS RFI Monitoring tools, enhancement of regulatory frameworks, and the promotion of global collaboration, the aviation industry can maintain the reliability and integrity of PNT systems.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate

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Real-time GNSS Interference and Spoofing Detection, Monitoring, and Analysis

July 2024

GPS Integrity and Threat Detection

ICAO APAC CNS SG/28

What are GPS Integrity anomalies?

Jamming and Interference

Involves the deliberate transmission of radio frequency signals that overwhelm the GNSS signals, or from faulty electronic devices, radio transmitters, or other equipment emitting signals within the GNSS frequency bands.

Jammers can be used maliciously to disrupt GNSS signals over a wide area (up to 250 NMi).

Signal Multipath

Multipath interference occurs when GNSS signals reflect off surfaces such as buildings, terrain, or other structures, causing multiple signals to be received by the GNSS receiver at different times.

Often occurs at or near airports. Can lead to errors in position calculation on a single flight.

GNSS Signal Spoofing (Deception)

Spoofing involves transmitting counterfeit GNSS signals that appear authentic but provide incorrect position, navigation, and timing information.

This can mislead GNSS receivers, potentially causing significant safety and security risks in aviation.

Transponder Signal Deception

1090 MHz spoofing involves the creation and transmission of false signals that mimic legitimate aircraft transponder communications. This can lead to the display of incorrect aircraft positions, identities, or other flight data on air traffic control systems and aircraft avionics.

Aviation must be resilient to all potential GNSS threats

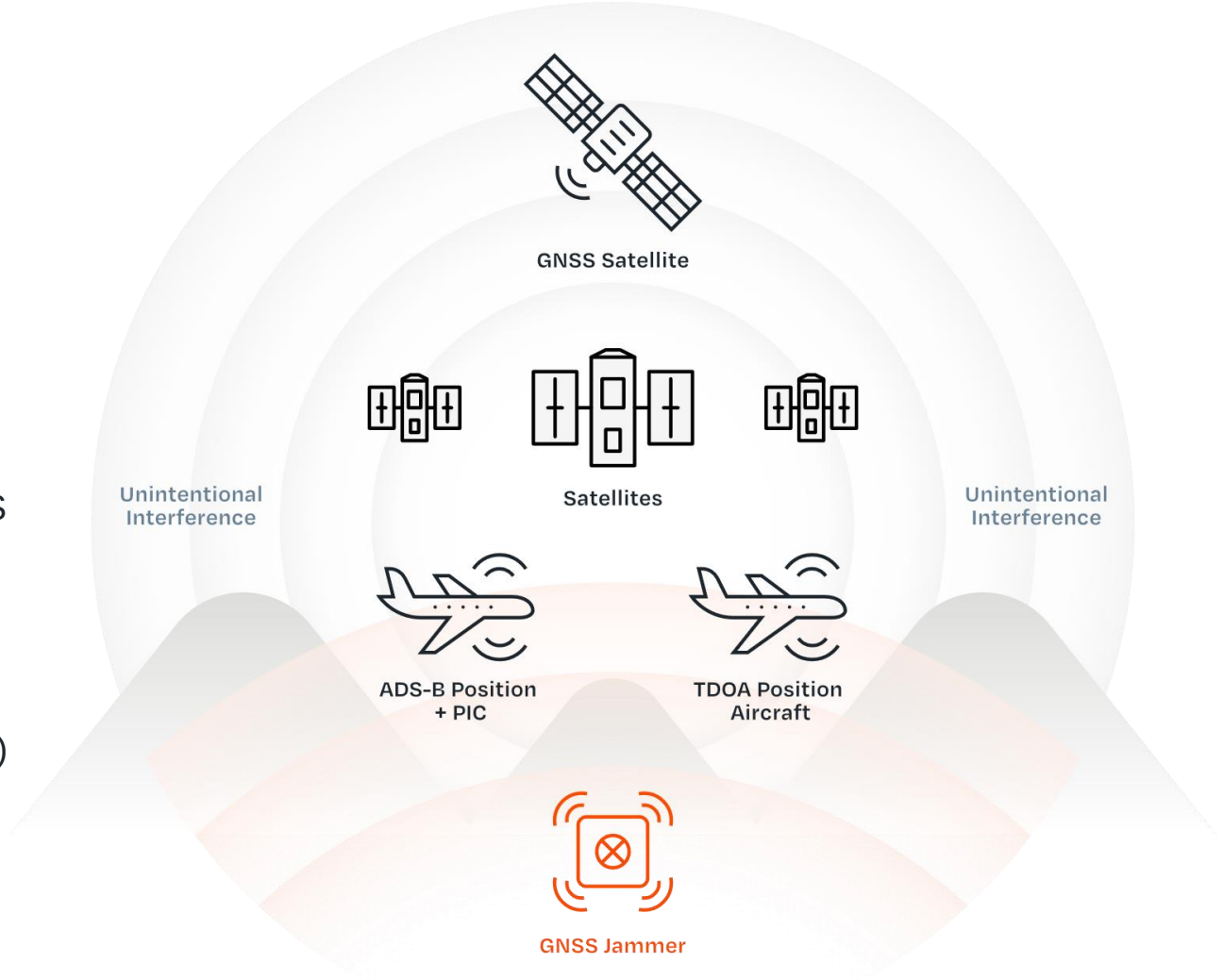
What types of position anomalies can be detected?

Unintentional

- GNSS/GPS Interference (terrain, multipath, space weather, L-Band noise)
- Malfunctioning avionics or aircraft GNSS receiver
- Malfunctioning GNSS constellation or payload

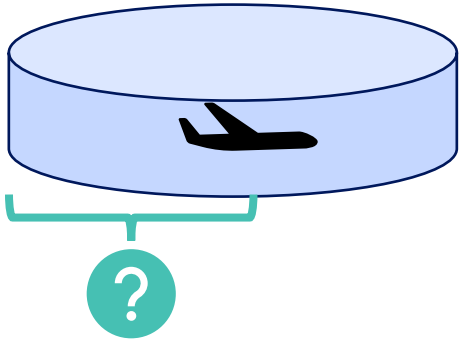
Intentional

- GNSS/GPS Interference (Ground-based, Air-based)
- GNSS/GPS Interference with a stronger GNSS/GPS signal (signal spoofing)
- Malfunctioning avionics (cyber event)
- ADS-B message spoofing (non-aircraft transmissions)



How does Aireon Detect GNSS events?

Real-time Monitoring
GPS Quality Reports from Aircraft

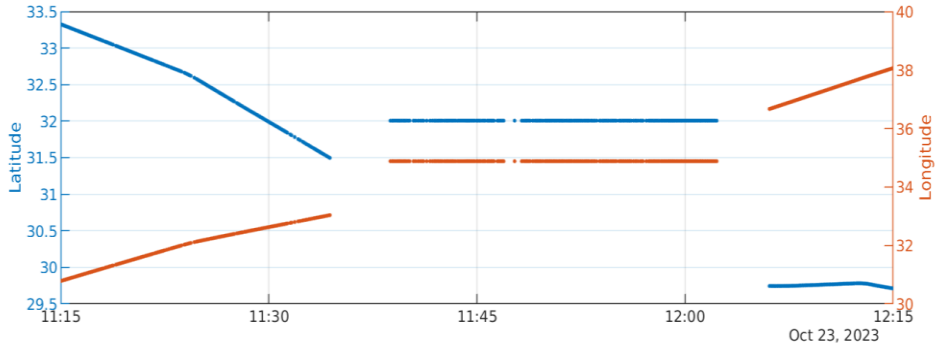


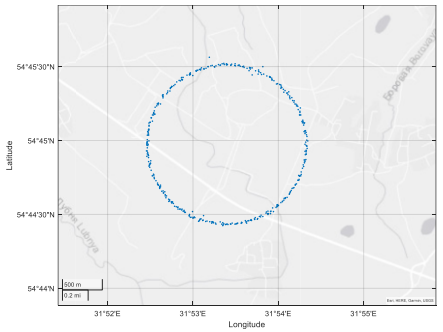
ADS-B position inconsistent with independent sources

Anomalous ADS-B Message (FTC0)

Latitude	Longitude
Unknown	Unknown

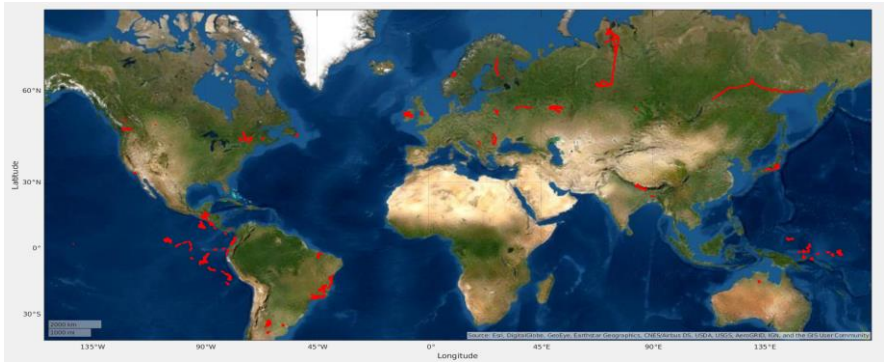
Anomalous Trajectory Data





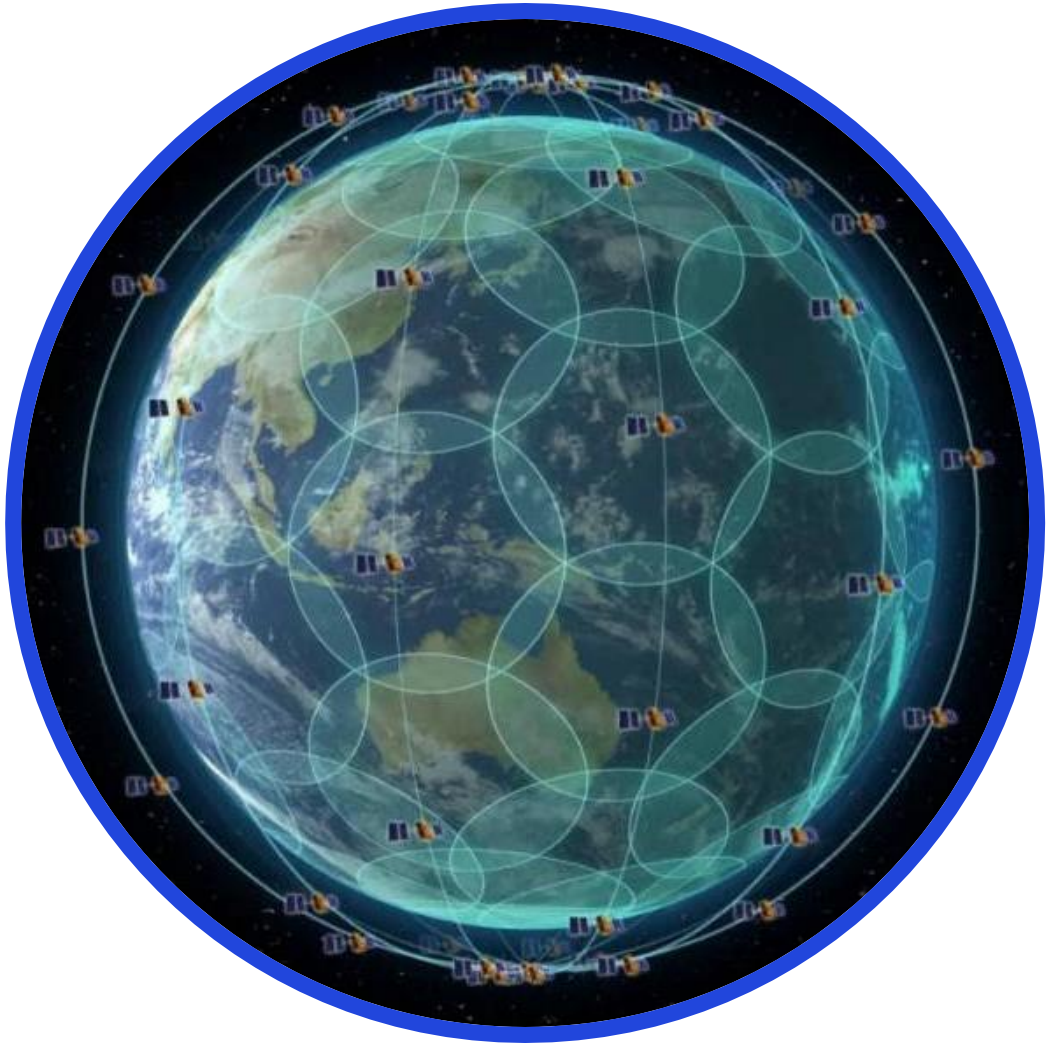
Known Risk Identification

Duplicate Address Behavior

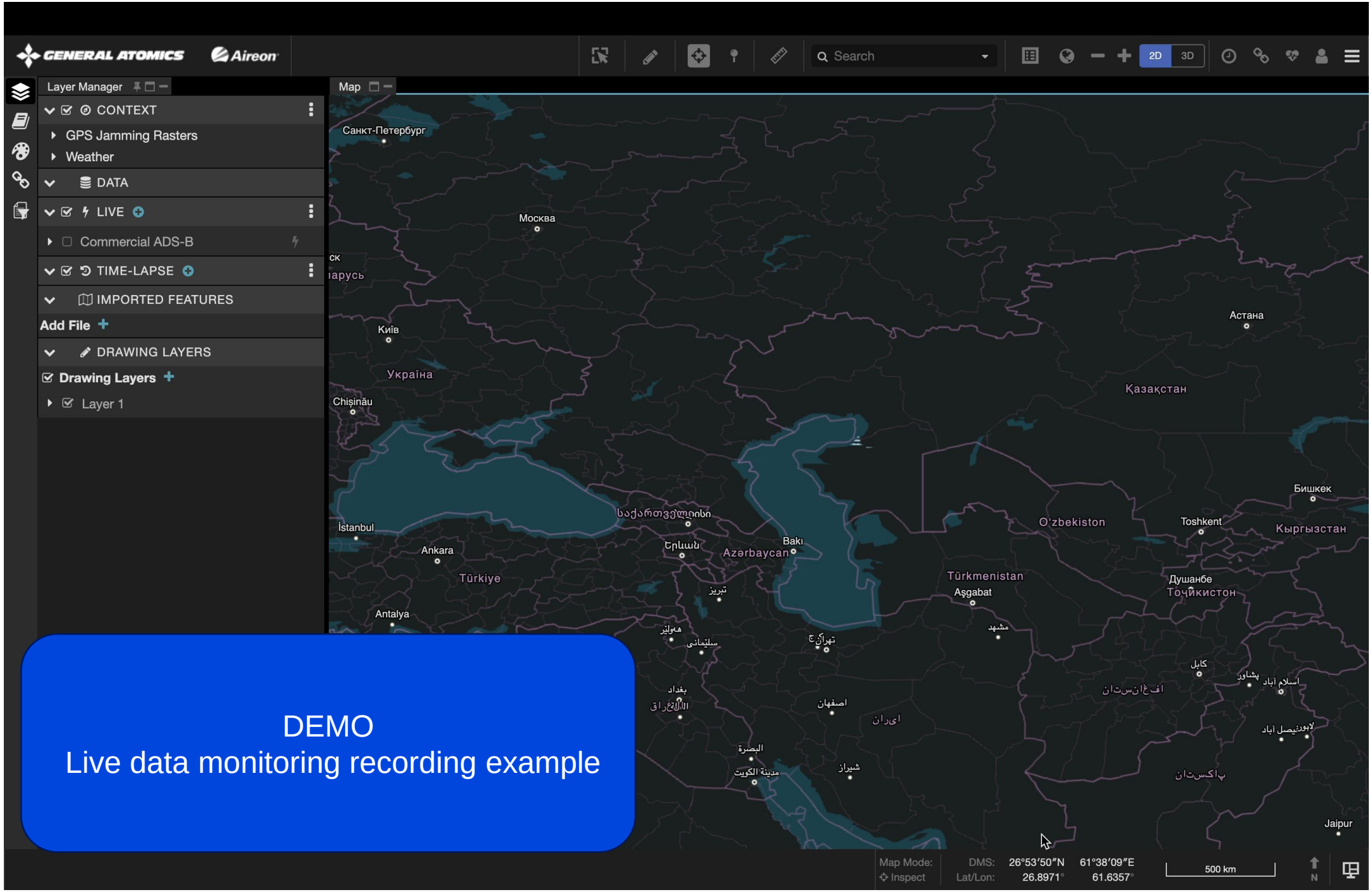


Why is Aireon’s Space-based technology advantageous for GNSS Interference detection?

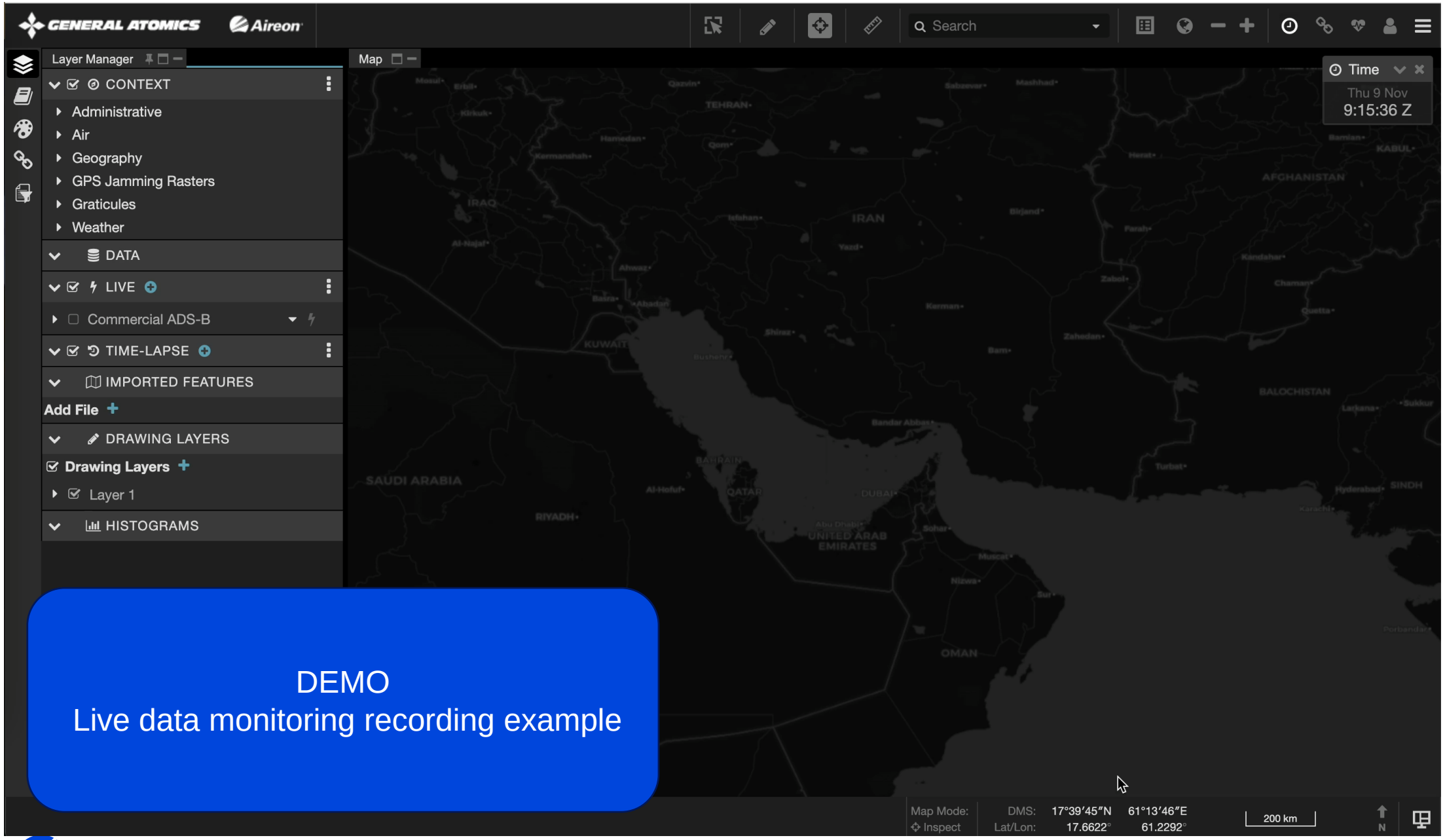
- Global persistent coverage
- Normalized Data that is processed by a system that is certified to standards
- Low latency "real time alerting"
- Multiple payload detection of events
- Time-difference-of-arrival (TDOA) geolocations
- Independent positioning Identification and reference track



Real Time Monitoring and Event Alerts

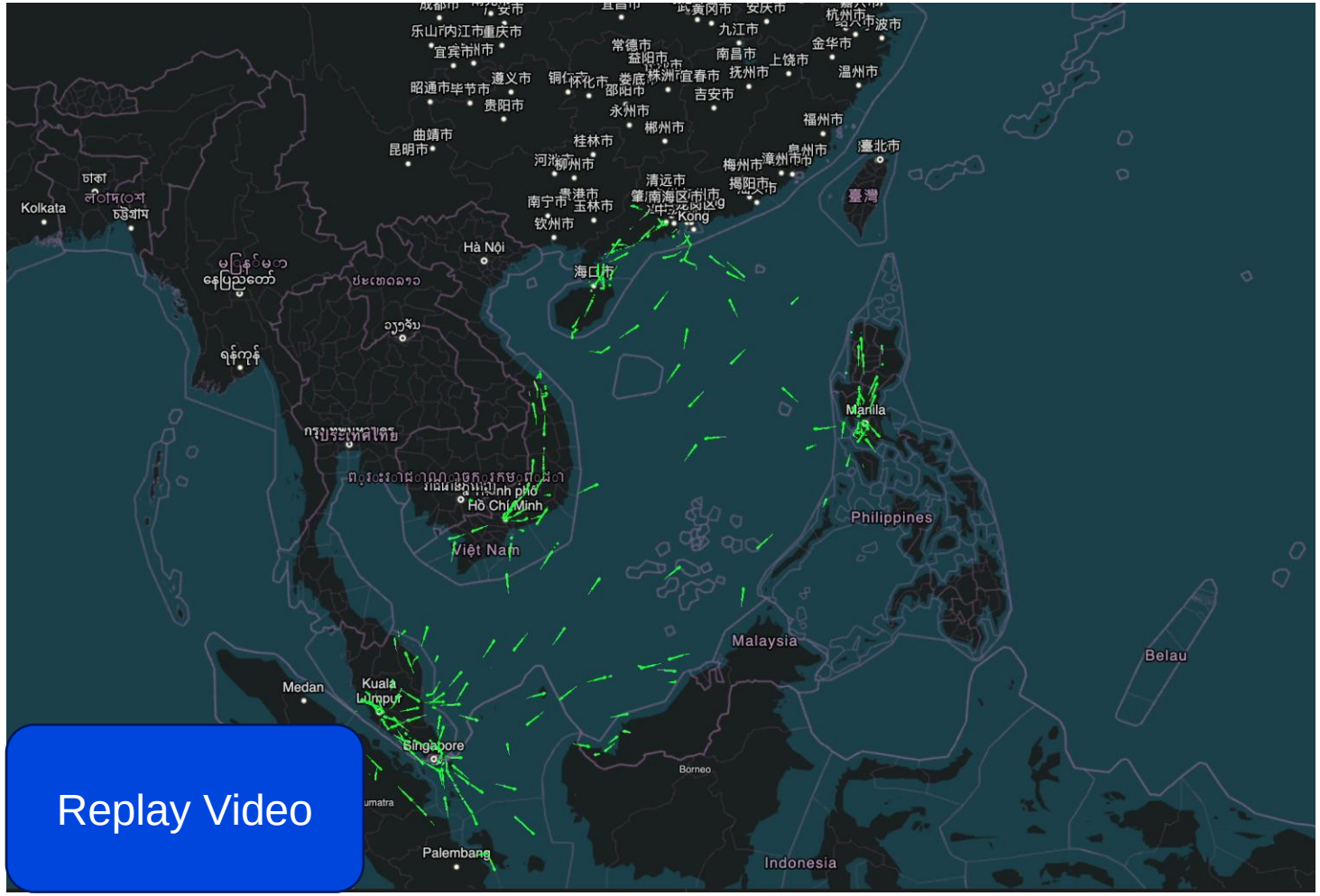

GENERAL ATOMICS
Aireon
Search
2D
3D
Layer Manager
CONTEXT
GPS Jamming Rasters
Weather
DATA
LIVE
Commercial ADS-B
TIME-LAPSE
IMPORTED FEATURES
Add File
DRAWING LAYERS
Drawing Layers
Layer 1
Map
Санкт-Петербург
Москва
Київ
Україна
Chișinău
İstanbul
Ankara
Türkiye
Antalya
საქართველოსი
Երևան
Azərbaycan
Bakı
تبریز
هەولێر
سلێمانی
تهران
مشهد
بغداد
العراق
اصفهان
ایران
البصرة
مدينة الكويت
شیراز
Astana
Қазақстан
Бишкек
Кыргызстан
Toshkent
O'zbekiston
Türkmenistan
Aşgabat
Душанбе
Тоҷикистон
کابل
پشاور
اسلام آباد
افغانستان
لاہور
فیصل آباد
پاکستان
Jaipur
DEMO
Live data monitoring recording example
Map Mode:
Inspect
DMS:
Lat/Lon:
26°53′50″N
61°38′09″E
26.8971°
61.6357°
500 km
N

Post- Event Analysis

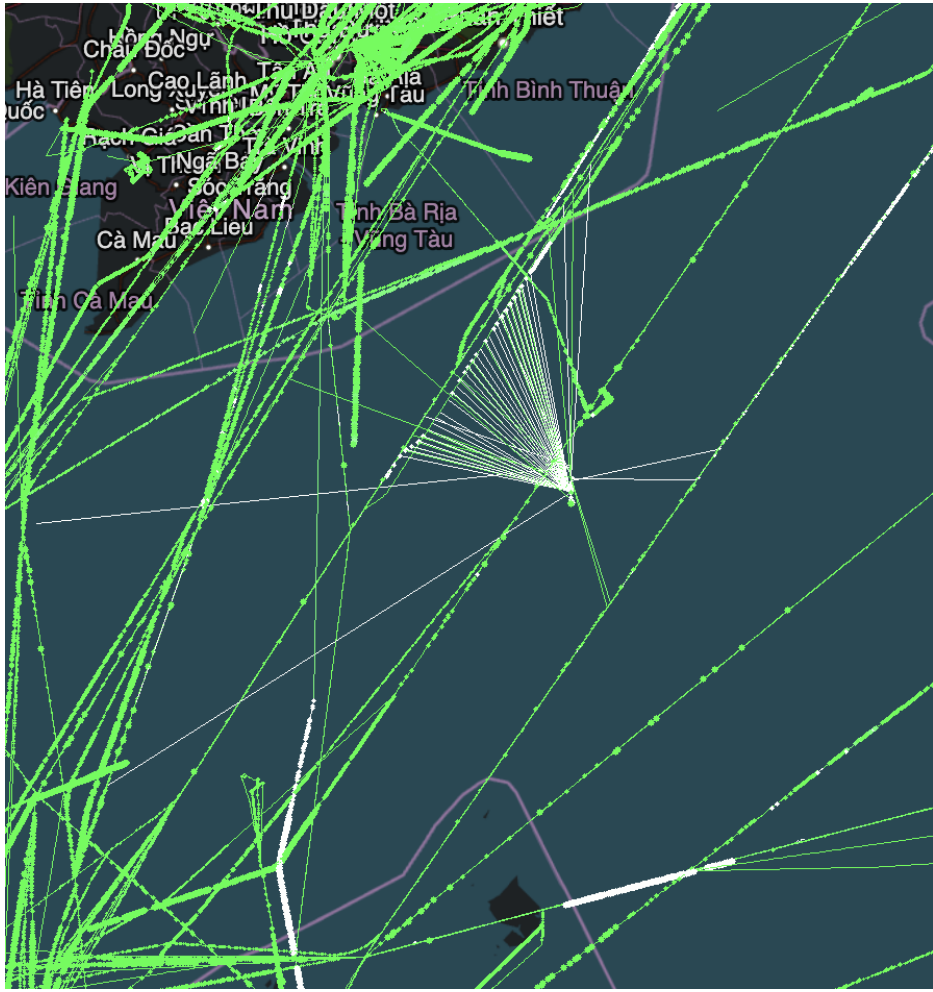


Singapore, Feb 2024

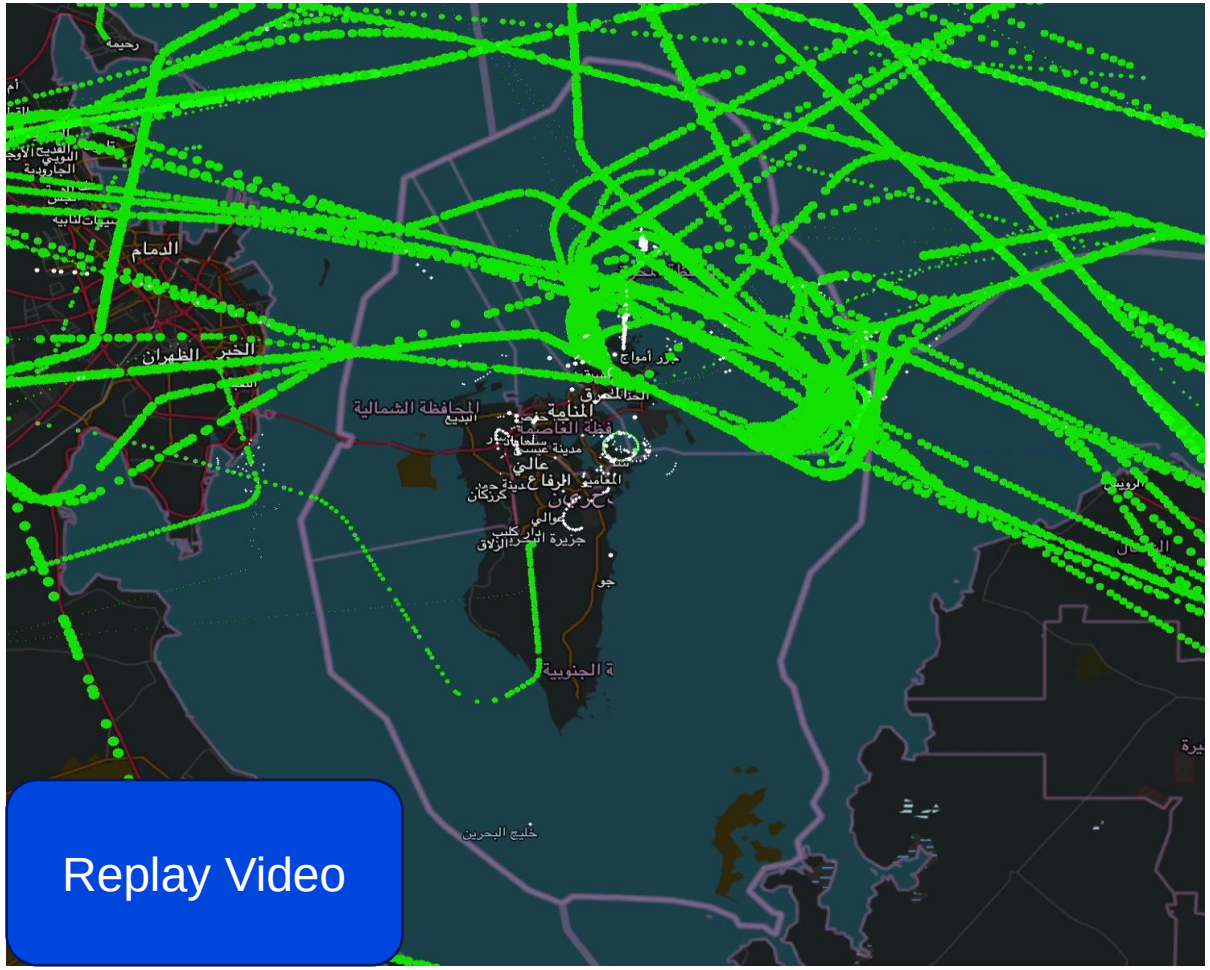
Multiple Aircraft reported GPS navigation issues

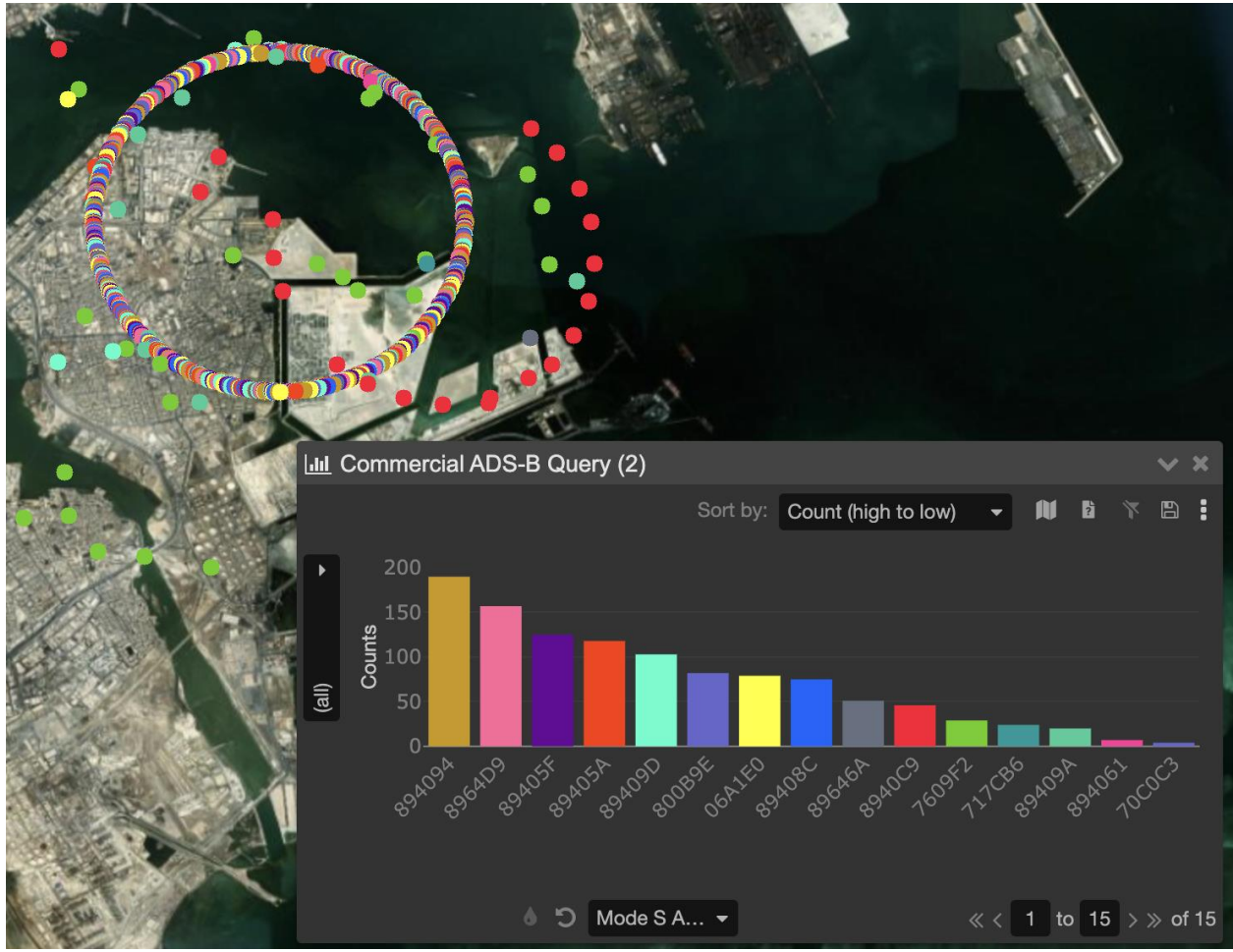


Replay Video

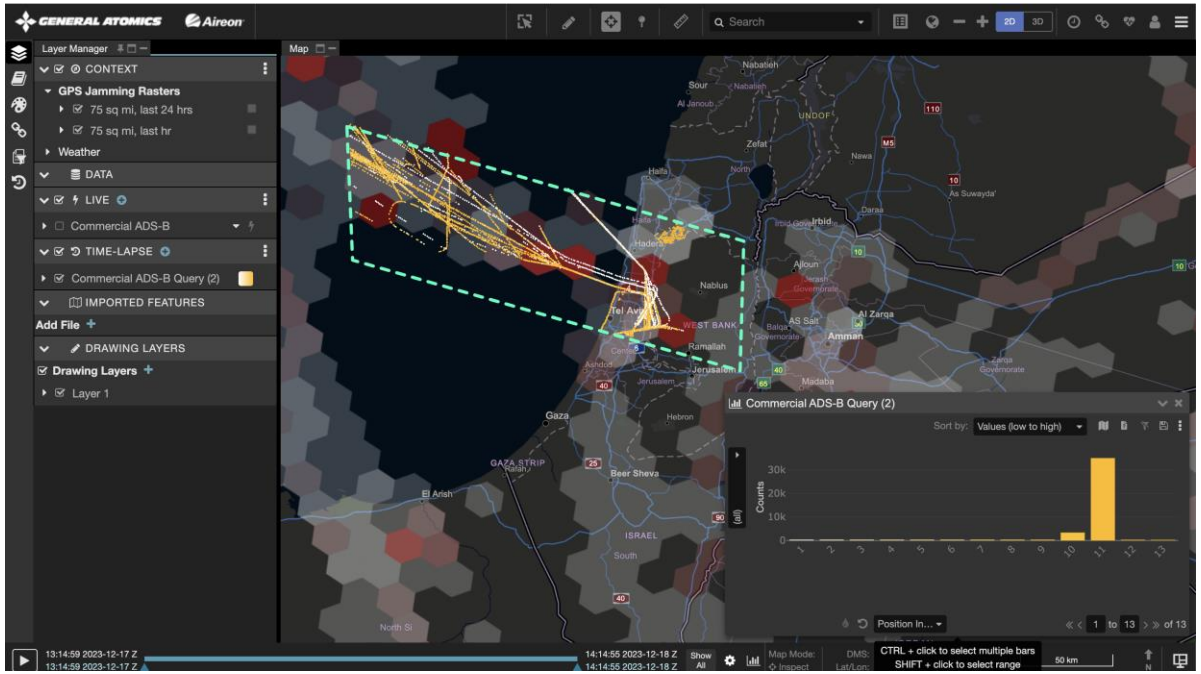


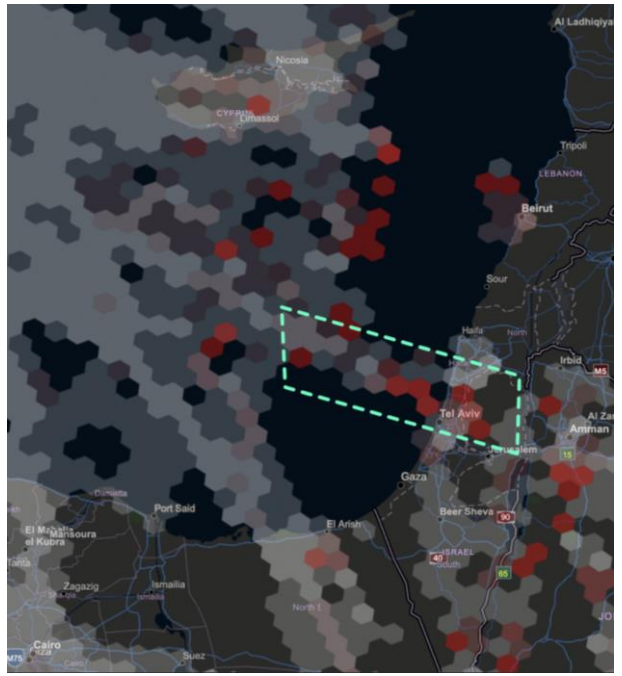
Bahrain, November 2023

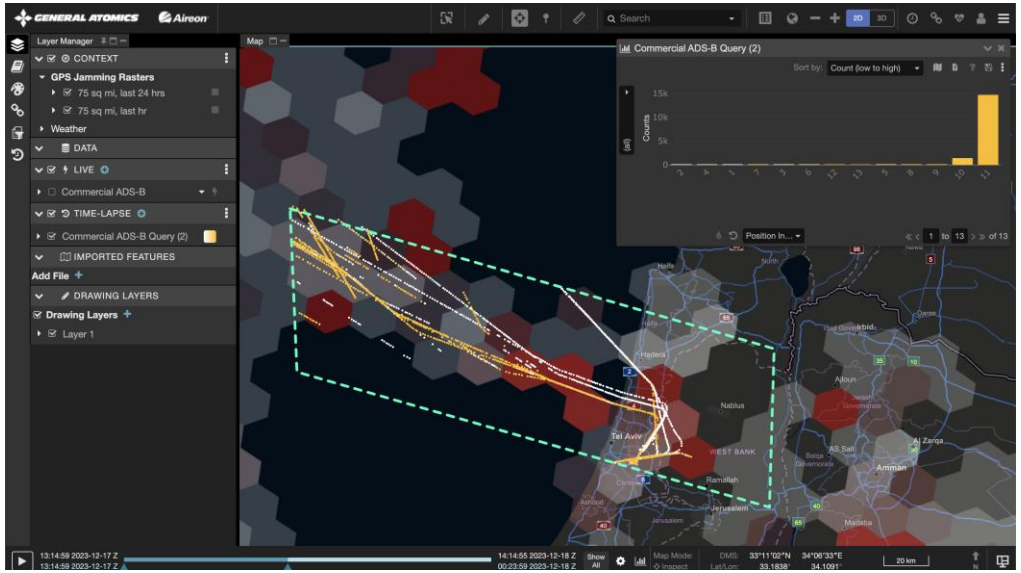


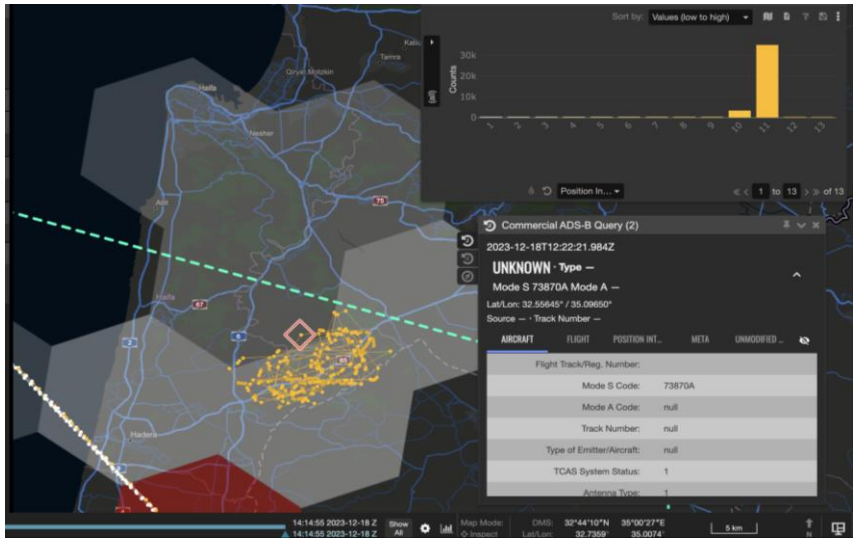


Israel - Real-time Monitoring of Flight Data





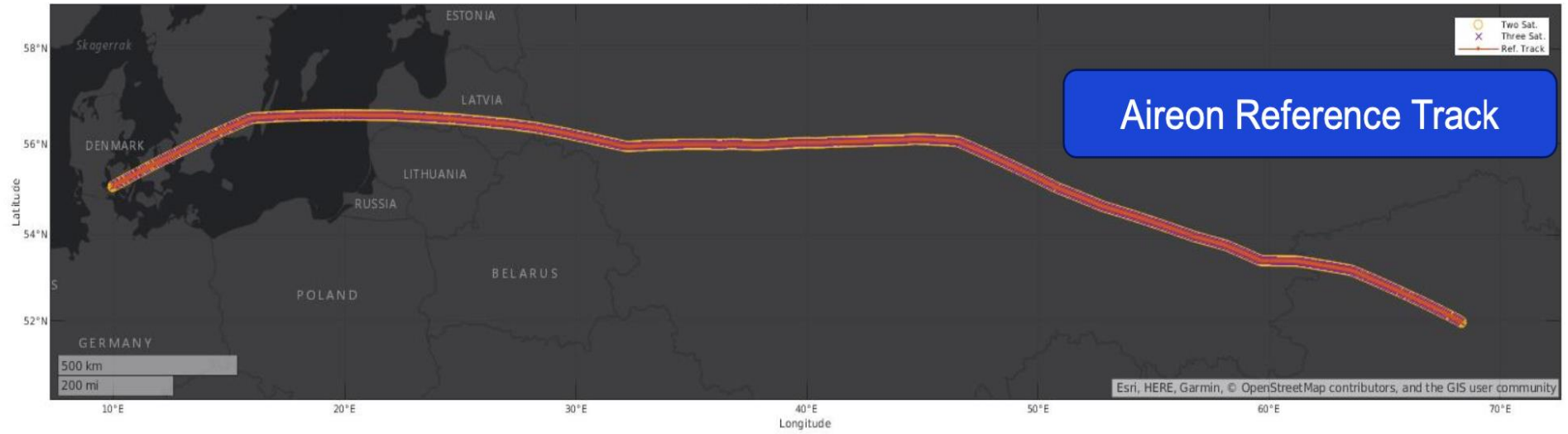




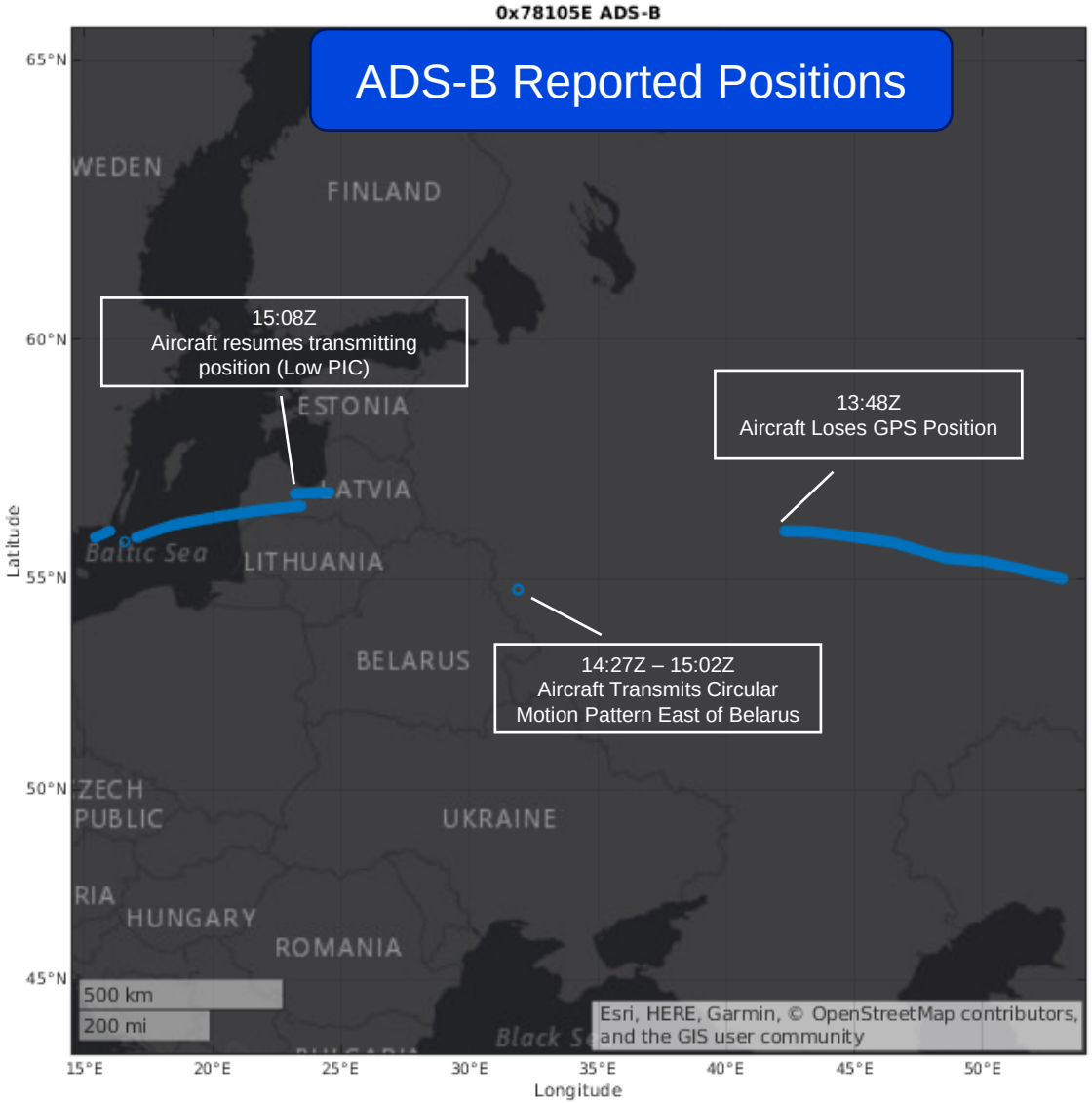
Independent Position Identification and Reference Track

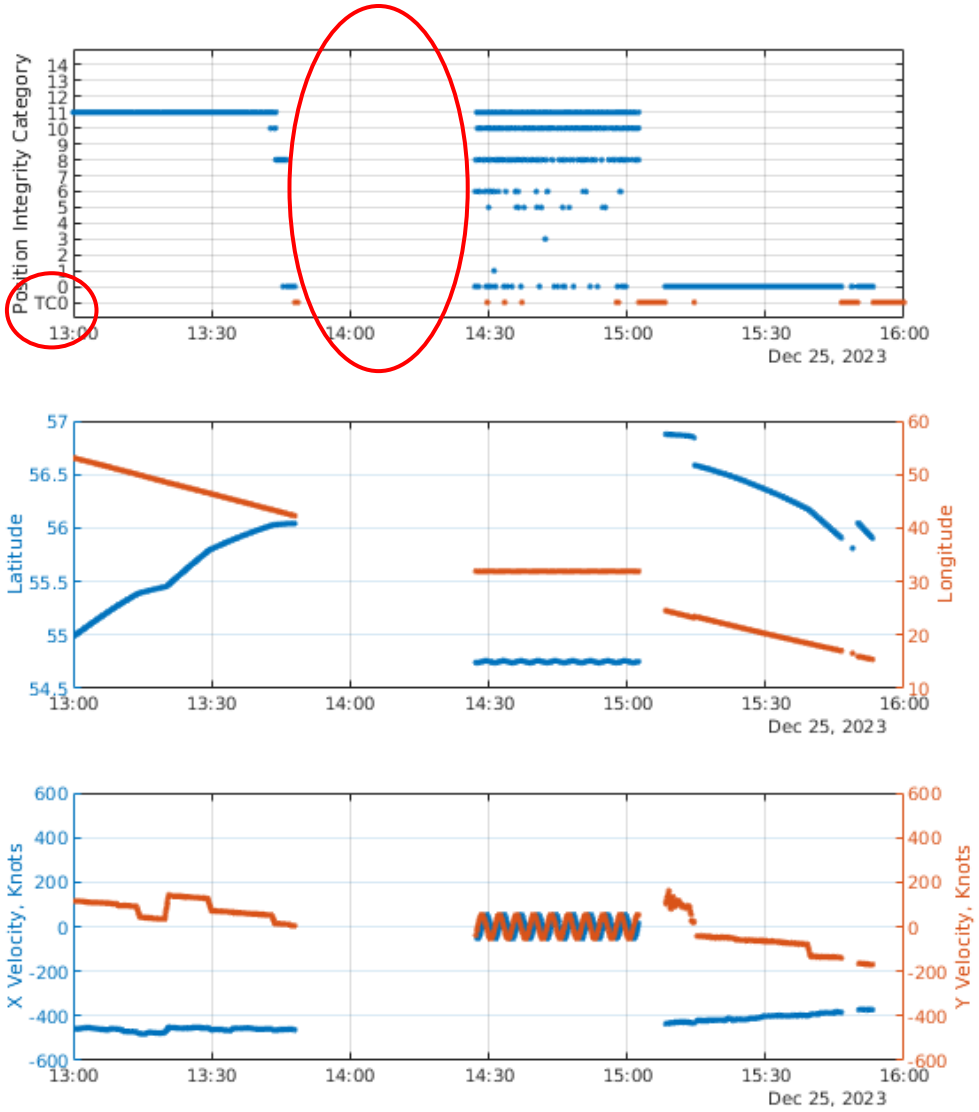
Multilateration and Reference Track

- Leveraging the precision and timing of the Iridium constellation, Aireon can detect the location of a transmitting aircraft even when the position reports are no longer valid
- Allows for the tracking of ADS-B equipped aircraft during periods of faulty avionics or when there may be environmental interference
- Provides resiliant source for GPS Integrity issues

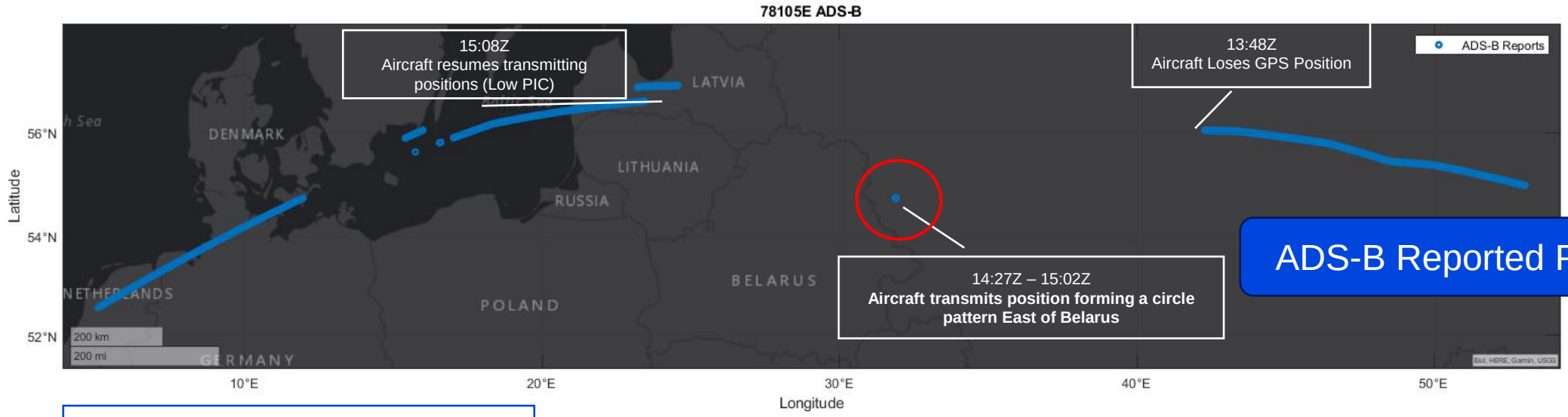


GNSS Interference and Spoofing: 25 December 2023 (CHH764)





GNSS Interference and Spoofing: 25 December 2023 (CHH764)



ADS-B Reported Positions

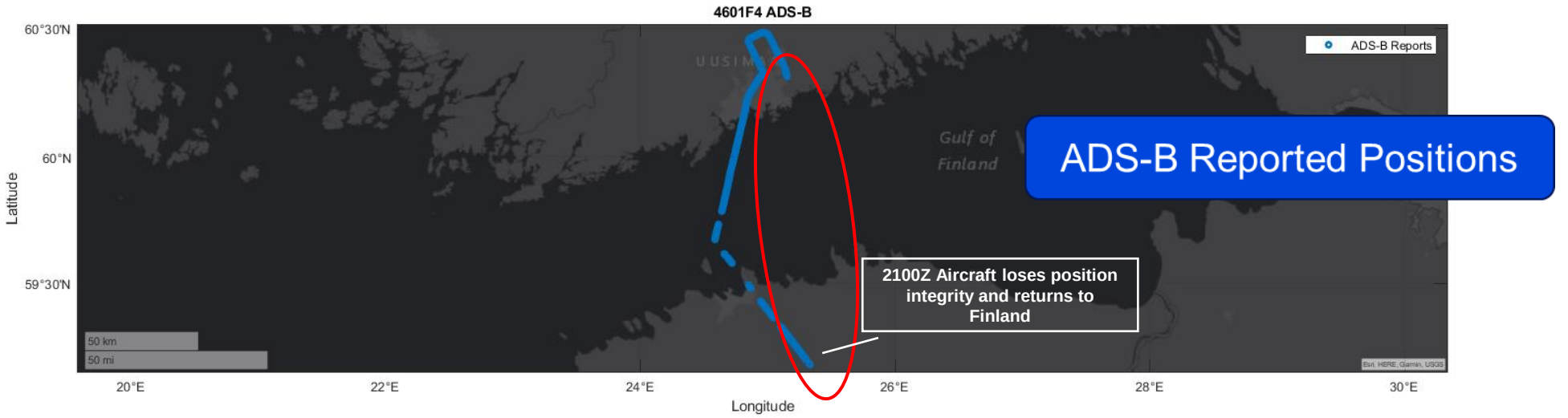
Changsha (CSX) to London (LHR):

- 05:45Z to 18:00Z
- Boeing 787-9 Dreamliner

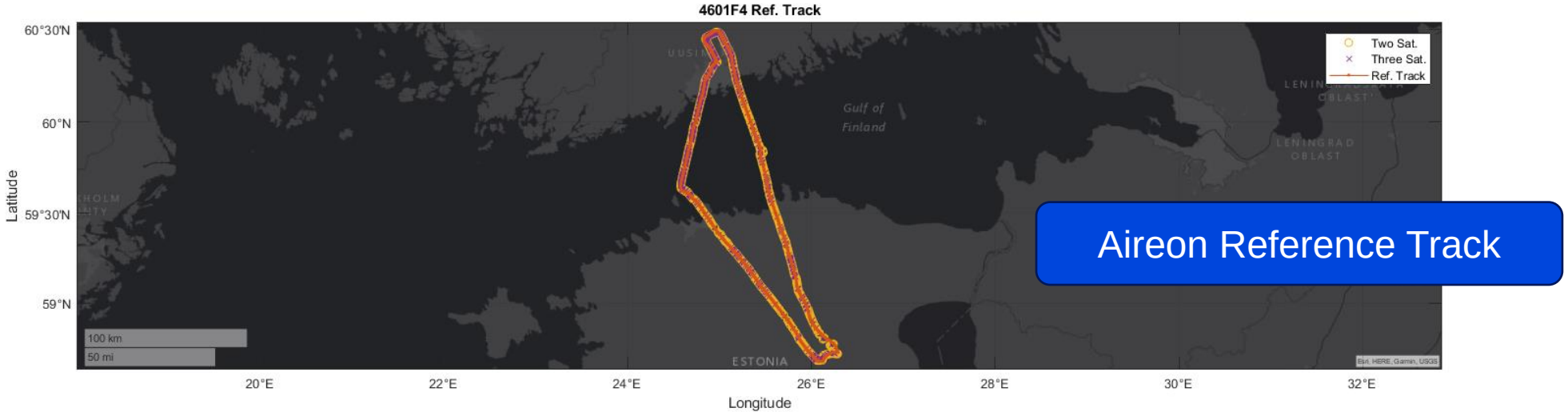
Aireon Reference Track

GNSS Interference & Position Spoofing

GNSS Interference: Finland 26 April 2024



ADS-B Reported Positions



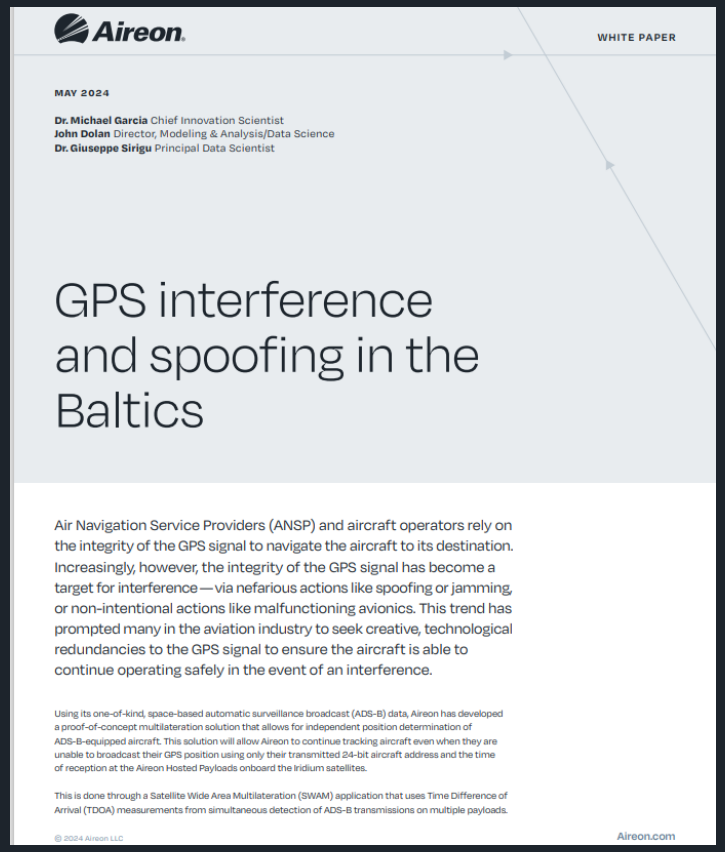
Aireon Reference Track

GNSS Interference

How Aireon is solving the GNSS Interference and Spoofing

- Real-time situational awareness of GPS Performance within Airspace
- Historical analysis of events and geographic GPS performance, Integration with Safety Dashboard
- Development of Independent Position Validation
- Real-time Alerting
- Development of Reference Track

Would you like to learn more?



Aireon

WHITE PAPER

MAY 2024

Dr. Michael Garcia Chief Innovation Scientist
John Dolan Director, Modeling & Analysis/Data Science
Dr. Giuseppe Sirigu Principal Data Scientist

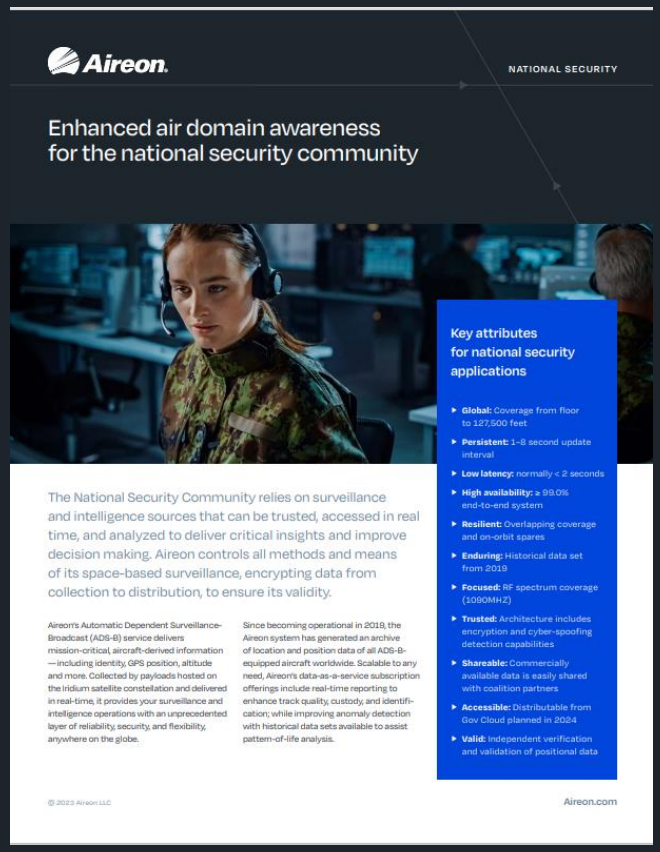
GPS interference and spoofing in the Baltics

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.

Aireon.com



Aireon

NATIONAL SECURITY

Enhanced air domain awareness for the national security community

The National Security Community relies on surveillance and intelligence sources that can be trusted, accessed in real time, and analyzed to deliver critical insights and improve decision making. Aireon controls all methods and means of its space-based surveillance, encrypting data from collection to distribution, to ensure its validity.

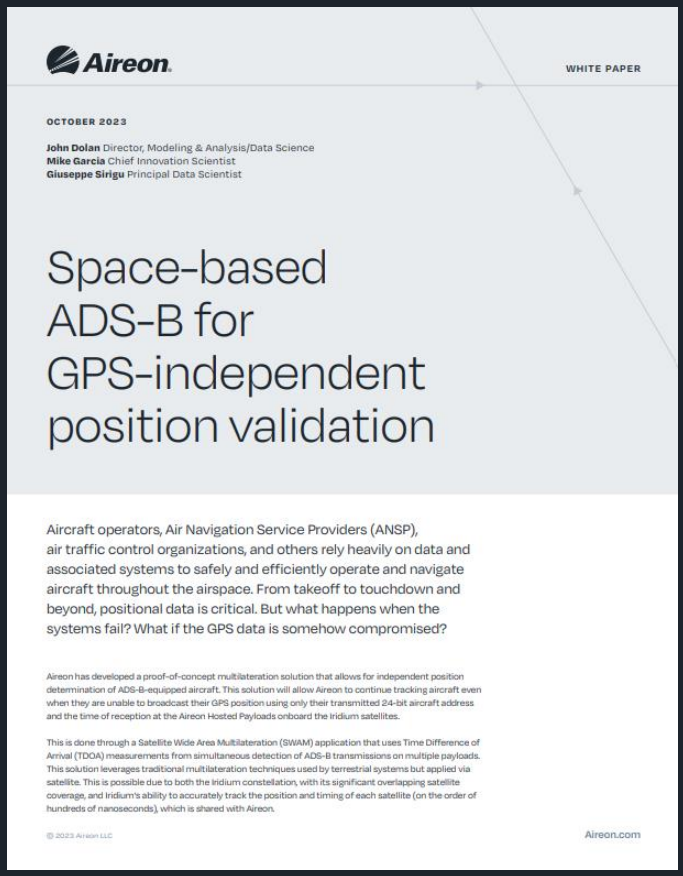
Aireon's Automatic Dependent Surveillance-Broadcast (ADS-B) service delivers mission-critical, aircraft-derived information — including identity, GPS position, altitude and more. Collected by payloads hosted on the Iridium satellite constellation and delivered in real-time, it provides your surveillance and intelligence operations with an unprecedented layer of reliability, security, and flexibility, anywhere on the globe.

Since becoming operational in 2019, the Aireon system has generated an archive of location and position data of all ADS-B-equipped aircraft worldwide. Scalable to any need, Aireon's data-as-a-service subscription offerings include real-time reporting to enhance track quality, custody, and identification; while improving anomaly detection with historical data sets available to assist pattern-of-life analysis.

Key attributes for national security applications

- **Global:** Coverage from floor to 127,500 feet
- **Persistent:** 1–8 second update interval
- **Low latency:** normally < 2 seconds
- **High availability:** ≥ 99.0% end-to-end system
- **Resilient:** Overlapping coverage and on-orbit spares
- **Enduring:** Historical data set from 2019
- **Focused:** RF spectrum coverage (1090MHZ)
- **Trusted:** Architecture includes encryption and cyber-spoofing detection capabilities
- **Shareable:** Commercially available data is easily shared with coalition partners
- **Accessible:** Distributable from Gov Cloud planned in 2024
- **Valid:** Independent verification and validation of positional data

Aireon.com



Aireon

WHITE PAPER

OCTOBER 2023

John Dolan Director, Modeling & Analysis/Data Science
Mike Garcia Chief Innovation Scientist
Giuseppe Sirigu Principal Data Scientist

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.

Aireon.com

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Available at Aireon.com

Thank You

Aireon.com

Diego Albert – Asia Pacific Director
diego.albert@aireon.com