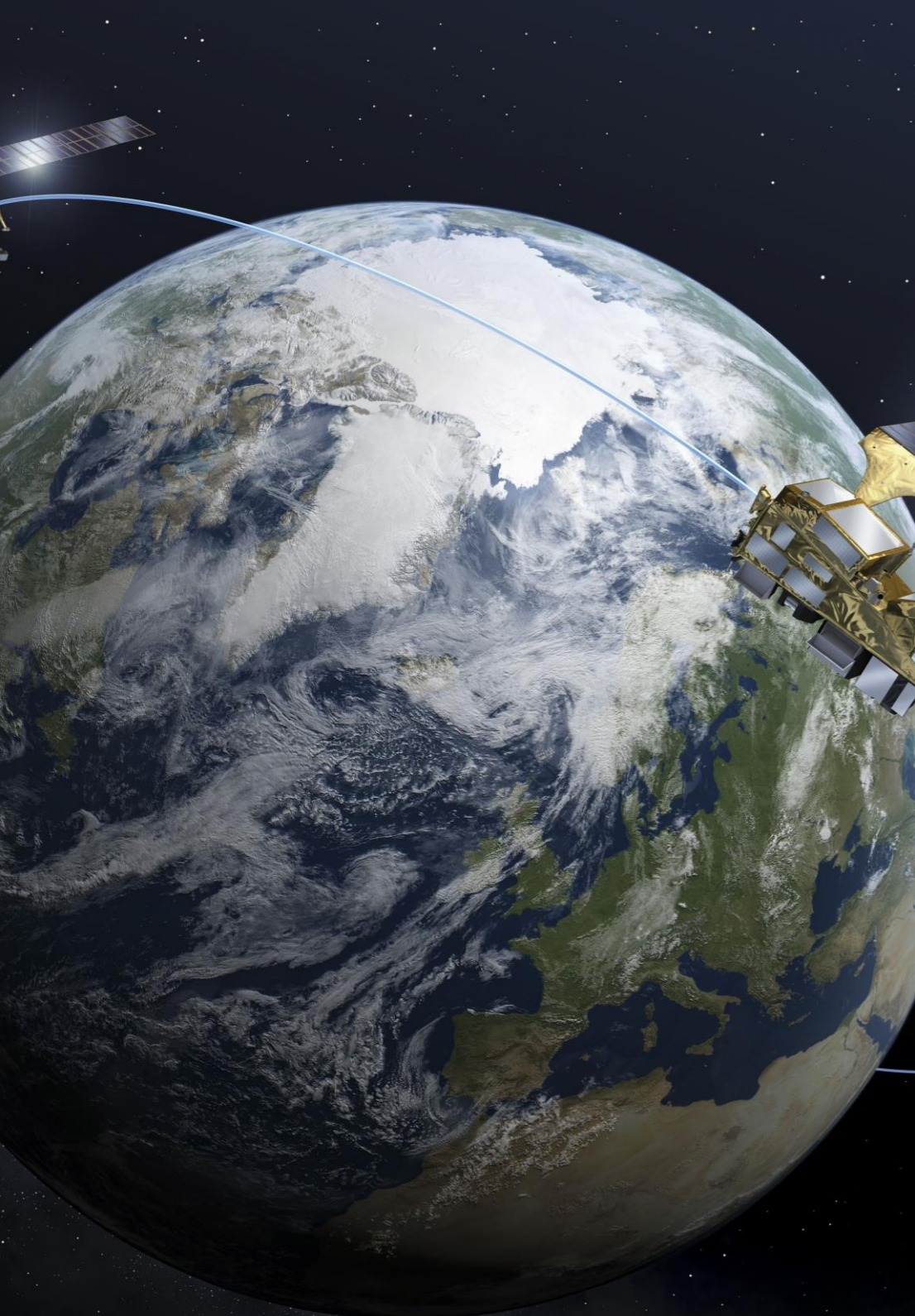




ESA – P. Carril



June 11, 2024

NAVISP EL3: ADG Innovation Lab

Prototyping and Testing GNSS systems with
Wideband Phase Aligned Multichannel Transceivers

Samah CHAZBECK

Principal Application Engineer – Payload Validation

NI (now part of Emerson)



AGENDA



- 14.40 ADG Open Innovation Lab: Introduction
- 14.45 The Role of Multichannel Phase Aligned Systems in GNSS Applications
- 14.50 Wideband Multiple RF-ports system: Features, Performances and Use Cases
- 15.00 Lab Access: Application & Submission



ADG Open Innovation Lab

EL3-027 Introduction

ADG Lab for Open Innovation



- Technology trend in multichannel systems, for satellite navigation, communications, and radar, including jamming and spoofing, requires innovative Test & Measurement technology for supporting the system life cycle from prototyping, design and production to the usage.
- The Open Innovation Lab, located in Debrecen within the manufacturing site of NI in Hungary, intends to boost the cooperation between the Industry and Academy by supporting the evaluation of testing needs of systems.



ADG Innovation Lab - Capability



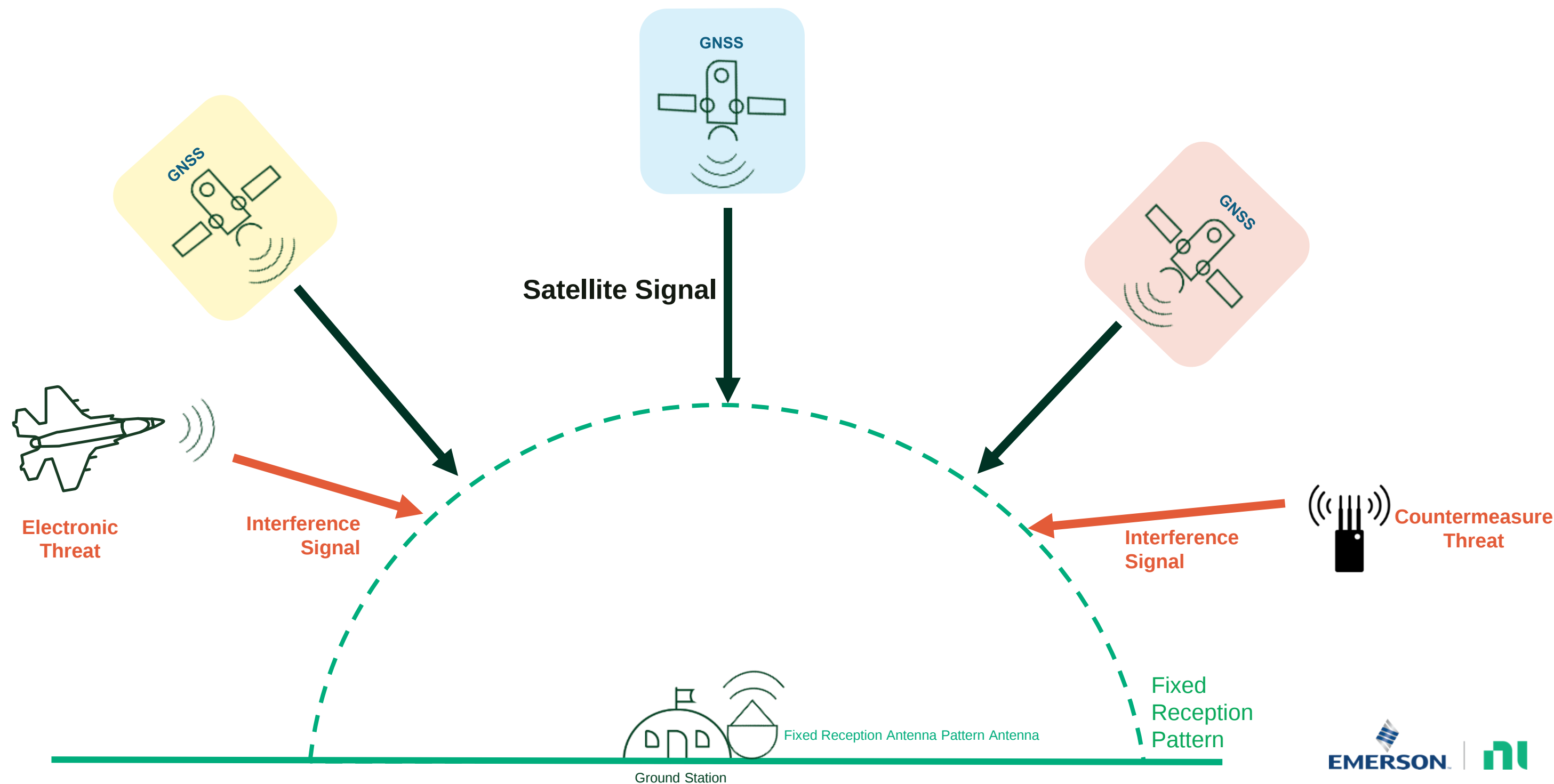
- 4x PXIe-5841, phase coherent or independent channels
- Application SW
 - Record & Playback
 - M3 Systems StellaNGC
 - NI ESAC reference architecture
 - Satellite Link Emulator
- Development tool: LabVIEW , Diadem



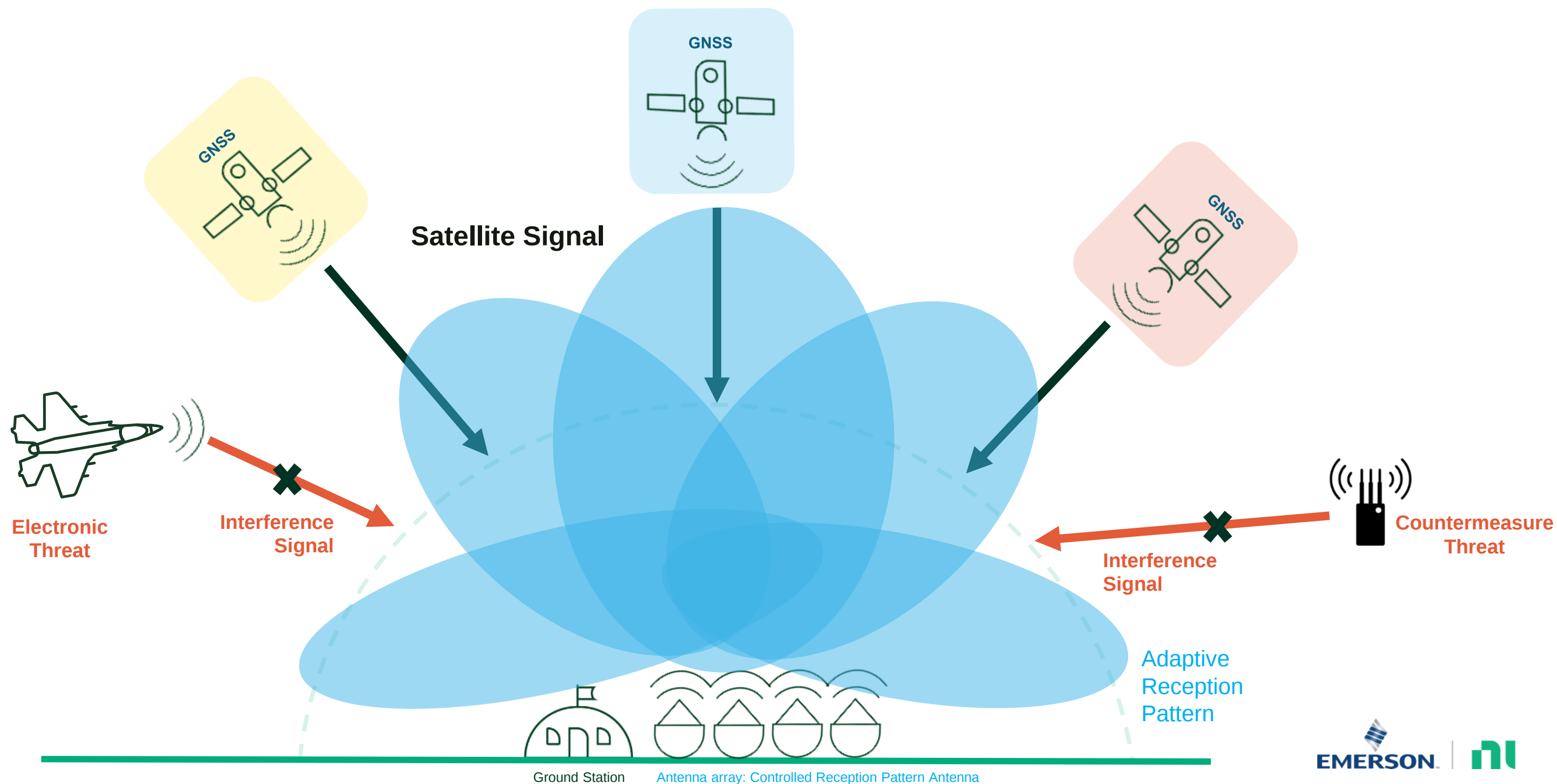
Multichannel Phase Aligned Systems

Role in GNSS Applications

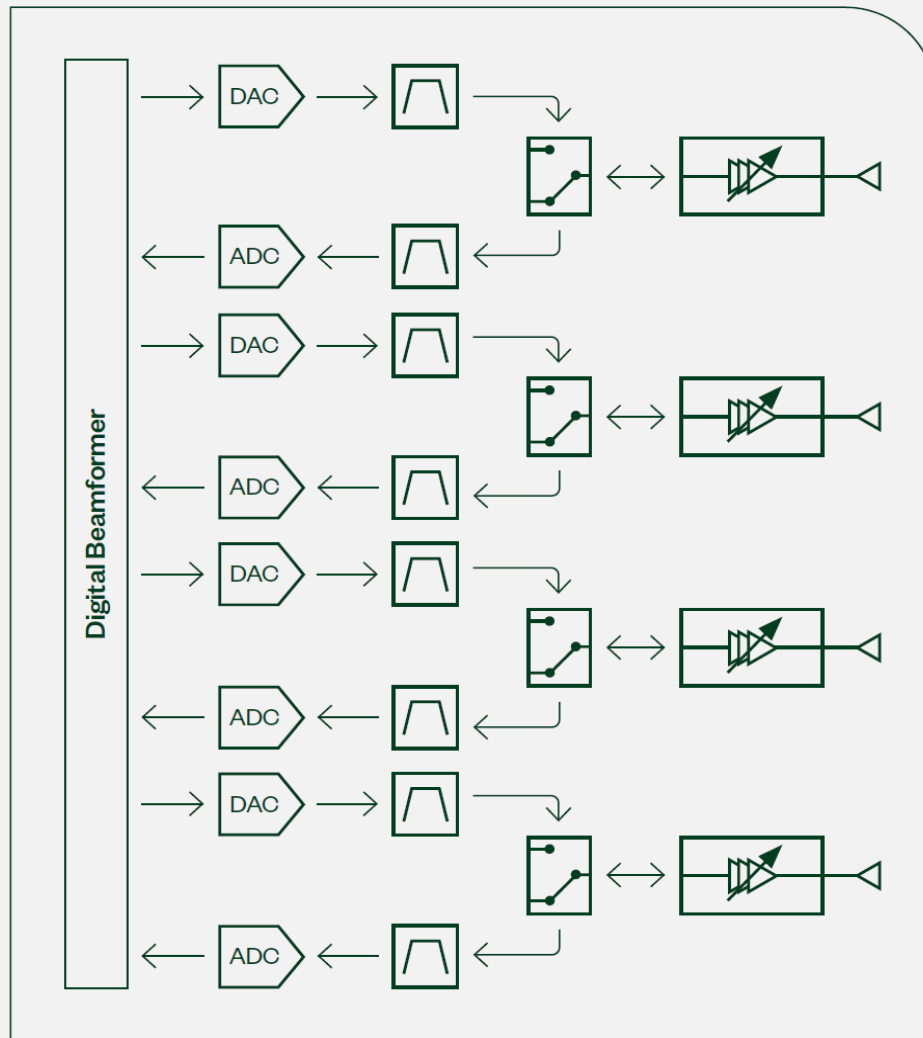
Need for Multichannel Receivers



Need for Multichannel Receivers: Spatial Diversity



Multichannel Transmitters / Receivers



MULTICHANNEL T/R MODULE

Advantages:

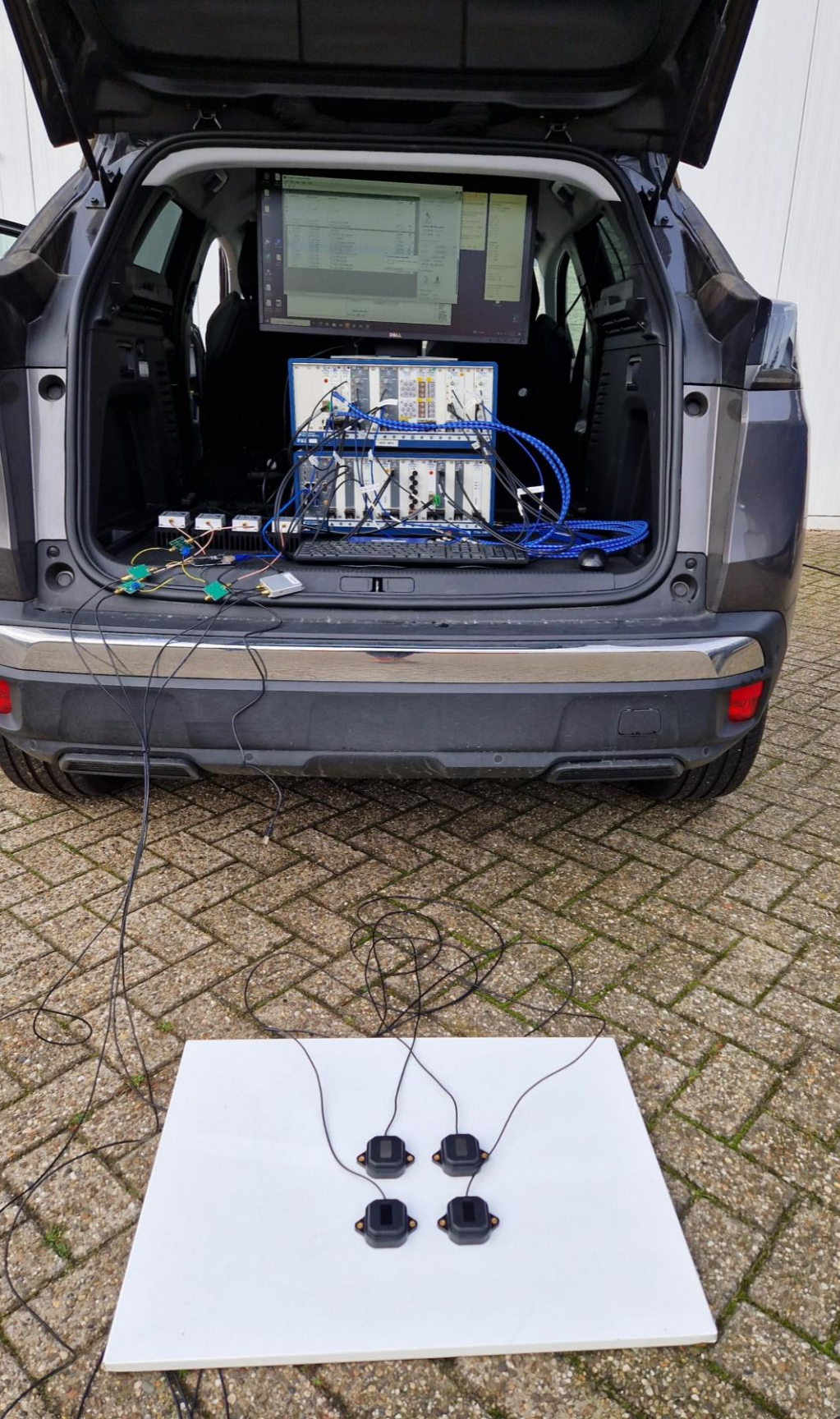
- Multidimensional (frequency, polarization, spatial channels) signal processing in detection, estimation and classification
- Digital Beamforming: beam steering and pointing agility, adaptive coverage, nulling, electronic protection (noise and jamming deception)
- Multifunctional array (higher efficiency, reconfigurability)

Challenges:

- synchronization issues of the channels or subsets of channels
- phase coherence among spatial channels for beamforming
- amplitude calibration of each channel to mitigate possible beam misalignments
- phase calibration is important for DOA estimation techniques, beam steering, and null placing
- high-rate sampling to support fully-digital architectures

Wideband Multiple RF-ports system for GNSS applications

Features, Performances, Use Cases



Enabling Validation of Complex GNSS Systems, and More



Multichannel Phase Aligned (MPA) System Overview

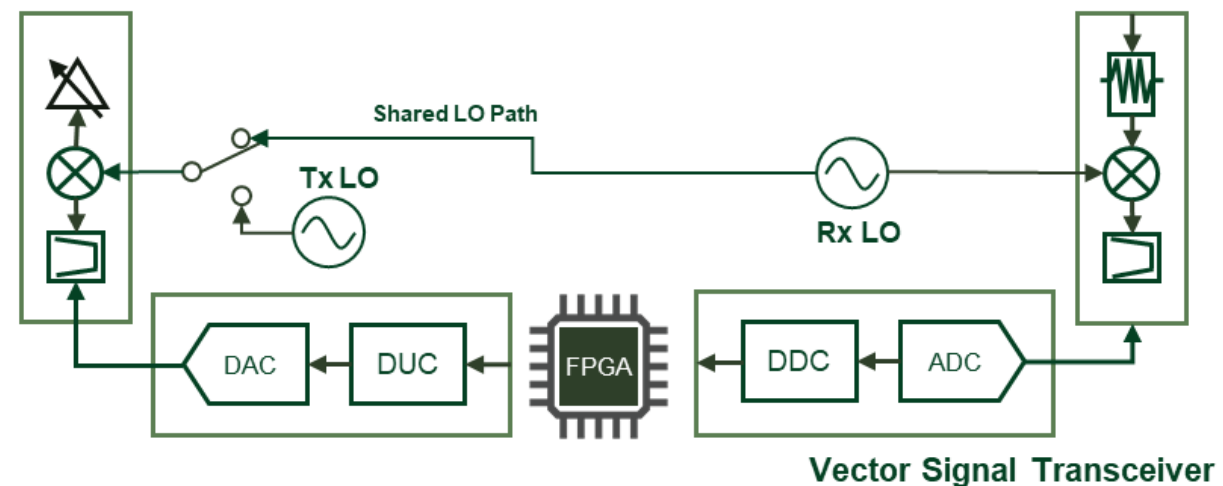
- MPA-RPS is based on cutting-edge, future-proof software and hardware, enabling the development of test strategies that effectively reduce costs and mitigate risks throughout the system development and deployment process.
- It includes NI modular software-defined instrumentation and application software to enable:
 - Testing Wideband Multichannel Phase Aligned Transceivers and Antenna systems
 - Performing functional and parametric tests of components and systems with All in one Instrument approach : Spectral Measurements, S-Parameters, Pulsed Analysis (Pulse Profile, Pulse Stability), Harmonics, Power Added Efficiency Measurement , etc...
 - Emulating a Wideband Satellite Link
 - Hardware-in-the-loop (HiL) simulation of multi GNSS constellations with support for antenna array configuration



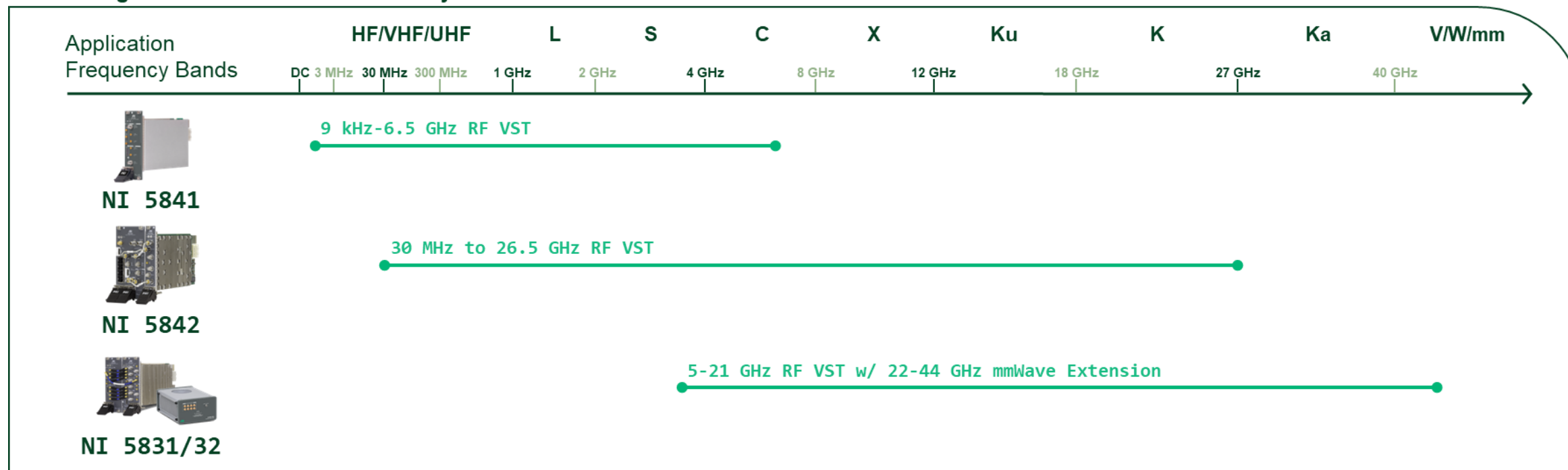
Vector Signal Transceiver



- Integrated, instrument grade Vector Signal Analyzer and Vector Signal Generator with up to 2 GHz of instantaneous bandwidth
- Support Onboard and External LO's for phase noise optimization
- Multi-Channel Synchronization (< 1nsec) and Phase Coherent LOs
- Easy SW and HW integration with mixed I/O and PXI
- Optimized for automated characterization and production
- Customizable firmware for deploying application IP or test speed optimization
 - Onboard, open FPGA
- Full rate peer to peer streaming to FPGA coprocessors



Vector Signal Transceiver Product Family



Commercial
Off-The Shelf

Modularity & Density

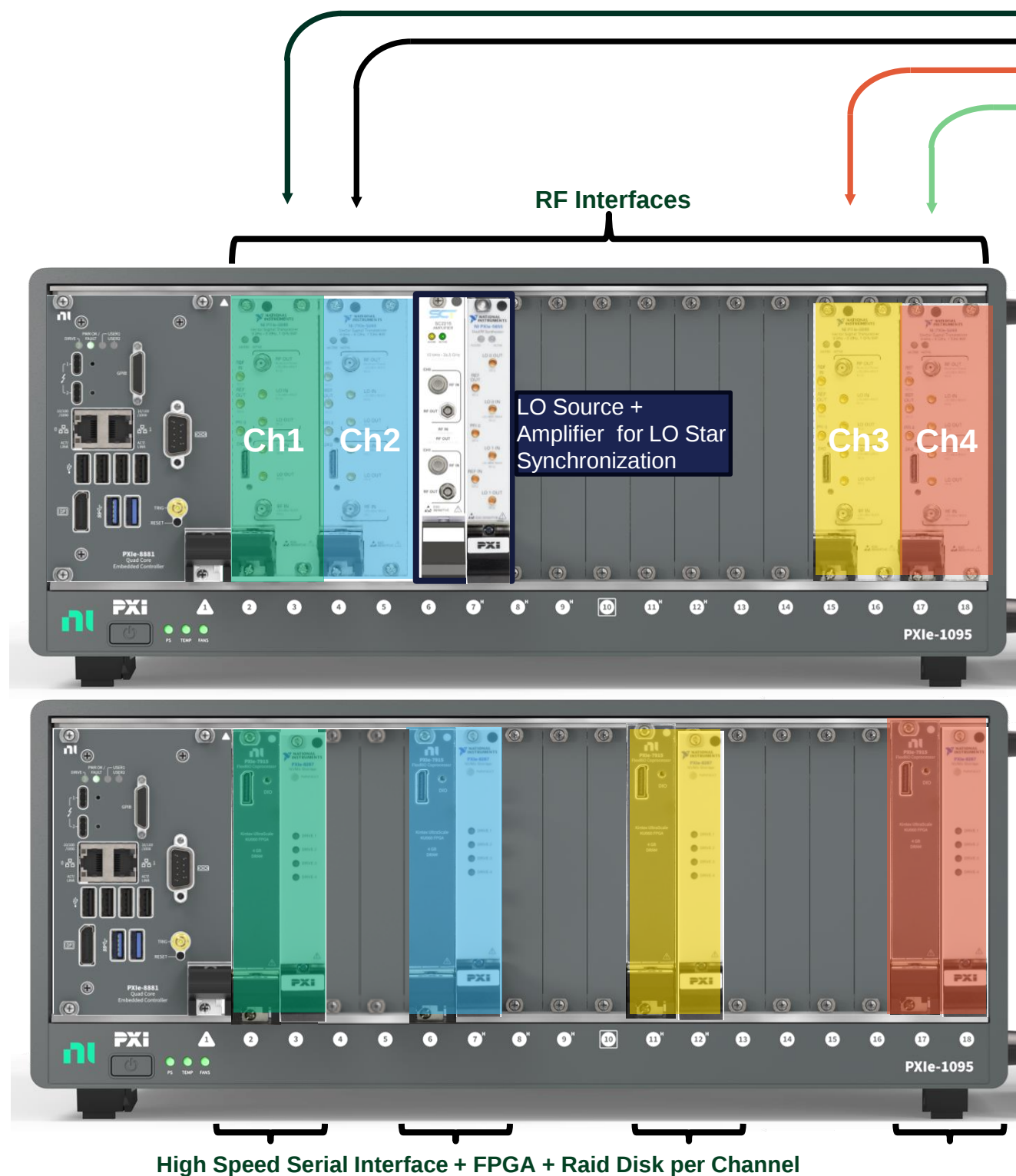
Open Hardware &
Software Standards

Heterogenous, Real-
Time Compute & DSP

Wideband, High-
Fidelity RF

Synchronization & RF
Phase Alignment

Full MPA Hardware Configuration VST 5841



SUT:
(CRPA Antenna
GNSS Receiver...)

- ❖ PXI chassis contains 4 PXIe-5841 Vector Signal Transceiver (VST) modules, with up to 1 GHz IBW (instantaneous bandwidth) and 9kHz to 6GHz frequency range
- ❖ Shared LO source, Ref Clock and triggering for synchronization; sync to external Ref Clock
- ❖ PXI extension chassis contains 4 FPGA FlexRIO cards PXIe-7915, one per RF channel for data streaming and data pre-processing (Custom Algorithms for spectral monitoring, beamforming...)
- ❖ 2 to 4 integrated RAID Disks, 4TB data storage each, NVMe technology for continuous data streaming of 1GHz IBW per disk for single RF channel to disk and 500MHz IBW for 2 channels aggregated data per disk

Phase Alignment (Mean and STD) – Full GNSS Band, fc 1.385GHz

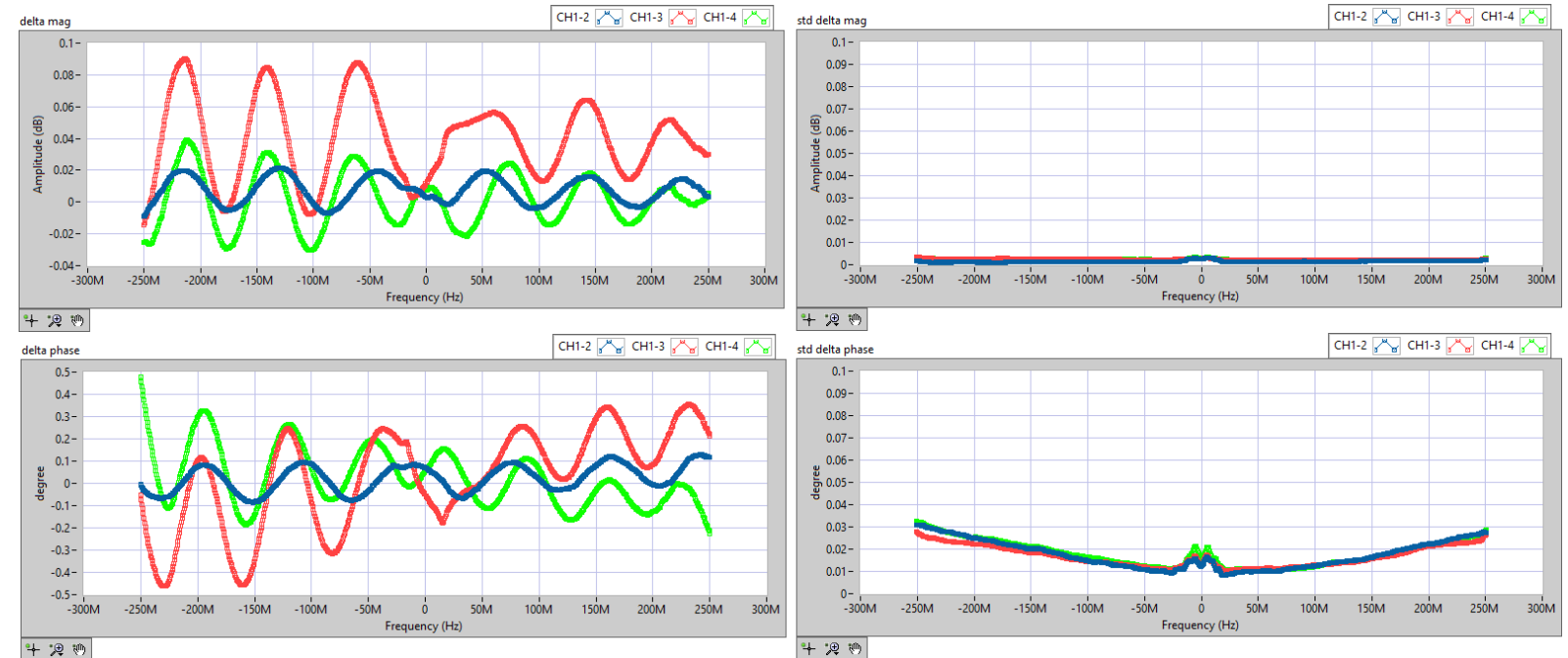
Acquisition

Phase Mean $< 0.5^\circ$

Phase STD $< 0.05^\circ$

Amplitude Mean $< 0.1\text{dB}$

Amplitude STD $< 0.01\text{ dB}$



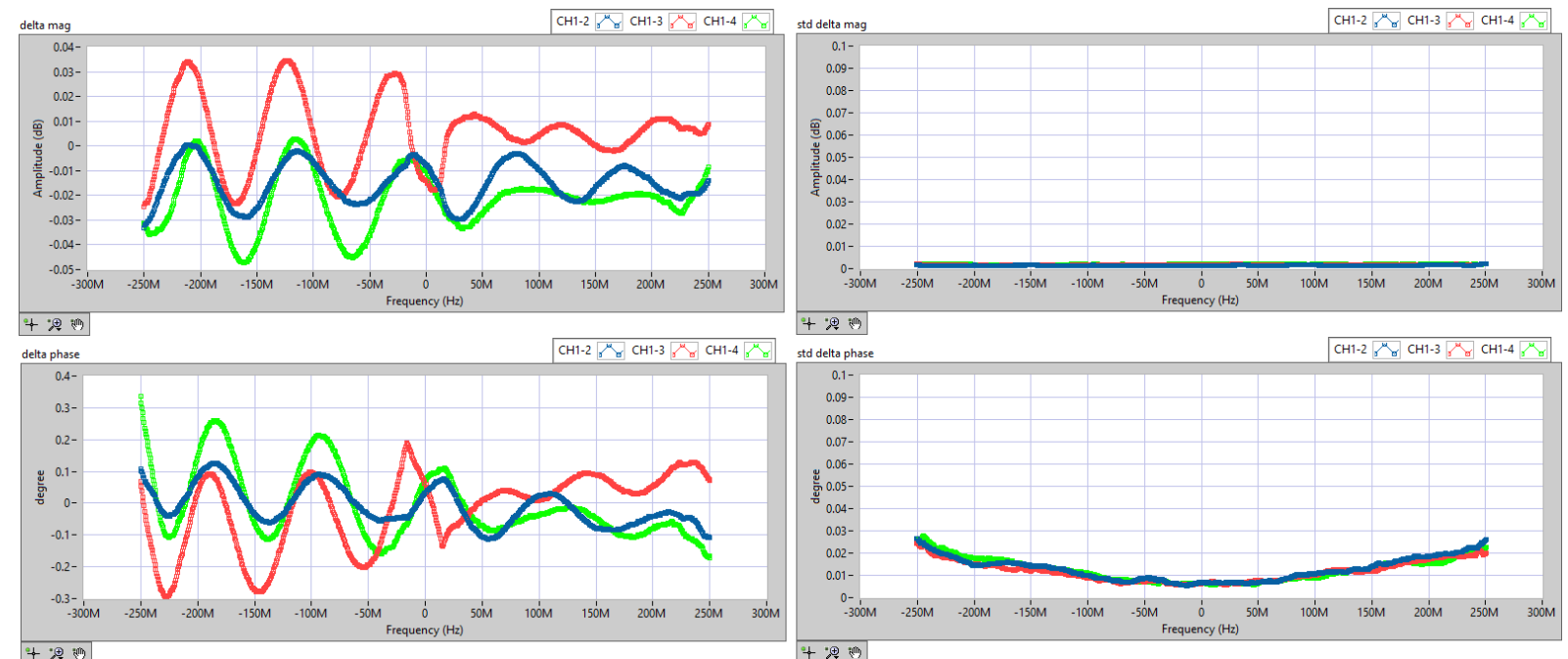
Generation

Phase Mean $< 0.5^\circ$

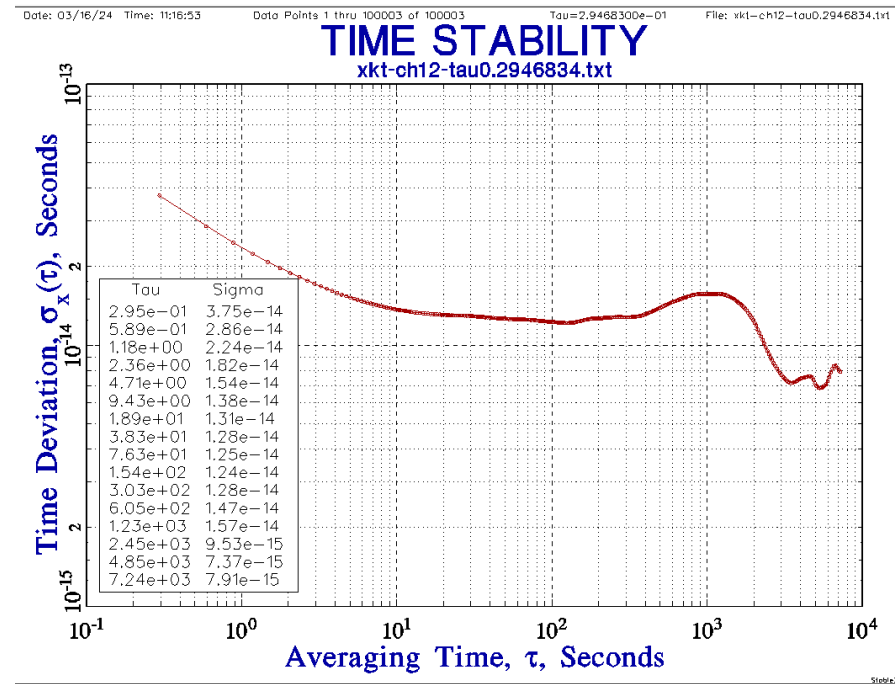
Phase STD $< 0.05^\circ$

Amplitude Mean $< 0.1\text{dB}$

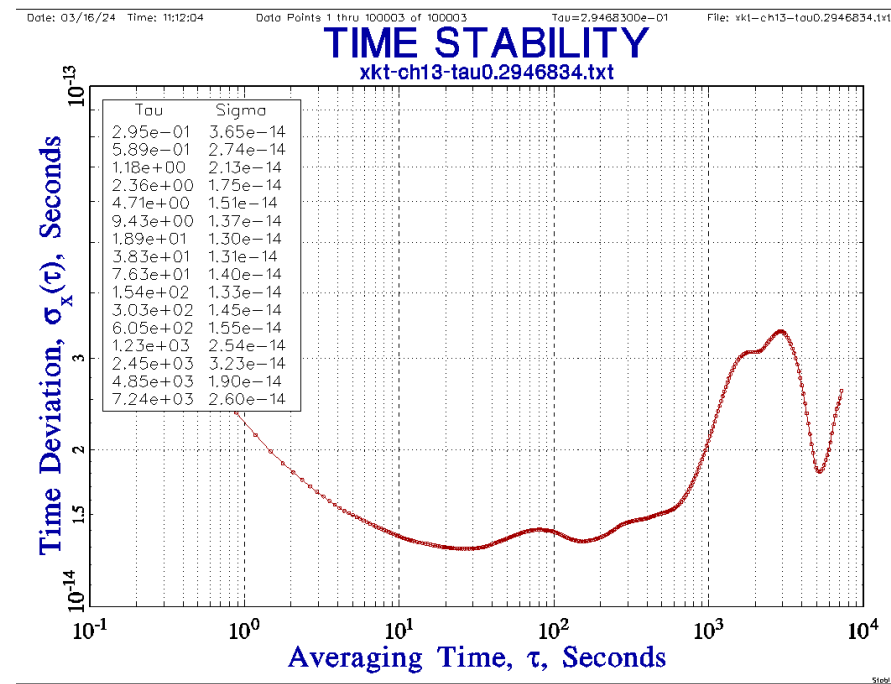
Amplitude STD $< 0.01\text{ dB}$



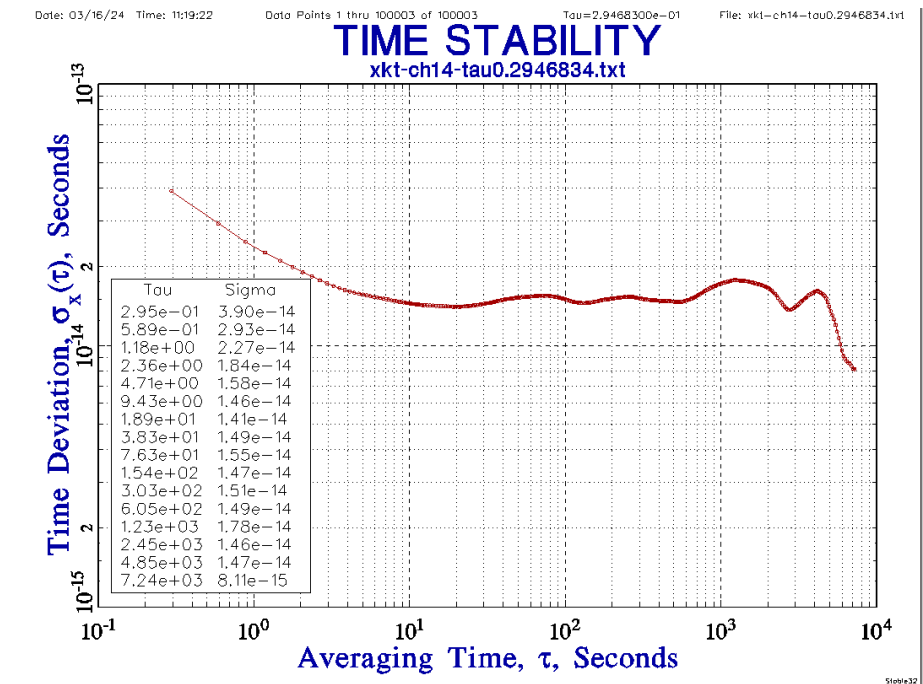
Phase Stability@L1 – 8hrs, fc 1.385GHz, full GNSS Band



Ch 1-2 Stability
TDEV < 20fs (0.02°)
 at L1 for integration
 time > 1000s

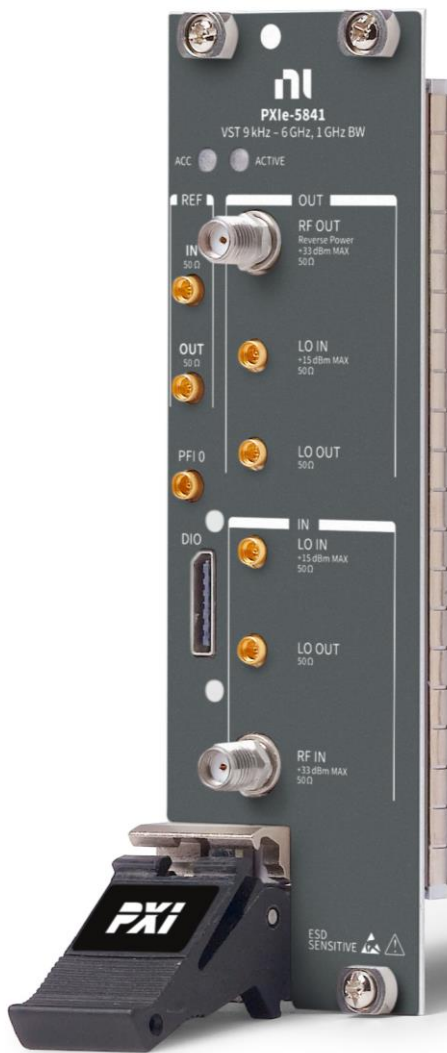


Ch 1-3 Stability
TDEV < 35fs (0.02°)
 at L1 for integration
 time > 1000s



Ch 1-4 Stability
TDEV < 20fs (0.02°)
 at L1 for integration
 time > 1000s

ADG Lab – VST Software Ecosystem



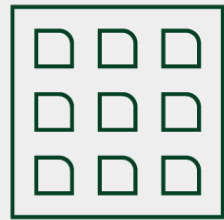
ADG Lab - Capability



- 4x PXIe-5841, phase coherent or independent channels
- Application SW
 - Custom Wideband Signal Generation
 - Spectral Analysis
 - Record & Playback
 - M3 Systems StellaNGC: GNSS Simulation
 - NI ESAC reference architecture
 - Satellite Link Emulator
- Main Development tools: LabVIEW , Diadem

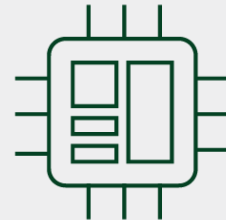


ADG Lab – Use Cases



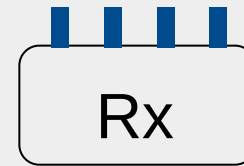
CRPA or Multichannel Antennas

T/R component, module
and system level
validation



Algorithm Validation

ex: Beamforming,
jamming mitigation
Software in the loop,
data collection offline



Multichannel Receiver Validation

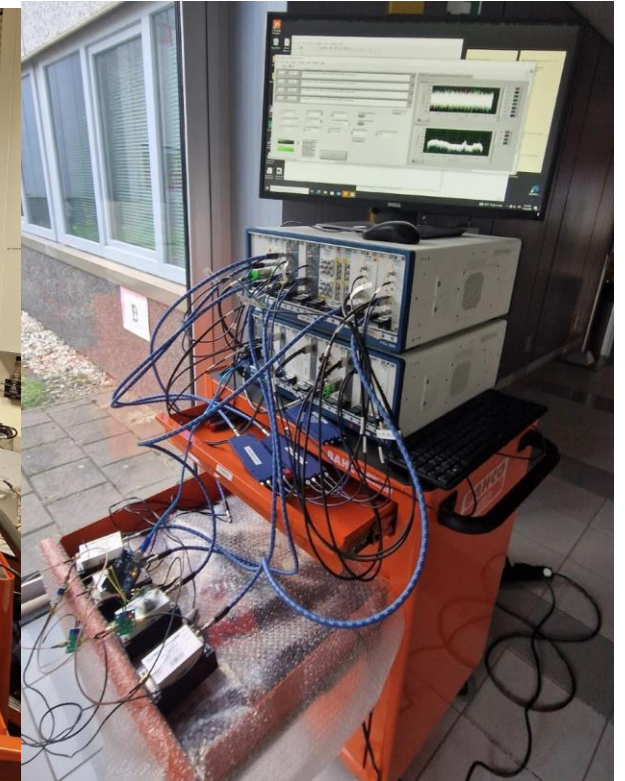
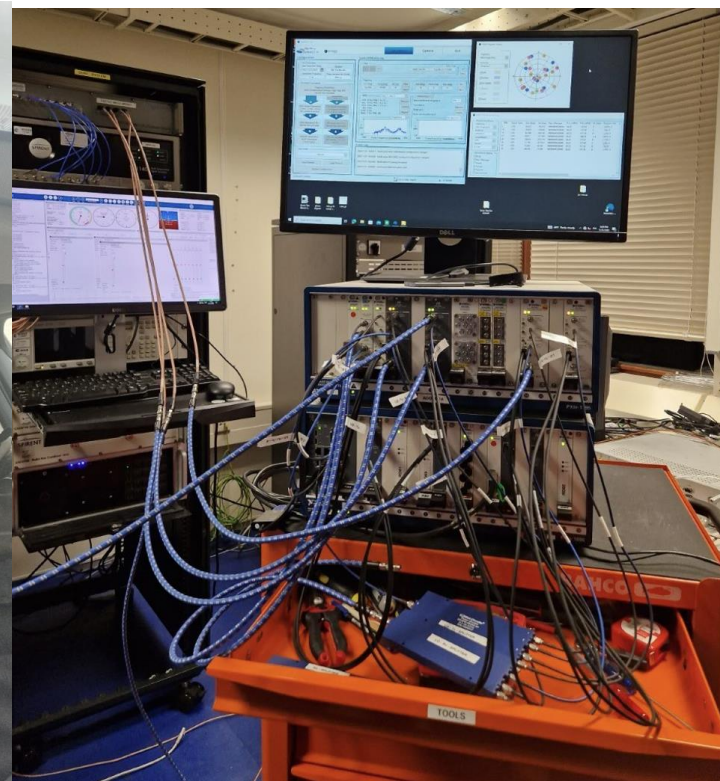
GNSS Simulation,
Record and Playback



Test Campaign



- Two test campaigns have been performed with ESA to validate the system capability.
- 42 TB of data has been collected so far!



Next Presentation

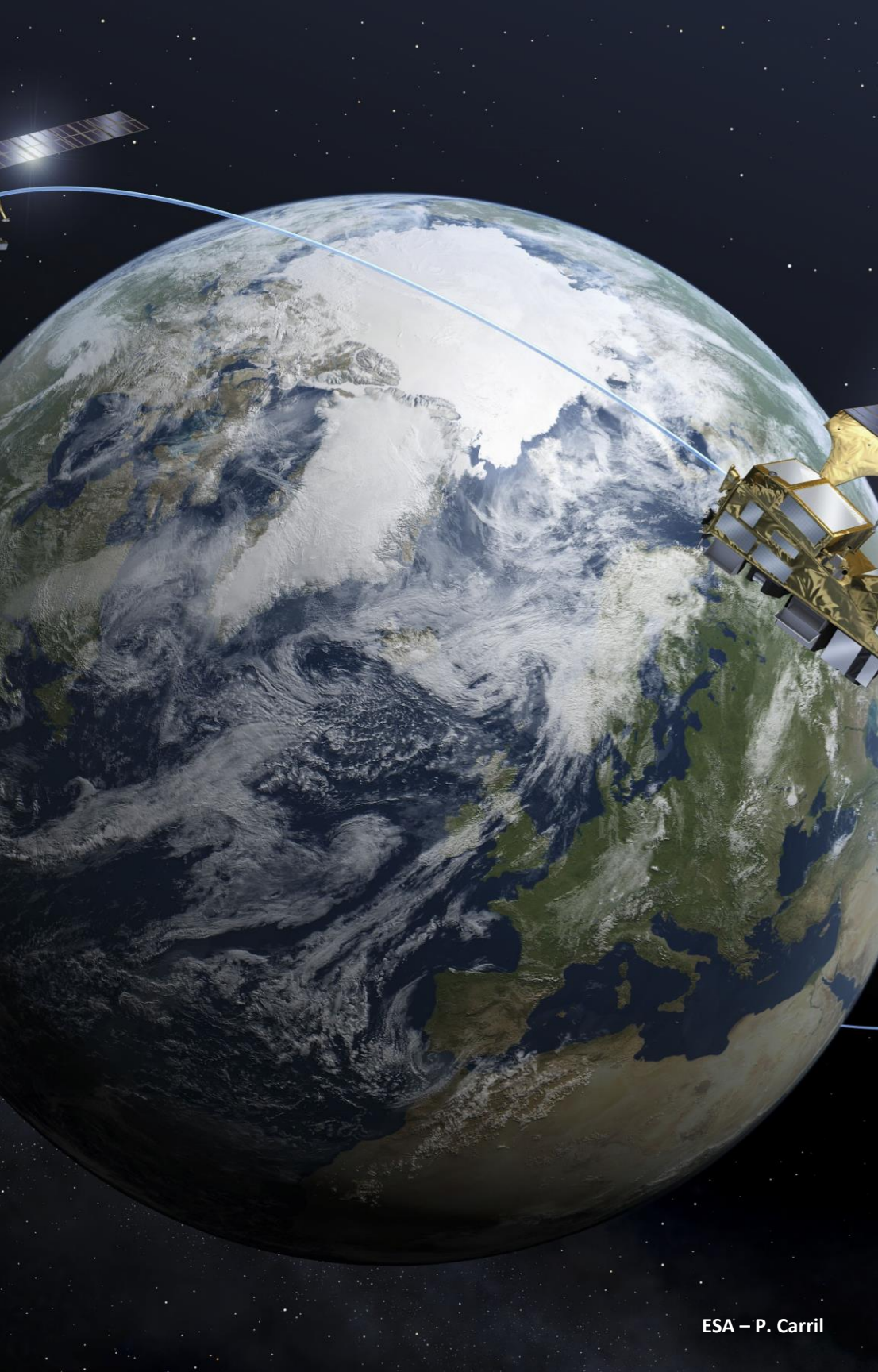


📍 Bleik, Norway

JAMMERTEST 2024

Sophisticated Attacks and
Robustness Testing

Recording various jamming,
spoofing, meaconing scenarios over
large BW



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Application & Submission

Lab Access



ADG Lab - Admission Rules

- **Users**

- European companies and universities, with priority to space, aeronautics and defence, with project in TRL 0-5
- European companies and universities, partnering with NI in projects funded by any EU program (BDMs lead this activity)
- Hackathons, GNSS Training Academies

- How to submit a proposal

- Submit a request with an abstract of the project NIH_OIL_Manager@ni.com
- The ADG Lab steering group will evaluate the relevance of the abstract, the support required and any implication of Defence Services



NI is now part of Emerson.