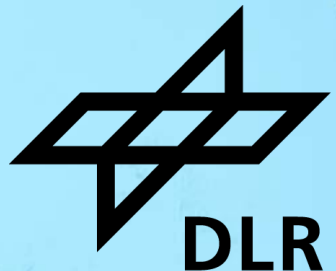# TOWARDS CYBER-SECURE GBAS: INITIAL EXPERIMENTAL SYSTEM VALIDATION

Daniel Gerbeth, Maria Caamano, *German Aerospace Center (DLR)*
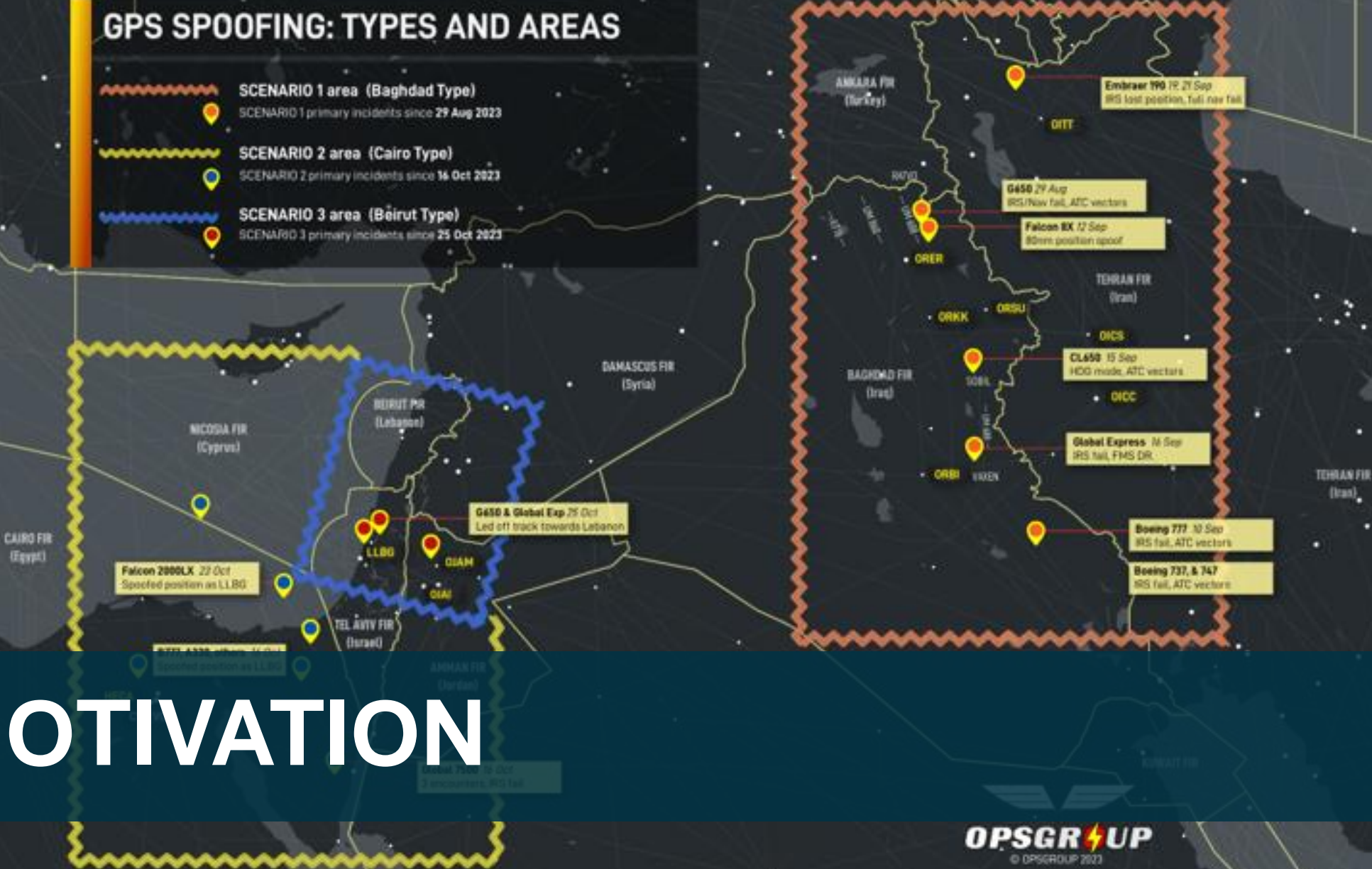
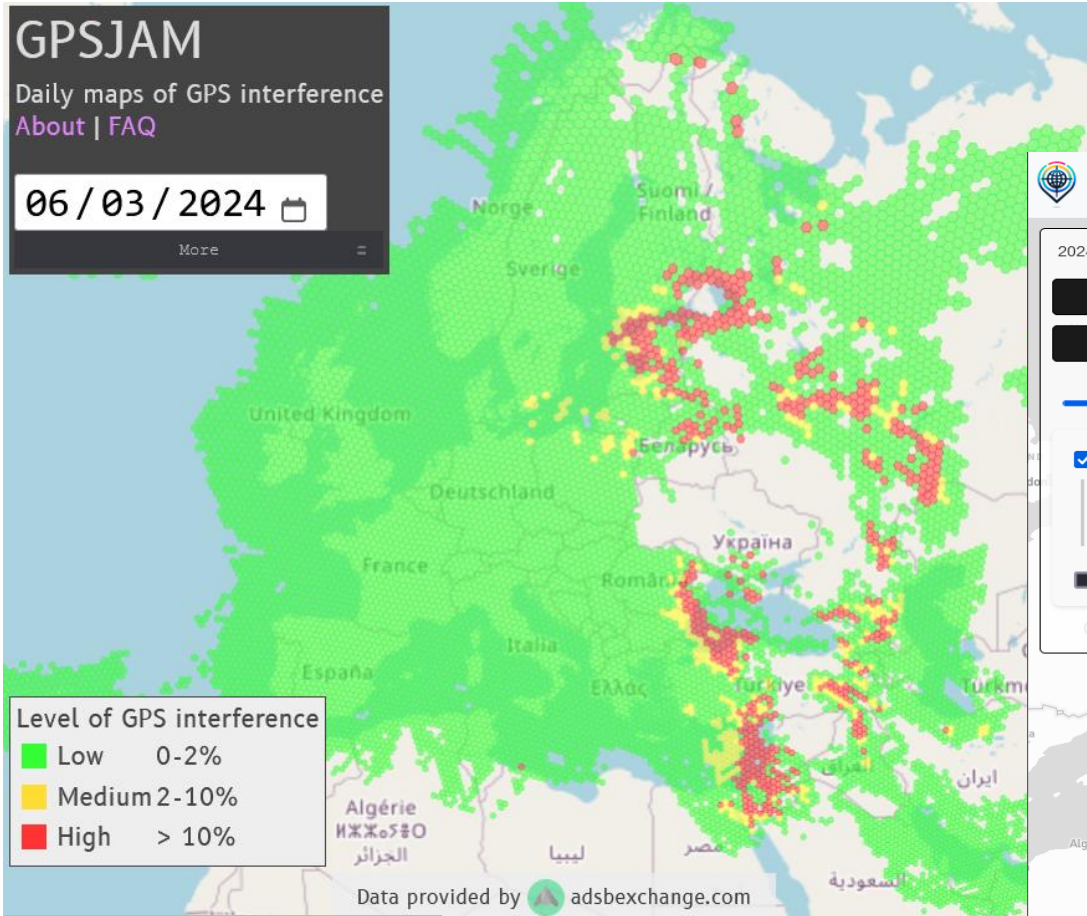*ION GNSS+ 2024, Baltimore, Maryland*

September 18th, 2024

DLR

MOTIVATION

Daniel Gerbeth, German Aerospace Center, September 18th 2024

Cyber Secure DFMC GBAS
Current Situation and Threats

Daniel Gerbeth, German Aerospace Center, September 18th 2024
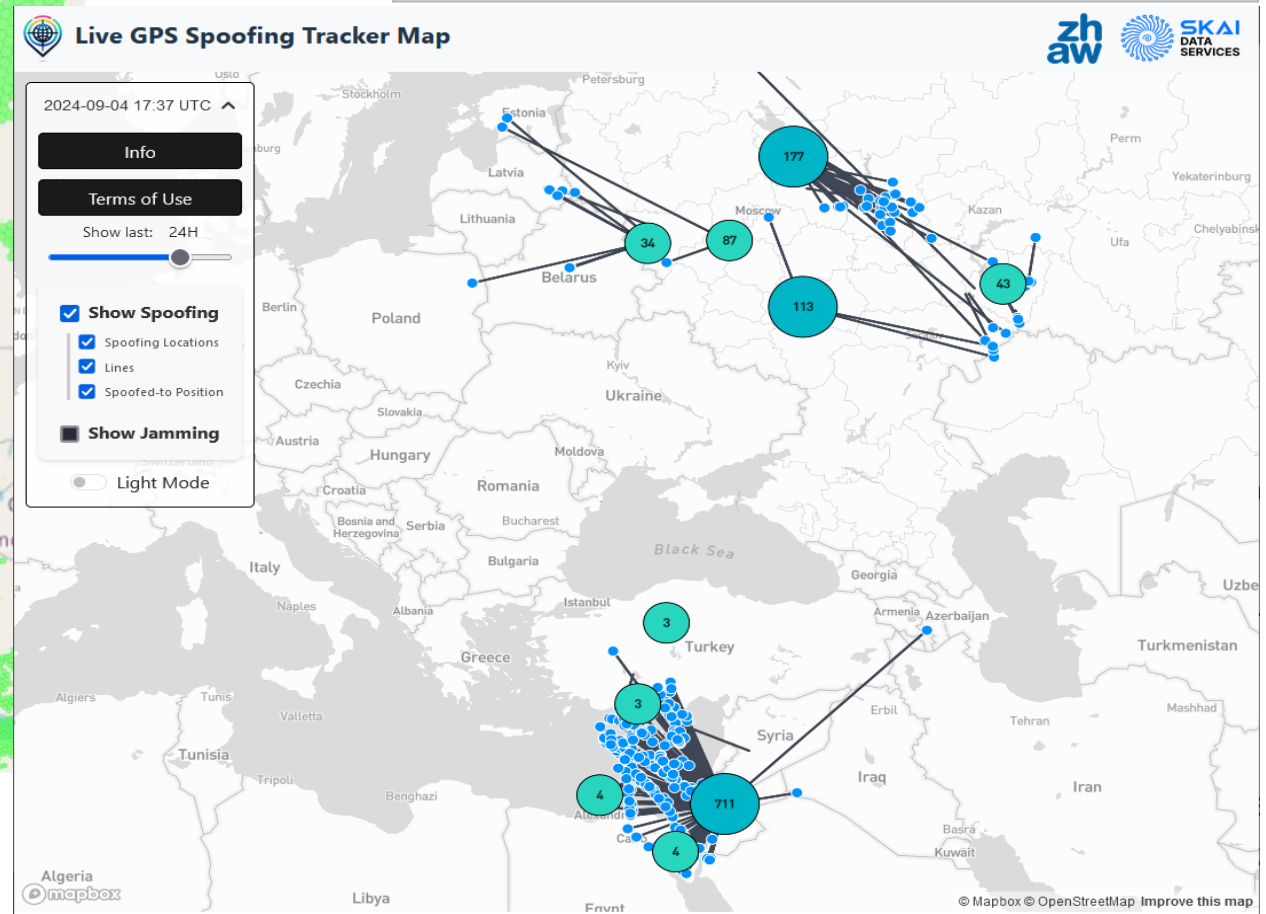
Cyber Secure DFMC GBAS
Current Situation and Threats

- **Increasing number of RFI** events observed in the last years

- Certain areas are **regularly affected** by severe interference (jamming)

- Since autumn 2023, a significant **increase in spoofing incidents** has been observed
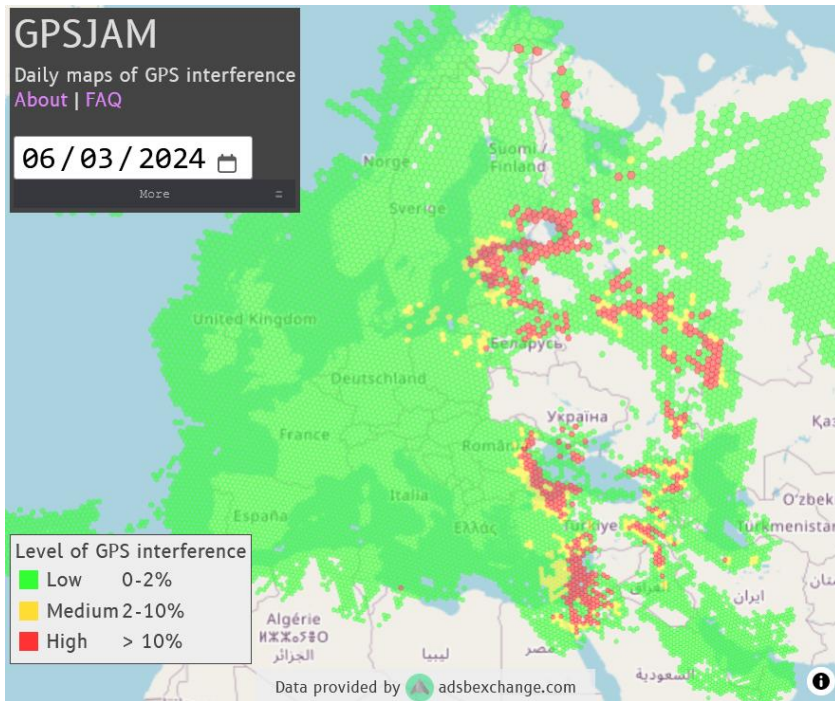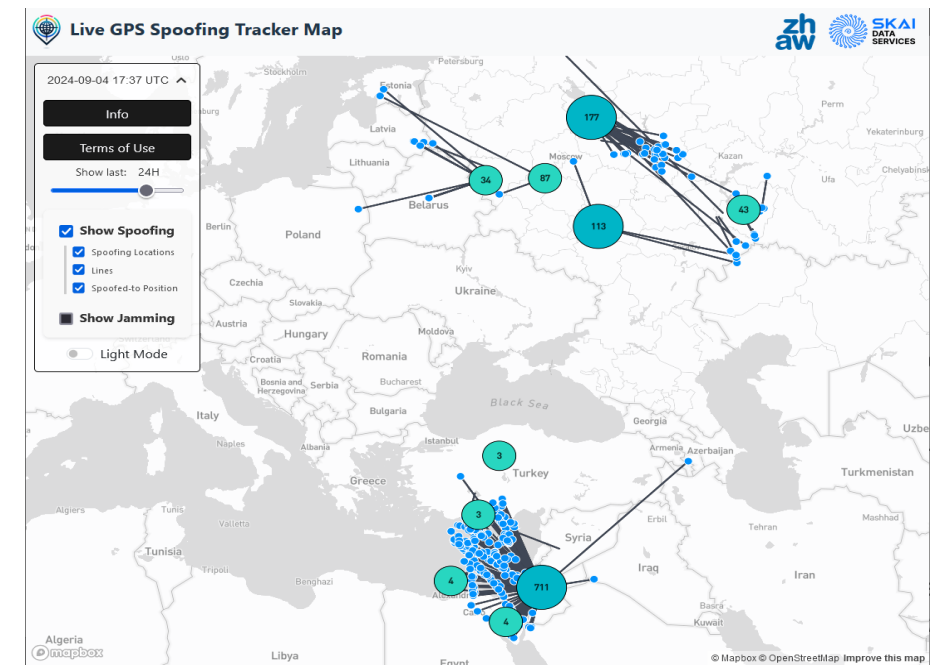
- Cybersecurity threats are an **increasing problem to GNSS**
    - → GBAS as GNSS-based system is **affected similarly**, even more sensitive to interference
    - → MFMC can improve robustness, **but not mitigate ultimately**

https://ops.group/blog/gps-spoofing-update-08nov2023/

Daniel Gerbeth, German Aerospace Center, September 18th 2024
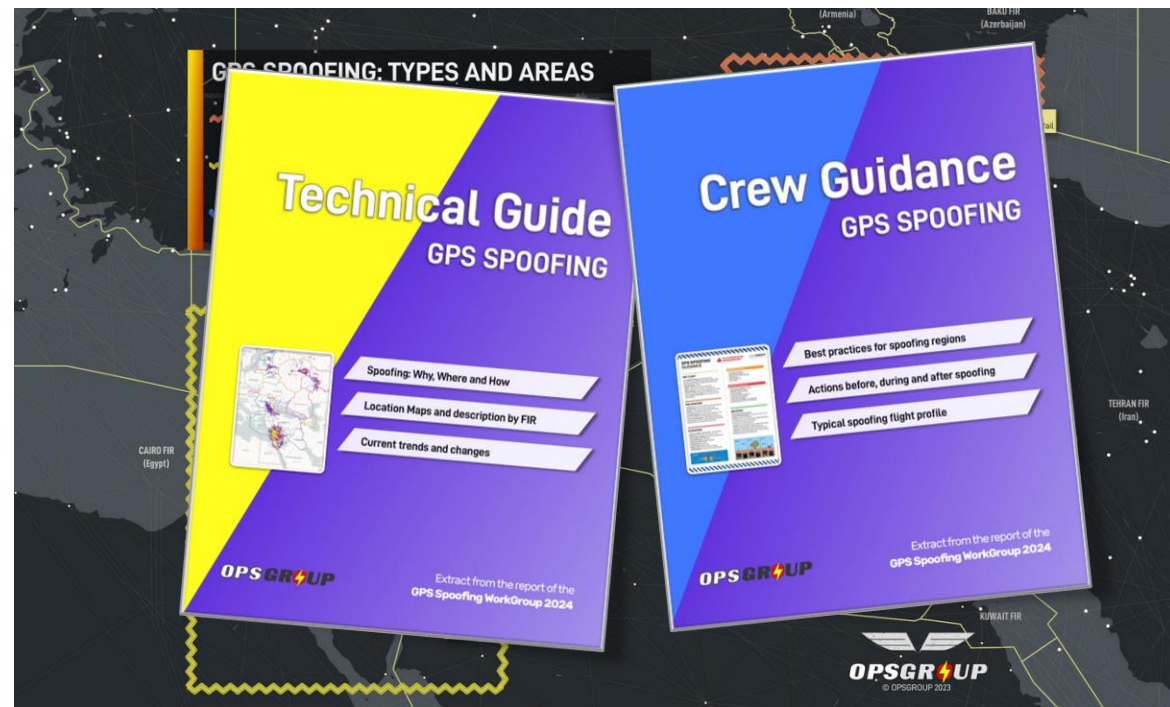
INTRODUCTION & METHODS

What is GBAS – Ground Based Augmentation System

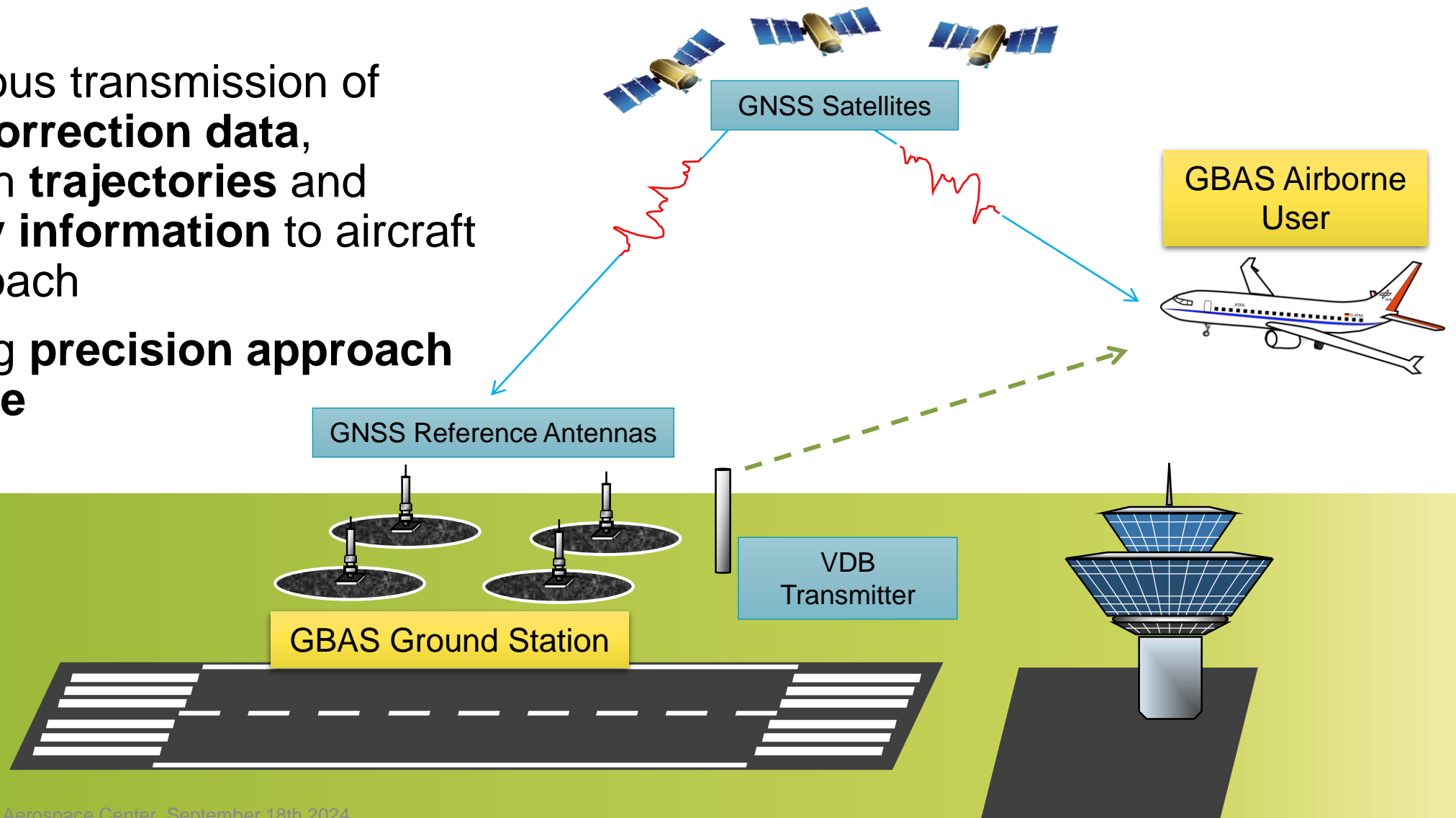- Continuous transmission of **GNSS correction data**, approach **trajectories** and **integrity information** to aircraft on approach

- Providing **precision approach guidance**

GNSS Satellites

GBAS Airborne User

GNSS Reference Antennas

VDB Transmitter

GBAS Ground Station

Cyber Secure DFMC GBAS
Requirements for Cyber Security

- Use of array antennas and appropriate receivers/processing to detect/suppress jamming and spoofing

- Both ground and air

GNSS Satellites

GBAS Airborne User

GNSS Reference Antennas

GBAS Ground Station

VDB Transmitter
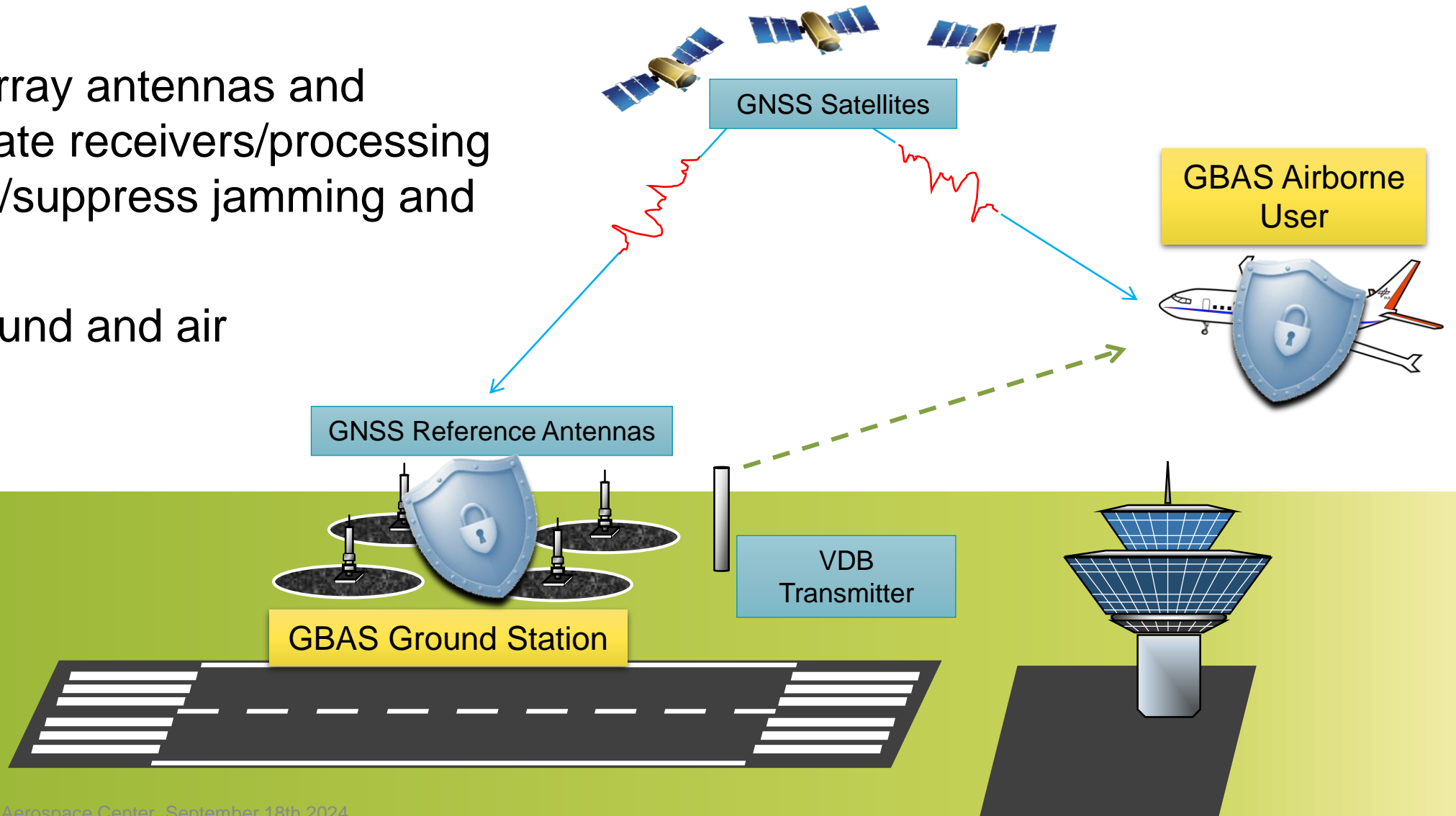
Cyber Secure DFMC GBAS
Requirements for Cyber Security

- Data link must be cyber-secure

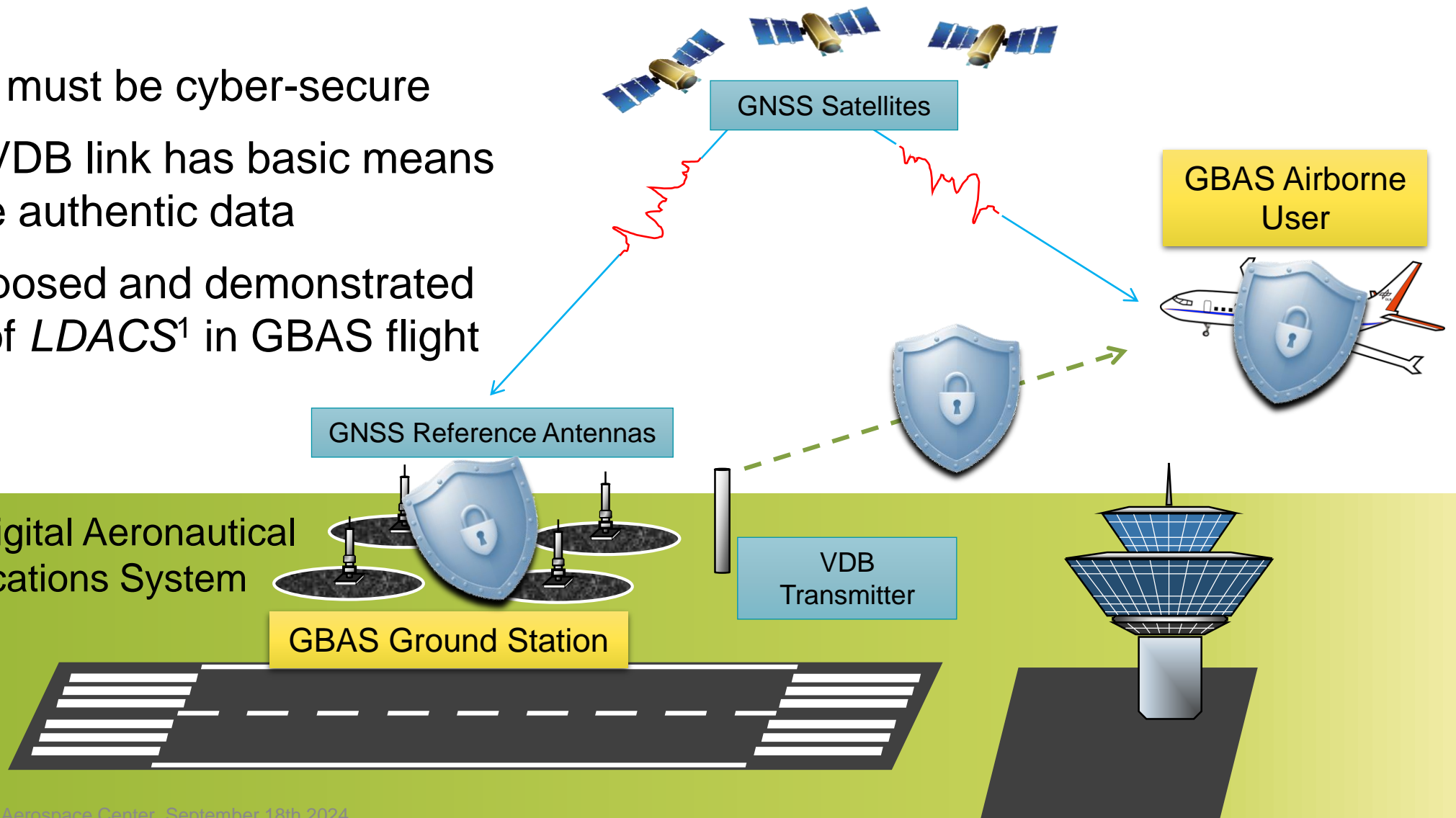- Current VDB link has basic means to ensure authentic data

- DLR proposed and demonstrated the use of *LDACS*[1] in GBAS flight trials

- [1]L-band Digital Aeronautical Communications System

GNSS Satellites

GBAS Airborne User

GNSS Reference Antennas

GBAS Ground Station

VDB Transmitter

Cyber Secure DFMC GBAS
Experimental System Overview

- Using DLR-developed resilient DFMC receivers/antennas in ground/airborne

- Ground stations with antennas on PCB design, Airborne in typical footprint

- GBAS processing comparable to current standard L1 processing with dual-frequency ionospheric monitoring

- Authenticated correction data broadcast

- Additional monitoring for interferences

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Cyber Secure DFMC GBAS
Initial Validation and Flight Campaign

- First successful validation with resilient hardware (ground/air) end of 2023
- 3 array based ground stations and array based airborne GNSS receiver
- Various tests including jamming/spoofing, conventional GNSS as reference

Cyber Secure DFMC GBAS
Initial Validation and Flight Campaign

- **All tests conducted around Cochstedt airport (EDBC)**
  - ATZ - orange
  - Spoofing zone – magenta
  - Flight paths
    for circling (green),
    spoofing trials (red)
    aerodrome circling (blue)

- **Permission to conduct
  in-flight spoofing and
  ground based jamming
  of aircraft on approach
  (Special Activity Area)**

Cyber Secure DFMC GBAS
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RESULTS

Daniel Gerbeth, German Aerospace Center, September 18th 2024
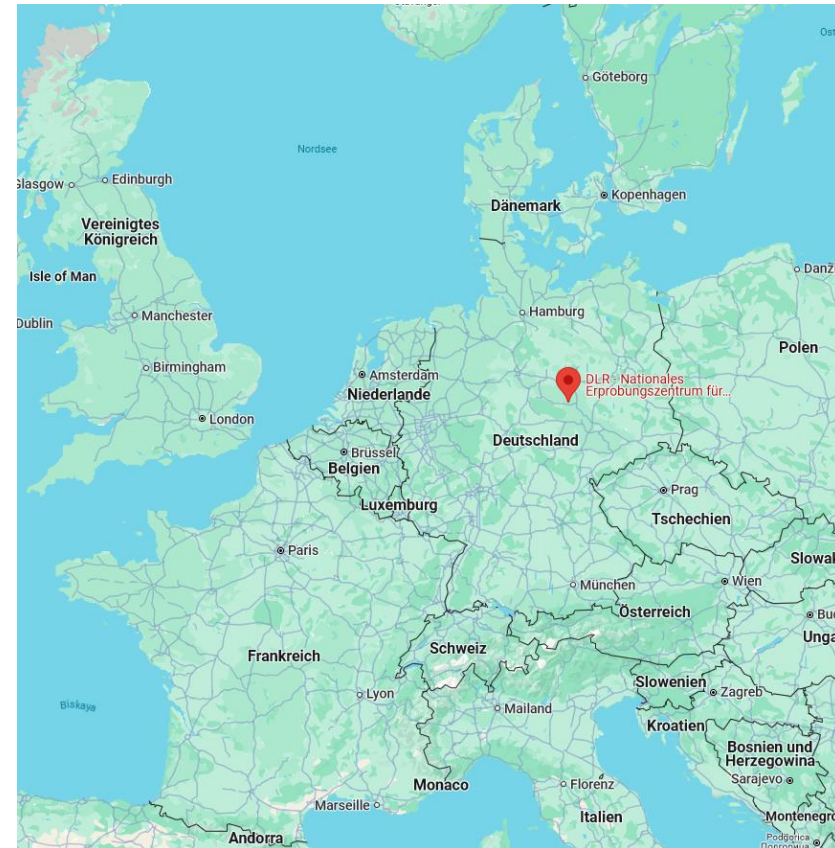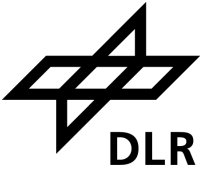
Cyber Secure DFMC GBAS
Ground + Airborne Noise & Multipath (Sigma Ground/Air)

- Ground: residual noise and multipath comparably high in low elevations, improving above 40°, between GAD-A and B requirements with preliminary **PCB-based** array antennas (!) and **without dedicated MP suppression**

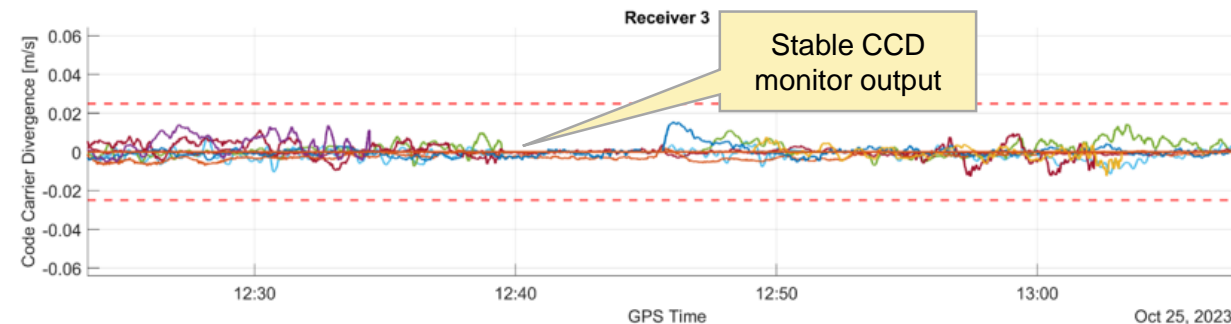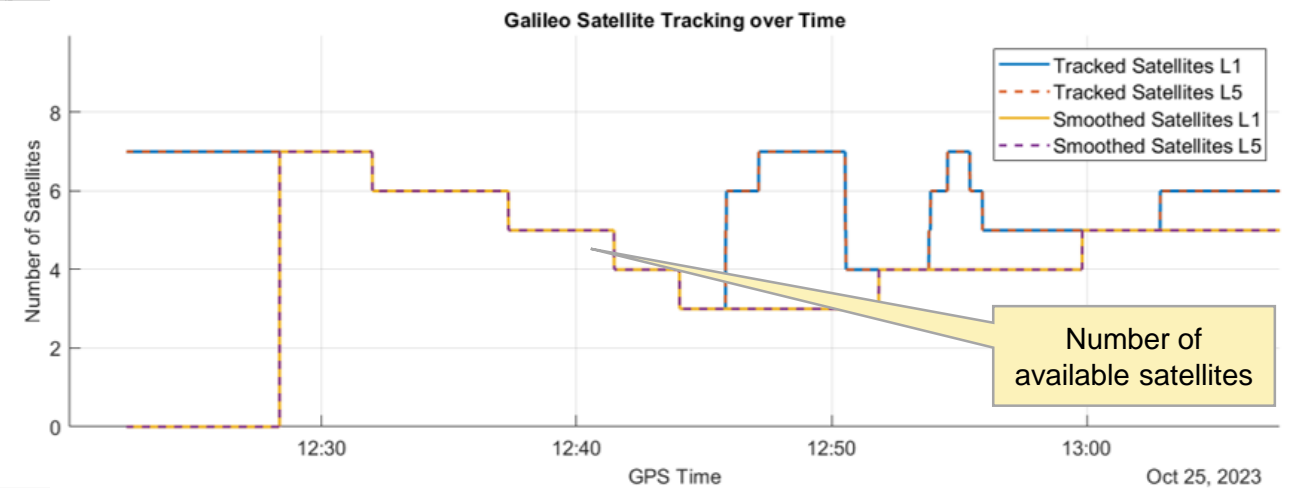- Air: Preliminary results due to number of samples (~3h usable flight data)
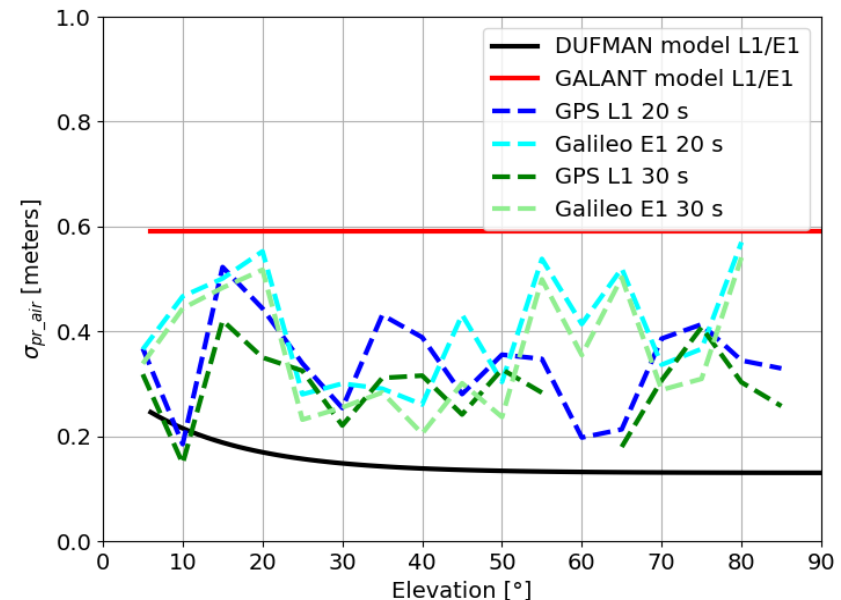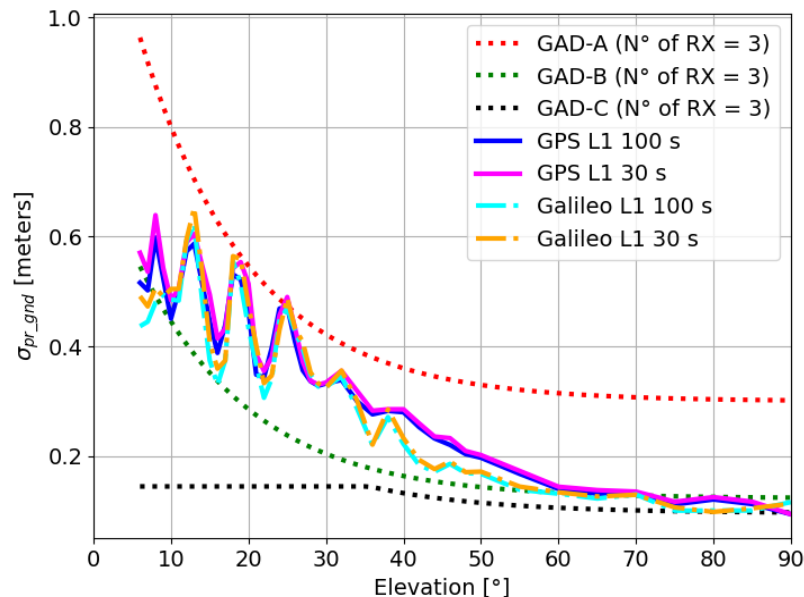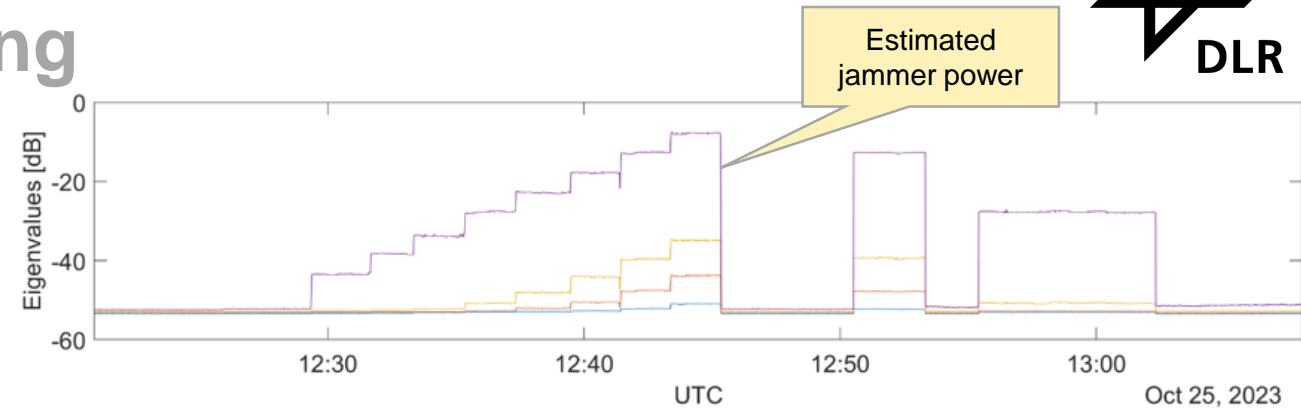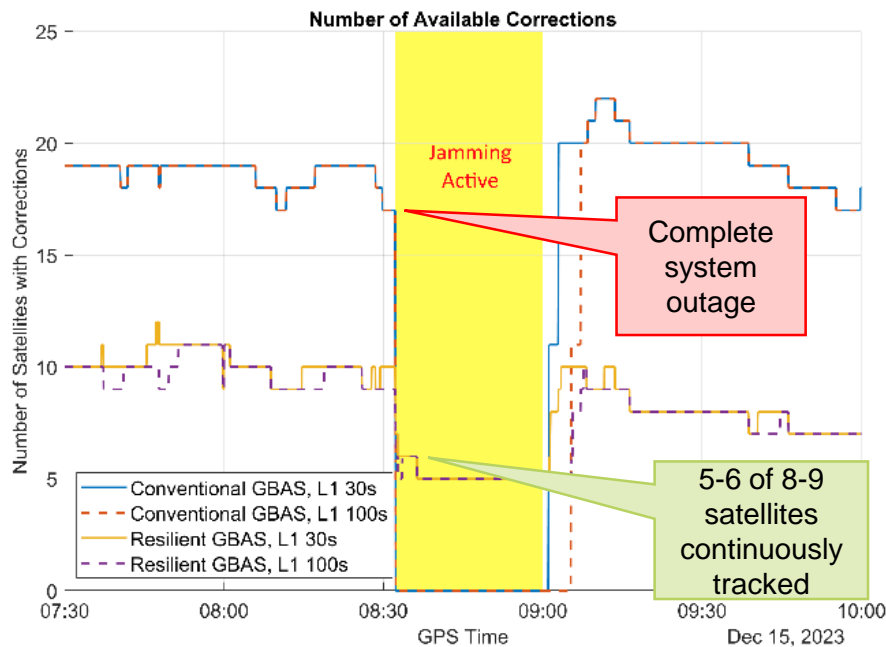
- Continuous operation during longer ground jamming tests

- Stable tracking of (remaining) satellites during interference

Estimated jammer power

Number of available satellites

Stable CCD monitor output

Complete system outage

Jamming Active

5-6 of 8-9 satellites continuously tracked

Daniel Gerbeth, German Aerospace Center, September 18th 2024

Cyber Secure DFMC GBAS
Airborne In-Cabin Spoofing Test

- Airborne spoofer (in-cabin) used to successfully deviate the position of an onboard Garmin GNSS

- Resilient receiver could reliably detect spoofed signals to avoid corruption of the (GBAS) position solution

- Active mitigation to maintain operation planned for 2024 flight campaign
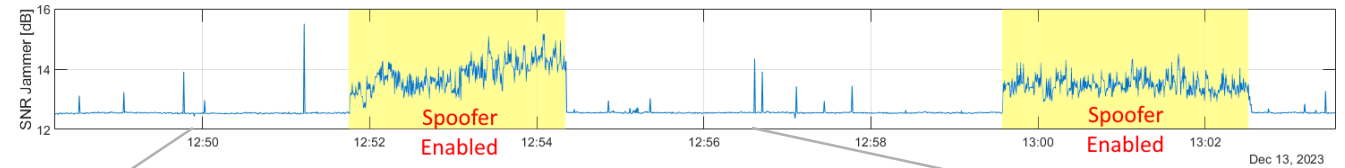
Cyber Secure DFMC GBAS
## System Availability in Airport Vicinity

- Good overall system availability throughout various tests in the airport area

- Service loss mainly due to low number of satellites in dynamic sections
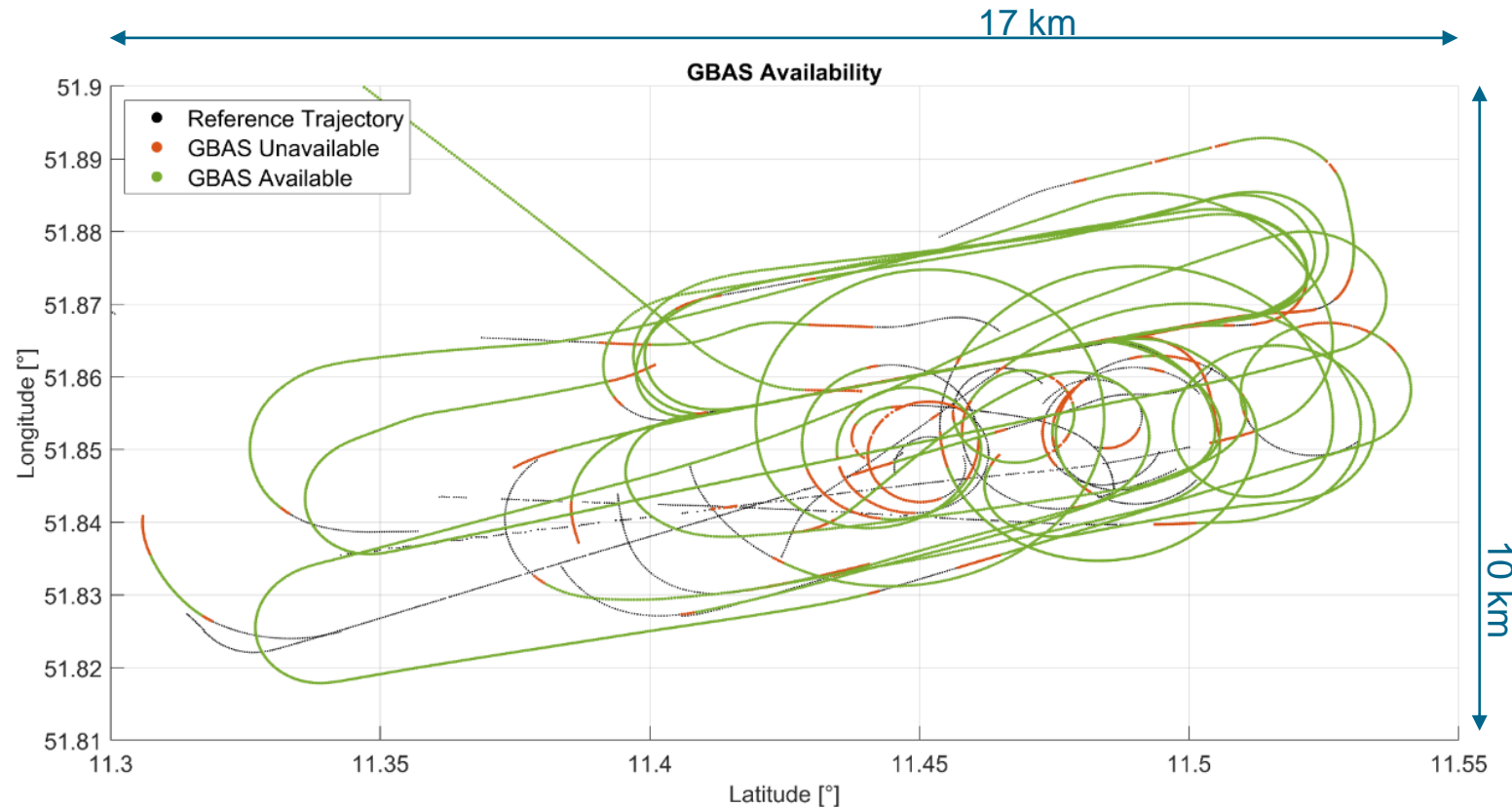
Cyber Secure DFMC GBAS
System Integrity and Availability

- Integrity plots for all flight segments within 40 km of the airport
- Including jamming/spoofing segments, go-arounds, tight circling etc.
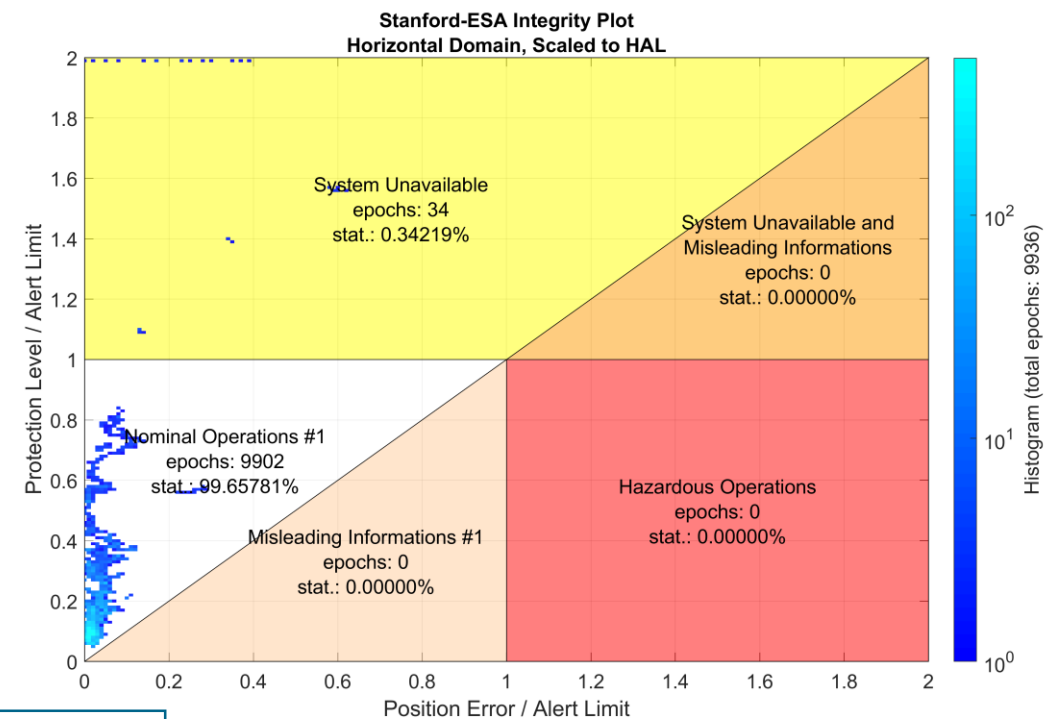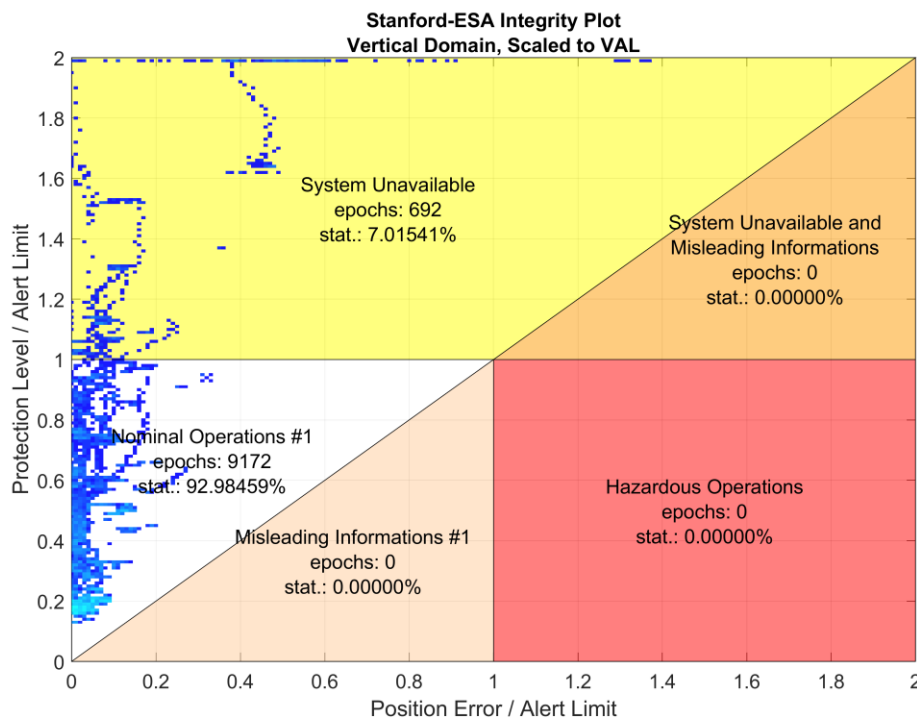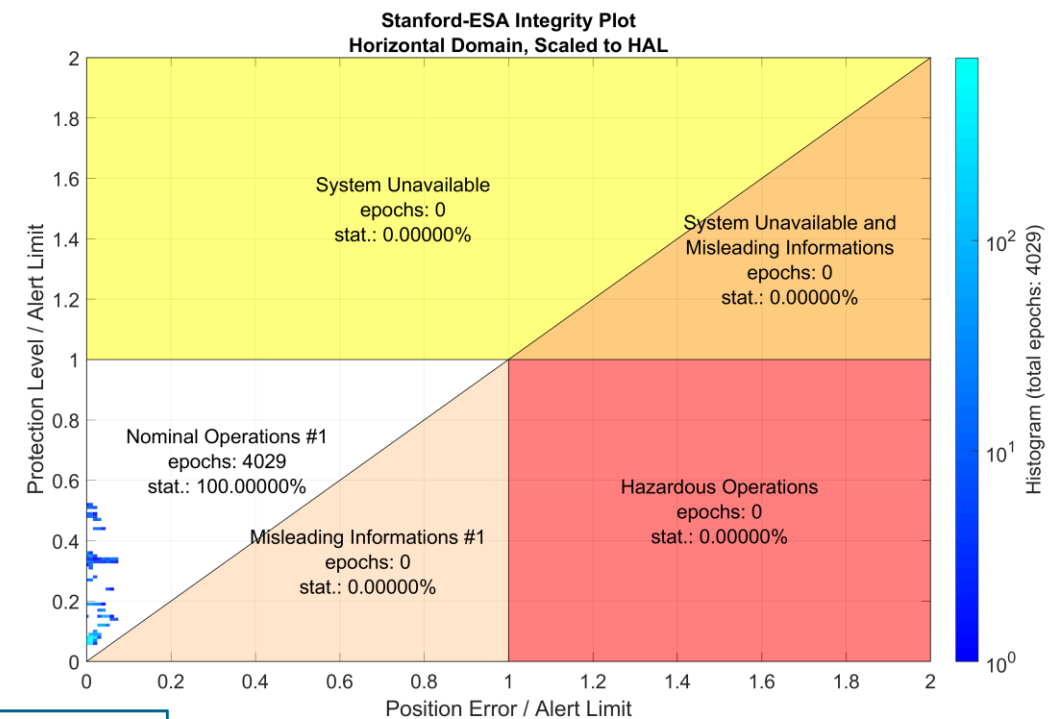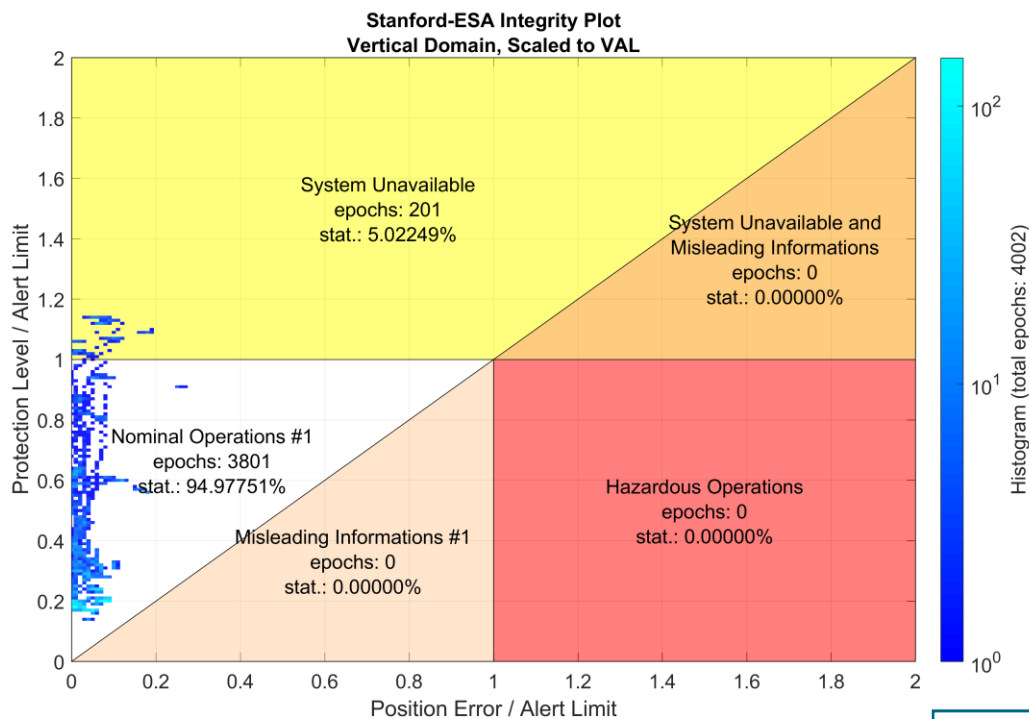

~2.7 hours of data

Cyber Secure DFMC GBAS
System Integrity and Availability

- Integrity plots for all flight segments within 40 km of the airport
- Excluding jamming/spoofing segments and tight circling

~1.1 hours of data

Protection Level Performance on Final Approach

- During approaches, PLs very close to CAT III requirements were achieved, even with current hardware limitations

- Vertical position error typically below 1.5 m on final approach

- Very promising for future tests with planned improvements

CONCLUSIONS & OUTLOOK

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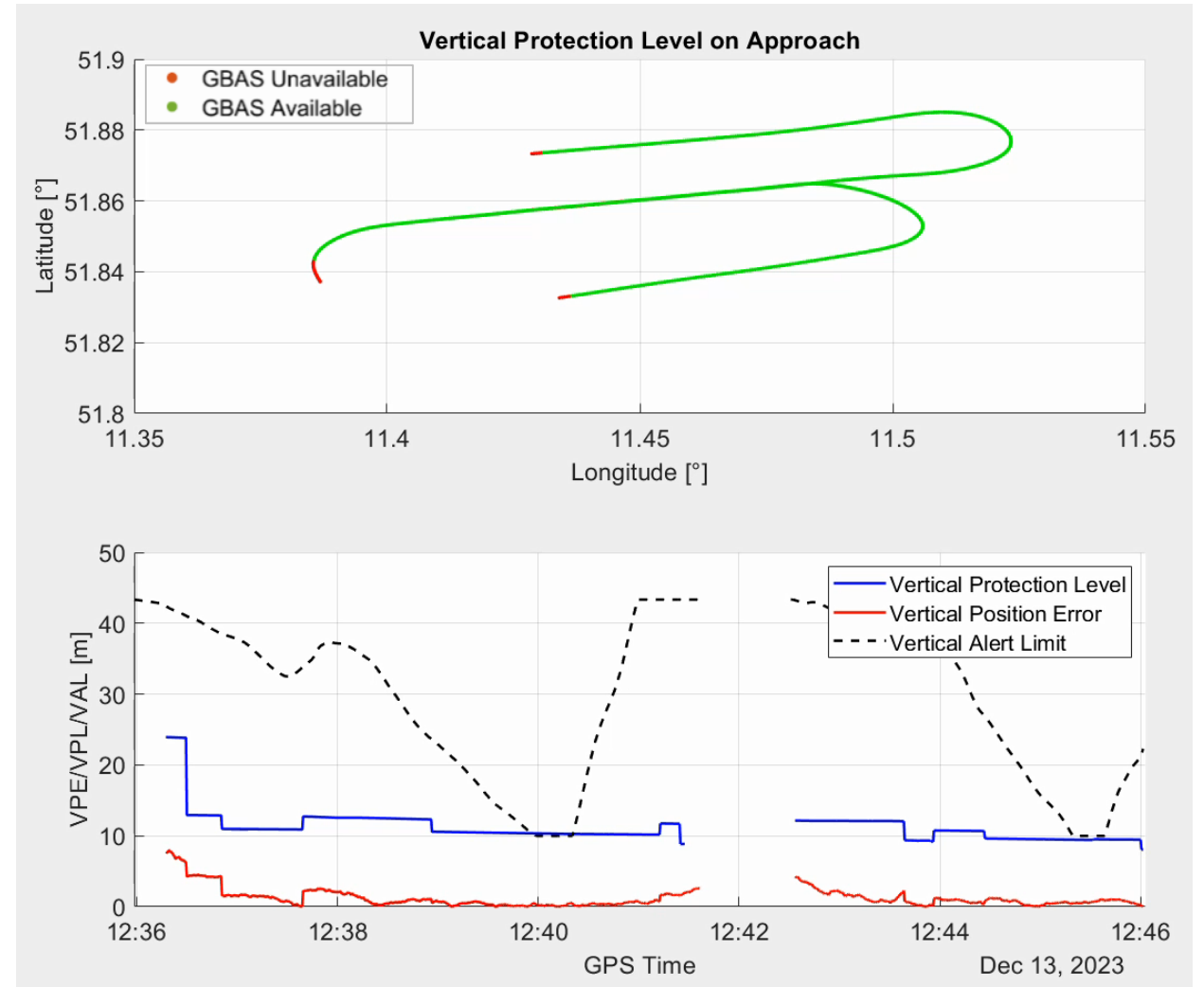
Conclusions & Outlook

- Initial accuracy/availability very promising considering the system limitations
  - Very limited number of tracking channels, air/gound antenna awaiting redesign, …

- System **ensured GBAS integrity** during all phases of flight and in static ground tests, **even under interference**

- Hardware provided **stable navigation under interference**, indicating the **suitability** of the approach **in demanding, safety-critical applications**

- Further flight tests upcoming (October 2024) to test refined hardware based on identified potential for optimizations

- Additional data to further refine models and enable final real-time demonstration of the complete system in 2025

THANK YOU FOR YOUR ATTENTION! QUESTIONS?

→ Daniel.Gerbeth@dlr.de

Cyber Secure DFMC GBAS
The Team Behind

- Daniel Gerbeth, Maria Caamano

- Andreas Winterstein, Manuel Cuntz, Philipp Rudnik, Simon Hengstermann

- Andriy Konovaltsev, Emilio Perez, Lothar Kurz, Tobias Bamberg

- Simon Hehenberger, Stefano Caizzone, Veenu Tripathi

- DLR Institute of Flight Experiments

- DLR National Experimental Test Center for Unmanned Aircraft Systems

Imprint

Topic: **ION GNSS+ 2024**
Towards Cyber-Secure GBAS: Initial Experimental System Validation

Date: 2024-09-18

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Institute: German Aerospace Center
Institute of Communications and Navigation

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