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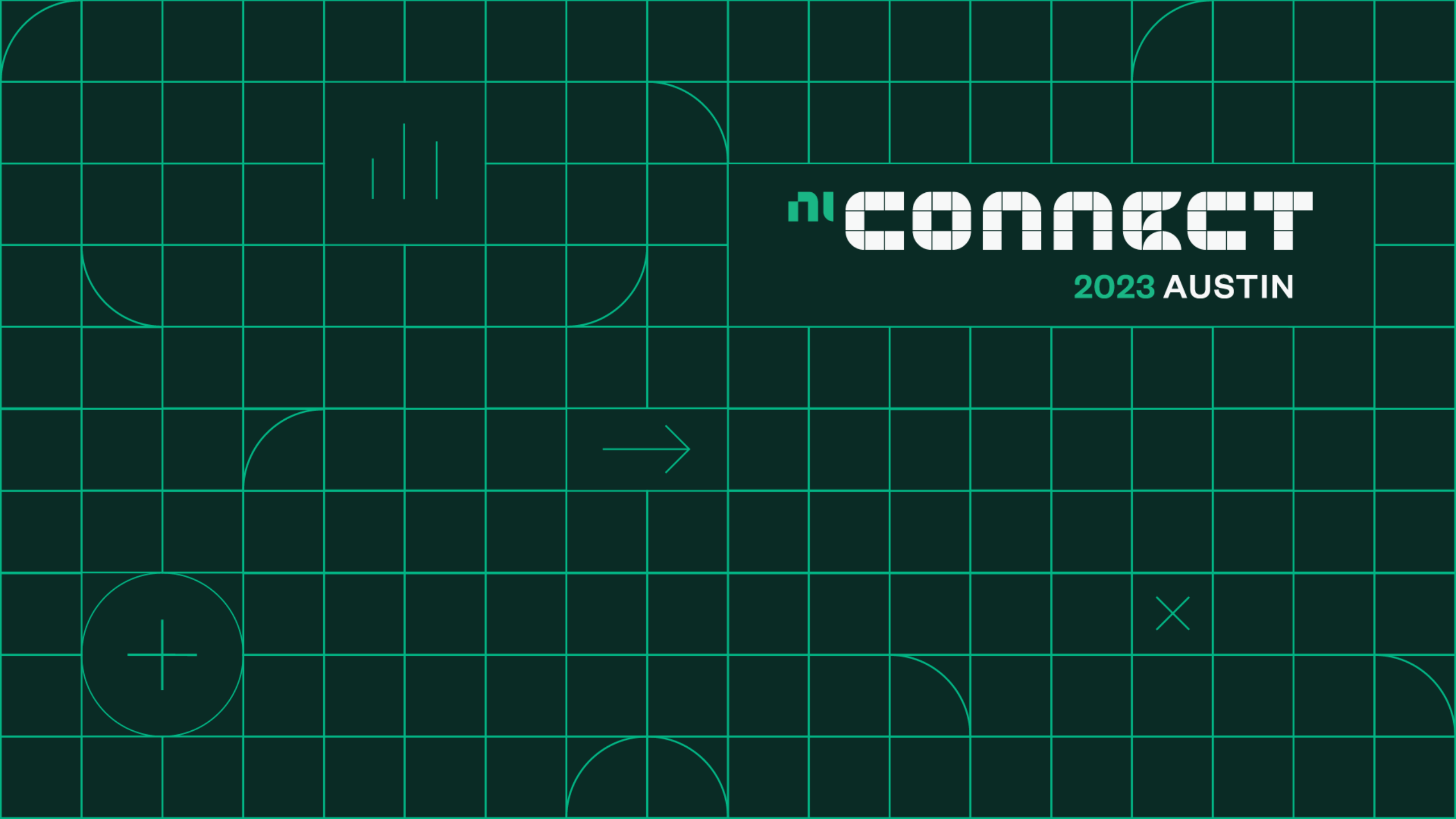

CONNECT
2023 AUSTIN

Validating Satellite Datalinks with HIL and SLE

Samah Chazbeck

Principal Applications Engineer

Agenda

- Market Trends in Space
- Satellite Datalinks – A System Validation Test Challenge
- Datalink (System Under Test) Emulation
- Environment (Channel) Emulation
- Leveraging HIL in the design and characterization workflow

Evolution of Number of Satellites

~ 1000 Satellites in 2010

~ 8200 Satellites in 2022

> 50000 Satellites in 2030

Defense, Security, Navigation, Earth Observation, Science, Health, Environment, Weather, Telecommunications, Connectivity

Commercialization of Space Applications

Space Industry Trends

Launch Services

Development of lunar and multi-planetary vehicles

Increased access to space at a lower price point

LEO payload support small sat launchers and payload adapter

Satellites

Increased constellation manufacturing and specialized payload deployment

Earth Imaging, Global Communications, Satellite Servicing

Space Habitats

Growth of LEO Economy

ISS Decommission in 2030

Multiple Commercial Space Stations

Ground Segment

Multi orbit and multi frequency ground station support

Cyber considerations for critical infrastructure

Space Industry Challenges

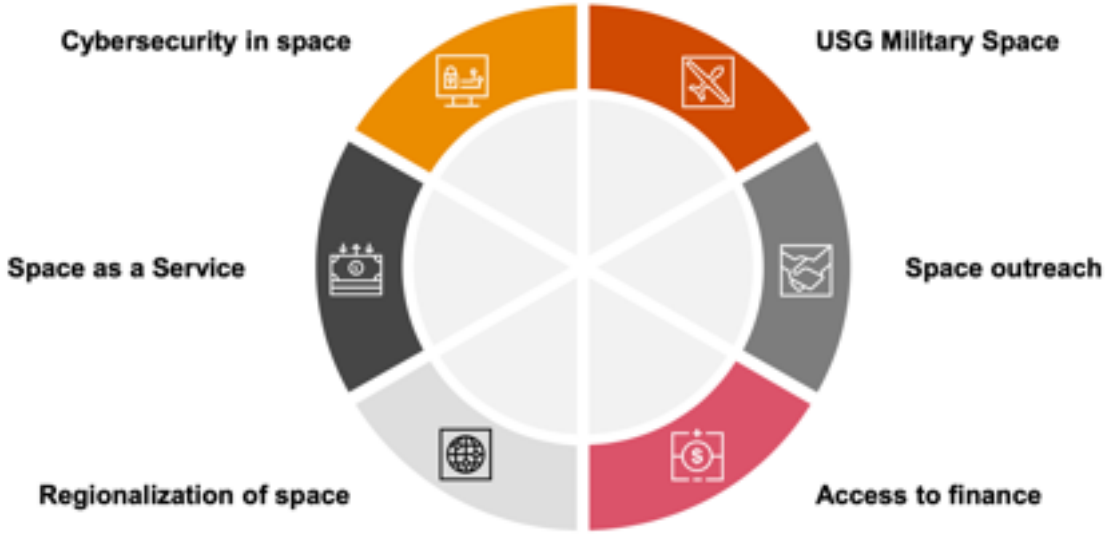
Market Challenges

- Increased customer cost pressure
- Increasing market competitors and investment from competition
- Time to market and customer delivery pressure
- Personnel bandwidth capacity and expertise recruitment

Technology Challenges

- Scaling production volumes
- More complex payloads
- HW quality and reliability
- More software and autonomy
- Digital Engineering

Industry Trends



NI Space Application Areas

Launch

Avionics HW Test

HIL and Integration & Test

TT&C, FTS, and RF Components

Launch Operations

Engine Test

Electronic Ground Support Equipment

Environmental, Structural, and Mechanical Test

Satellites

Avionics HW Test

HIL and Integration & Test

TT&C, RF Comp., Channel Emulation,

Power Systems Tests

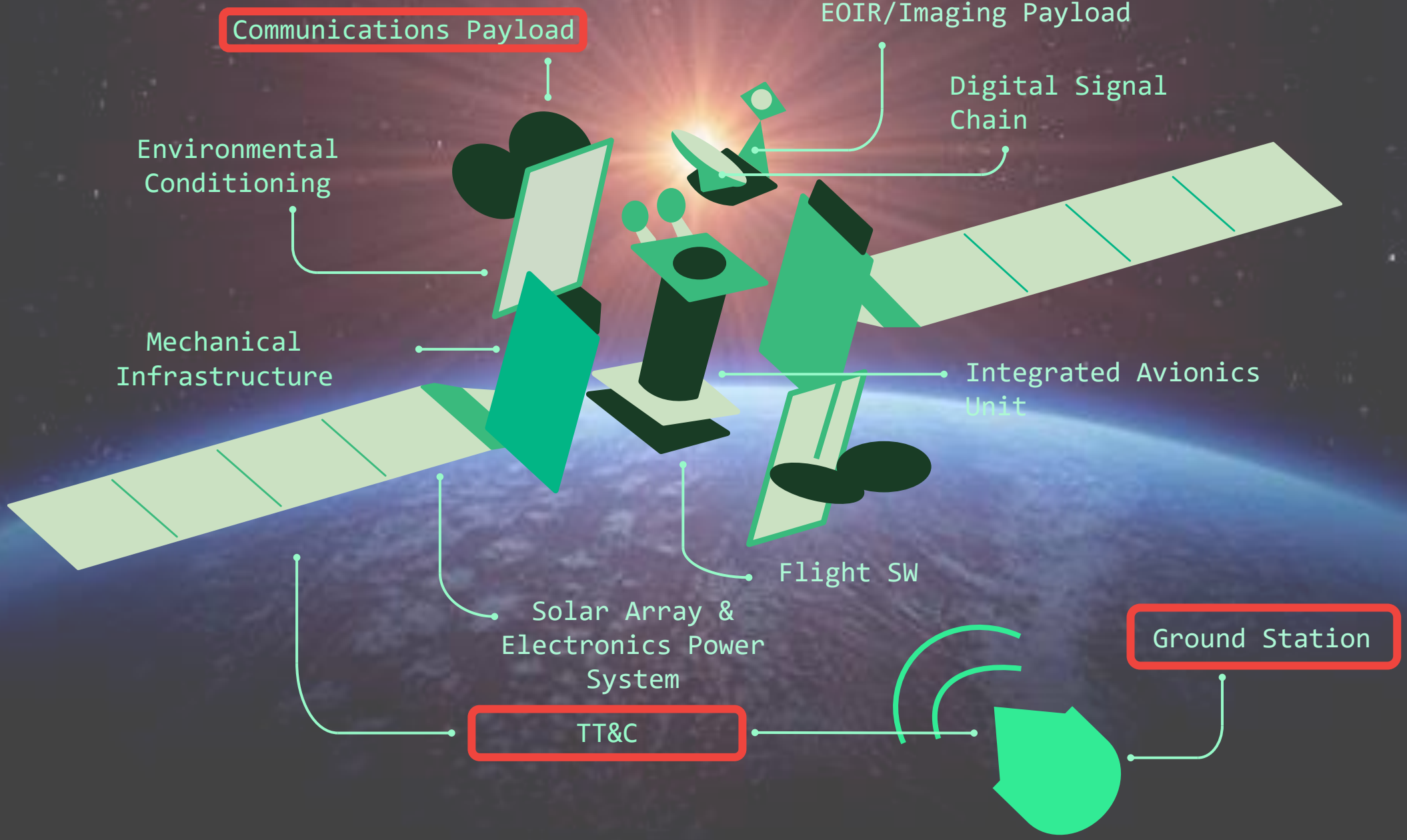
EOIR, SAR, and Comms Payloads

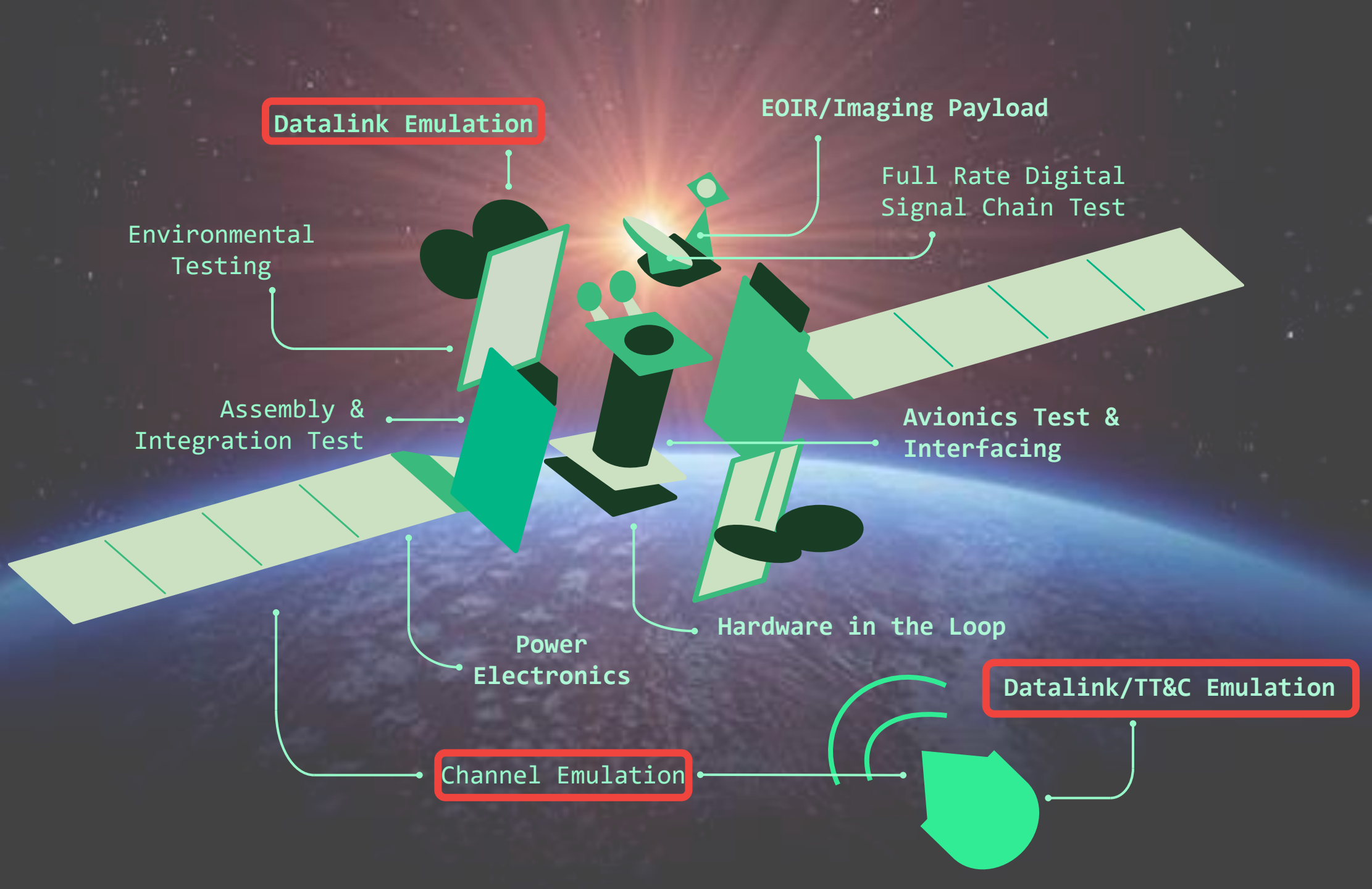
Electronic Ground Support Equipment

Environmental, Structural, and Mechanical Test

Enterprise Test, Data, and Systems Management Software

Satellite Components




Datalink Emulation
EOIR/Imaging Payload
Full Rate Digital Signal Chain Test
Environmental Testing
Assembly & Integration Test
Avionics Test & Interfacing
Power Electronics
Hardware in the Loop
Datalink/TT&C Emulation
Channel Emulation

Datalink Payload and TT&C Product Lifecycle

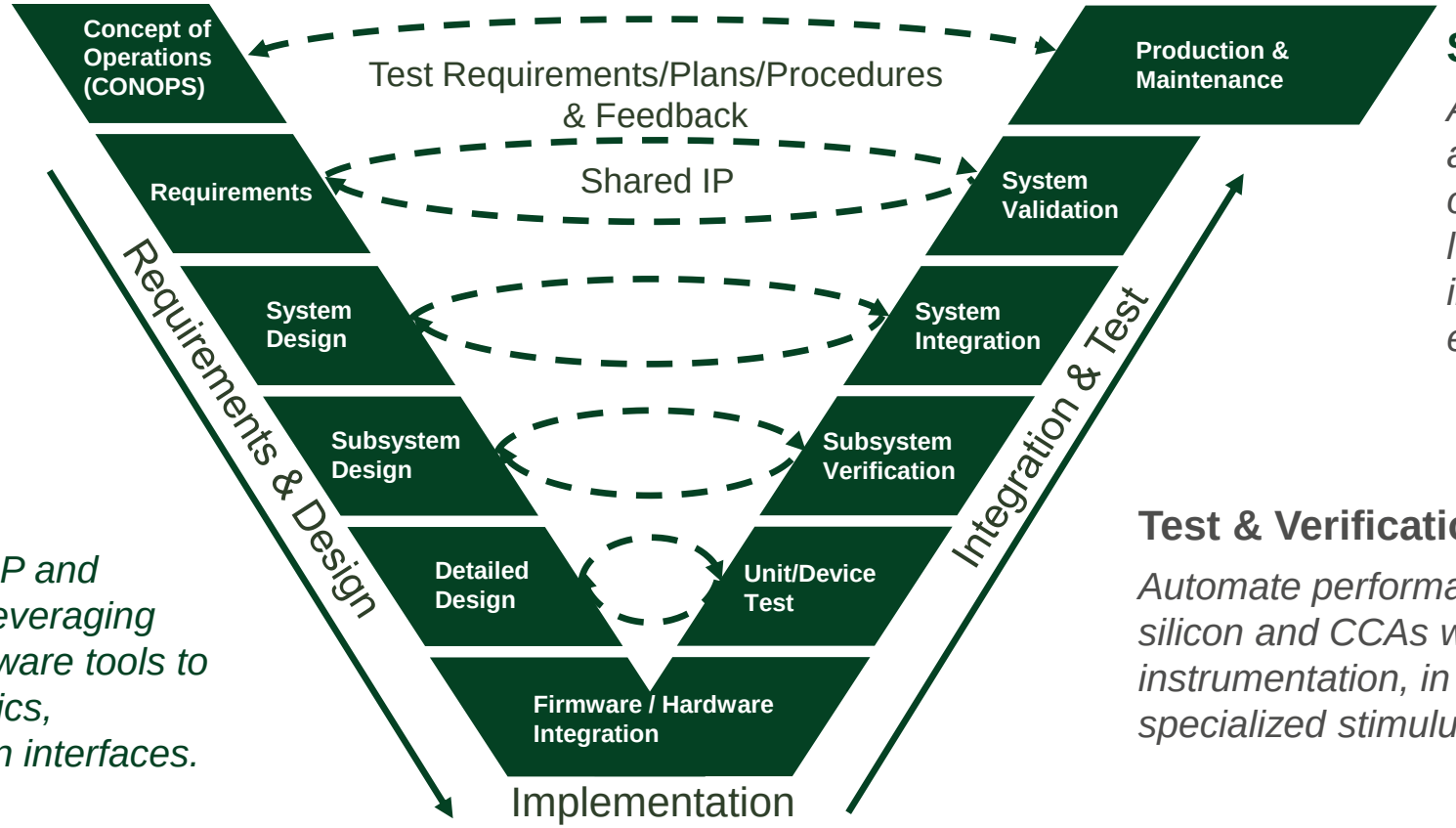
Incrementally Developed & Validated Throughout the Entire Lifecycle

System Design

Rapidly develop product IP and functional simulators by leveraging COTS hardware and software tools to model and verify electronics, command and data interfaces.

Subsystem Design

Rapidly develop product IP and functional simulators by leveraging COTS hardware and software tools to model and verify electronics, command and test pattern interfaces.



System Validation

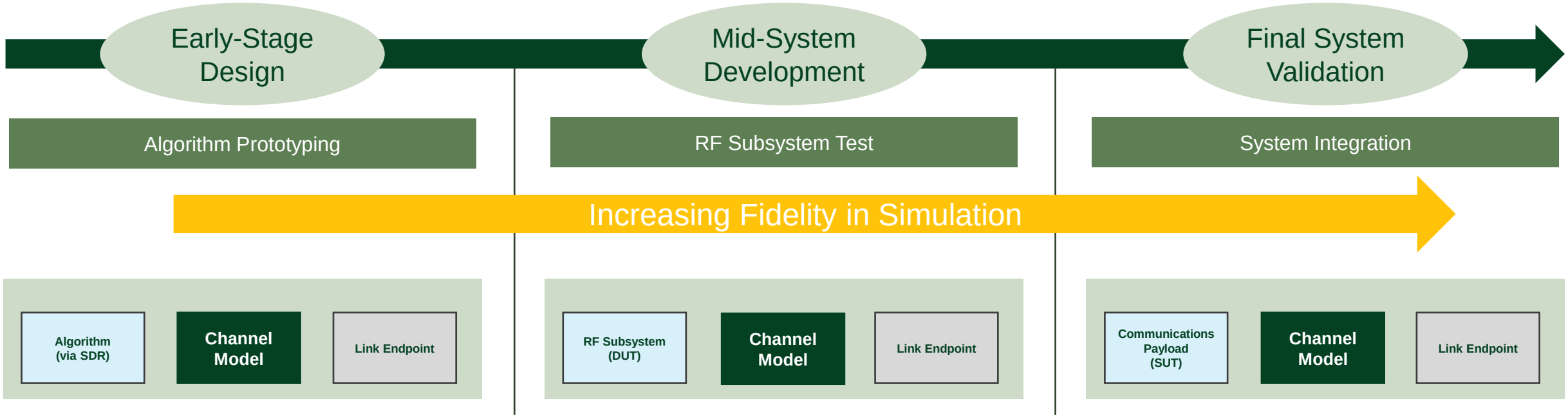
Automate the calibration and performance validation of mission hardware by leveraging COTS instrumentation and test execution software.

Test & Verification

Automate performance validation of silicon and CCAs with COTS instrumentation, in combination with specialized stimulus hardware.

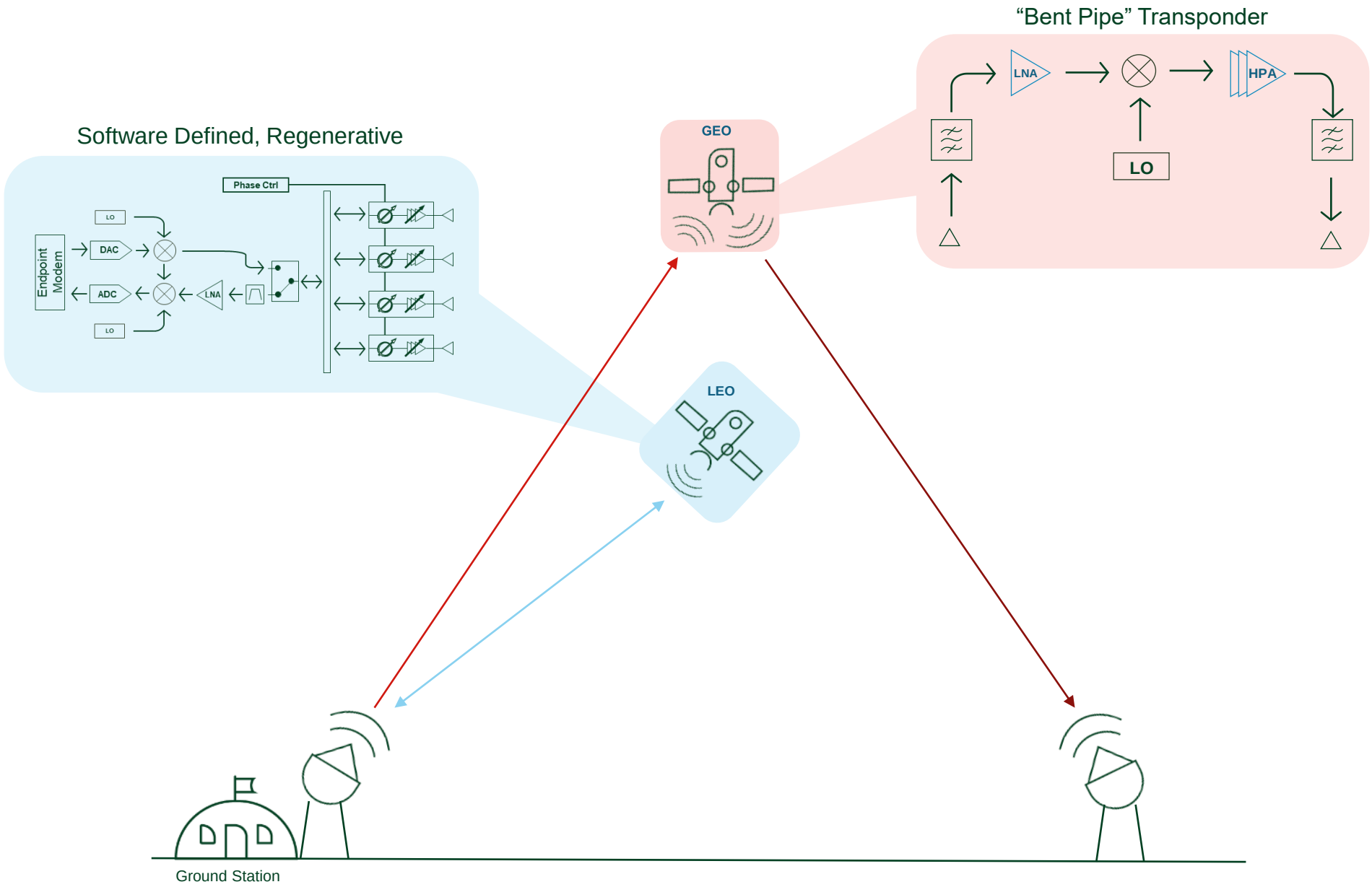
Shared IP & Simulation Across the Design, Integration & Test Cycle Reduces Risk & Time-to-Market

Design Workflow | Datalink and TT&C



Datalink (System Under Test) Emulation

Application – Datalink Endpoint Validation



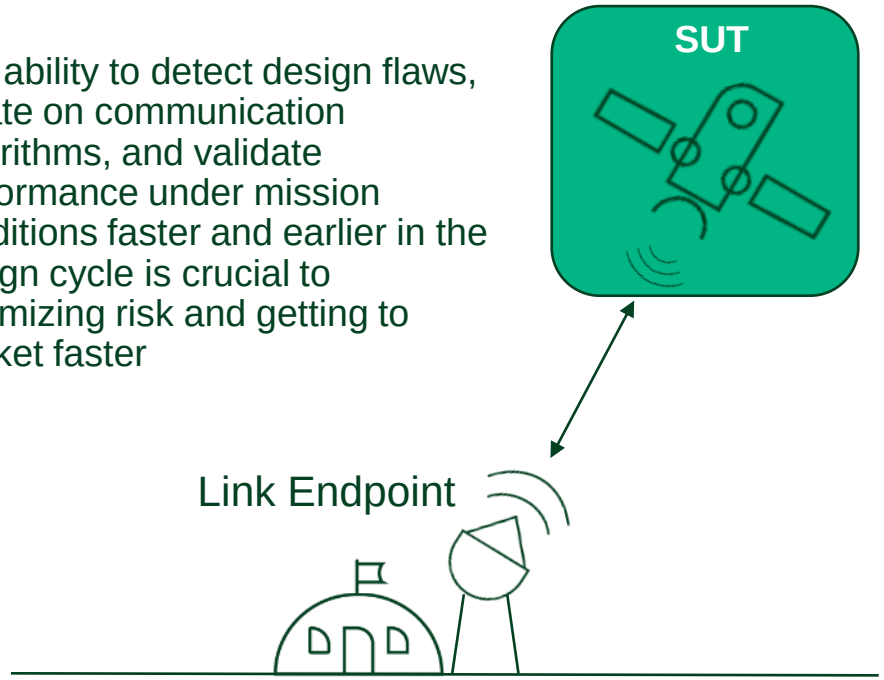
Design Workflow | Validating a SatCom Payload

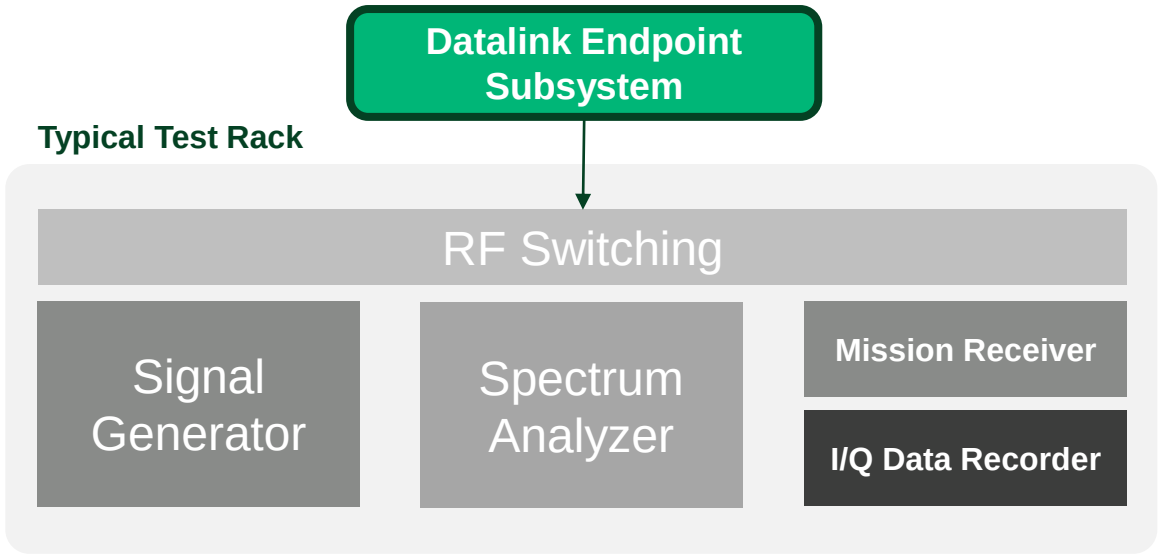
RF Subsystem Characterization

Validation of a communications payload or telemetry transmitter can be performed at various stages of the design cycle.

- Software Prototyping – Algorithm Validation
- **RF Subsystem Characterization**
- Final Payload Integration

The ability to detect design flaws, iterate on communication algorithms, and validate performance under mission conditions faster and earlier in the design cycle is crucial to minimizing risk and getting to market faster





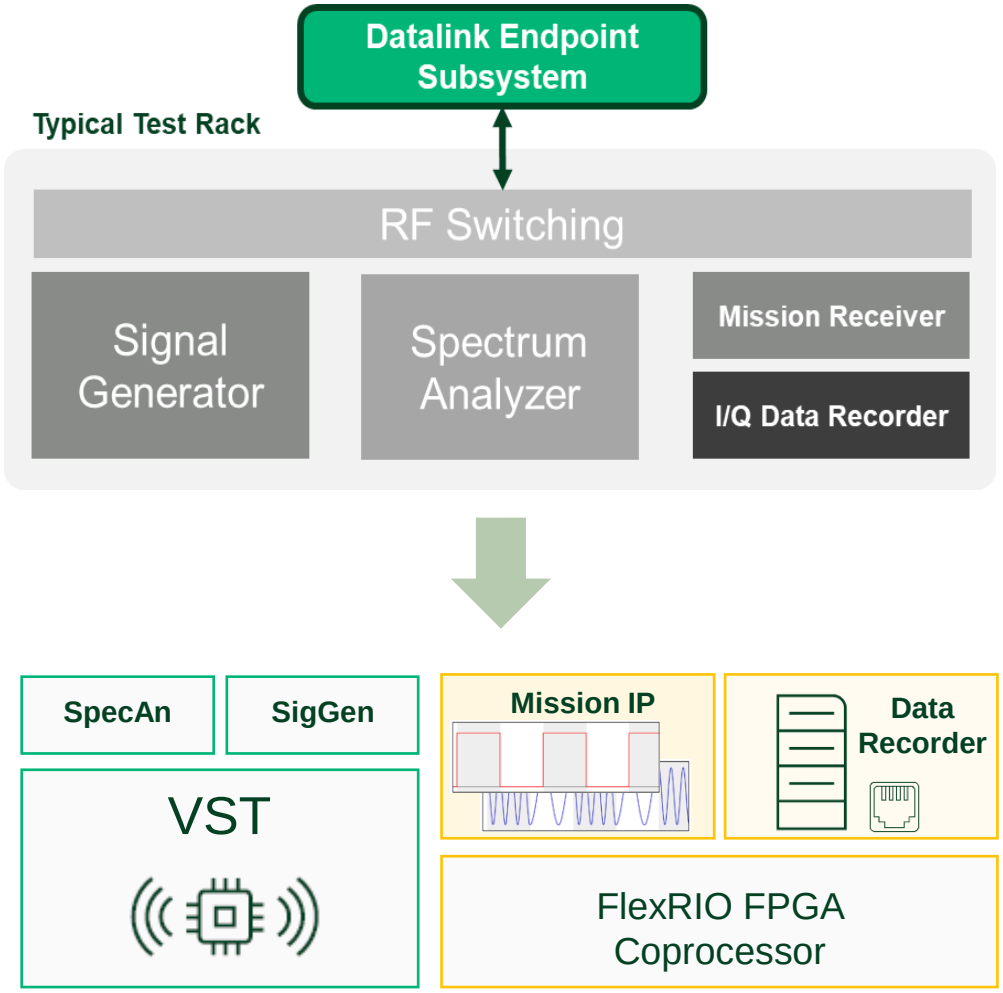
RF Subsystem Design validation requires a mix measurement capabilities

- **RF Parametric:** Gain/Phase, Phase Noise, Channel Power, Linearity/Compression
- **Application:** Modulation Quality, Error Vector Magnitude (EVM), Bit Error Rate (BER), I/Q or Data Recording

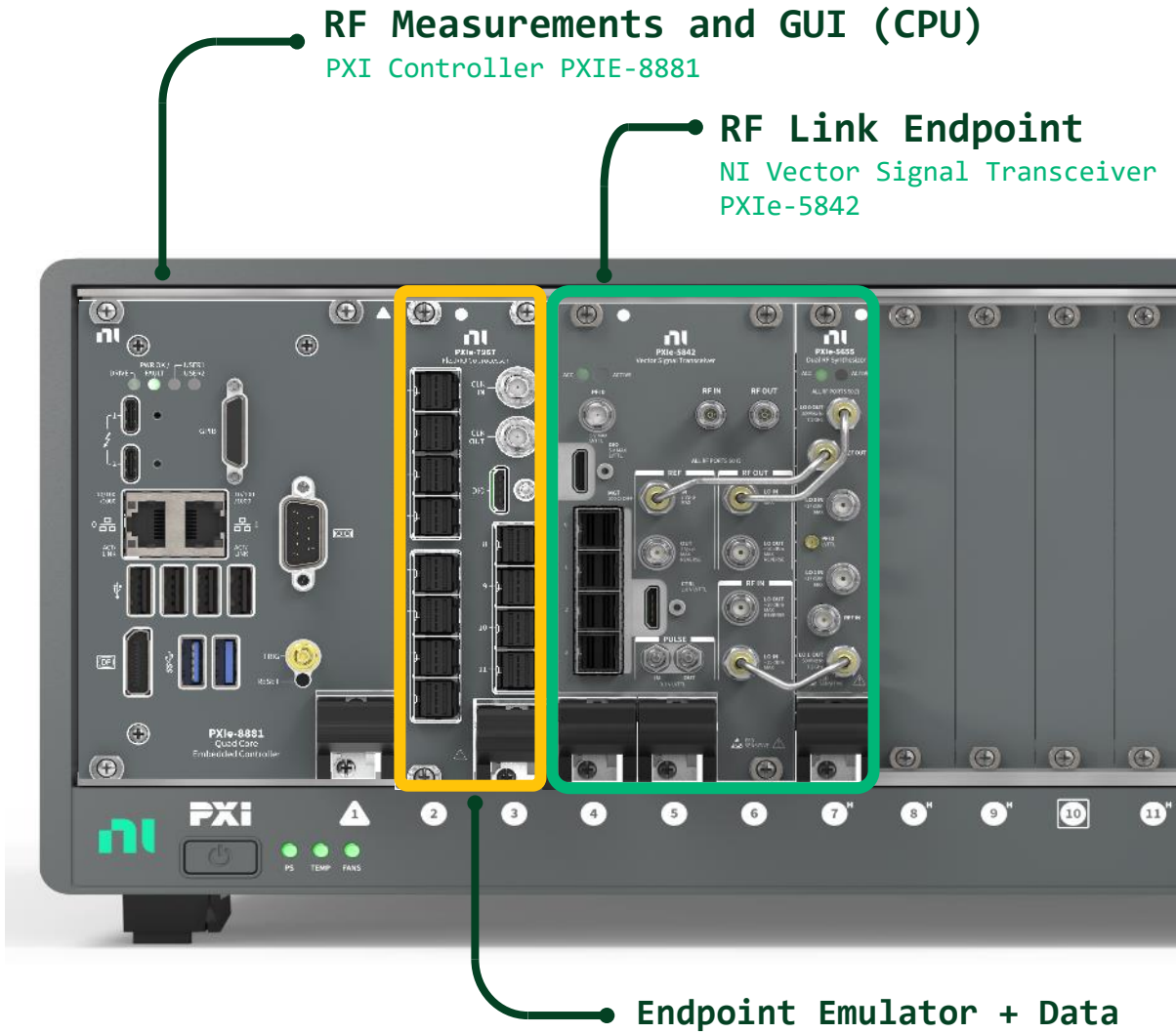
Traditional test and measurement vendors have solved these needs with separate instruments – leading to a large, expensive, and often mixed vendor test stand

Application or Mission validation is often performed with “golden SUTs” or black box receivers that are expensive to maintain and scale.

Satellite Link Emulator | Hardware Architecture



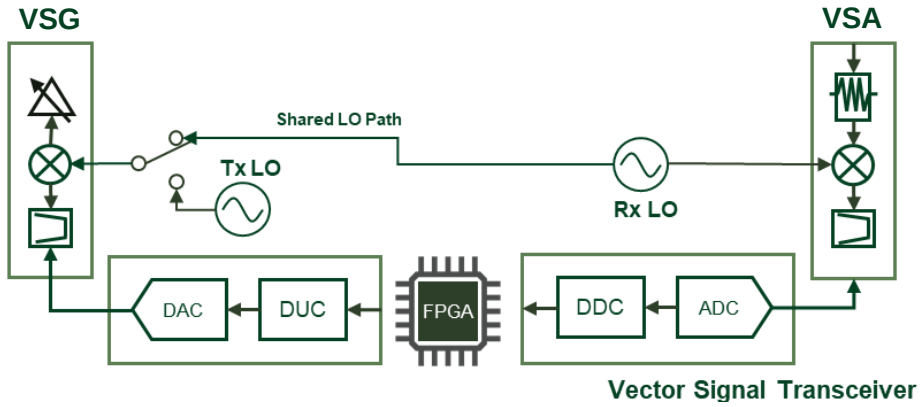
Consolidated Instrumentation in a single, scalable, Software Connected PXI System



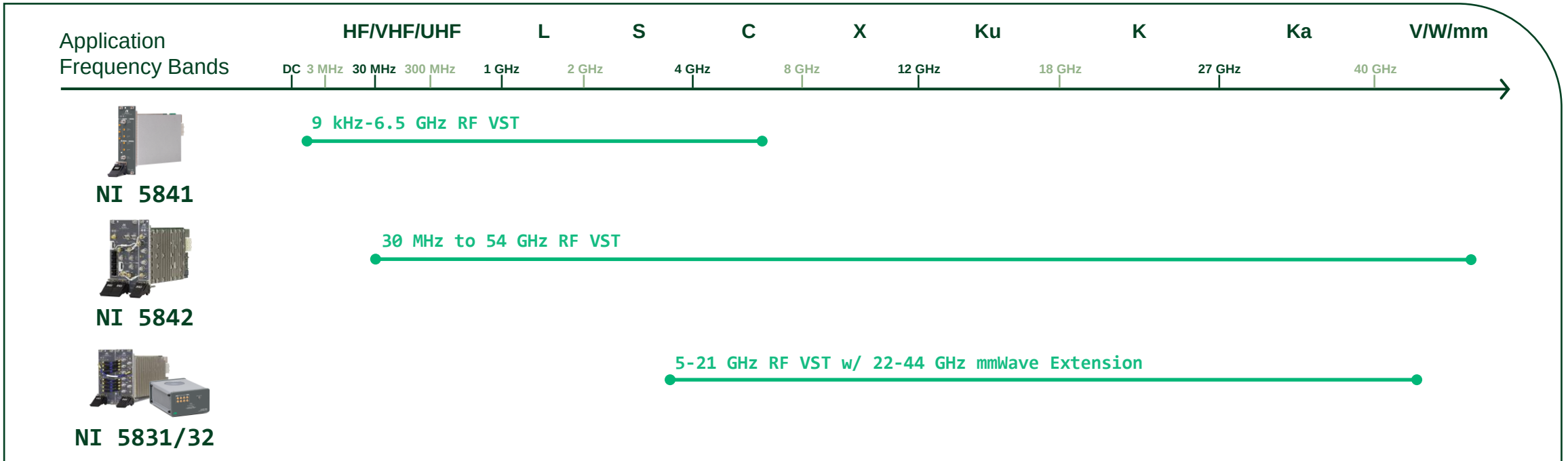
Vector Signal Transceiver

Integrated, instrument grade VSA and VSG with up to 1 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



PXIe-5842 26.5 GHz VST

- Expand Capabilities with Flexible Licensing/Upgrade Options
- Expand Functionality with additional HW
  - mmWave extension up to 54GHz
- Common SW tools to PXIe-583x and PXIe-5841
- Full IBW I/Q Data movement supported via integrated High-Speed MGT interfaces and PXI ecosystem – including the new NI 7903 FPGA Co-Processor

Parameter	Instrument Capability
Frequency Range	30 MHz – 23 GHz (Q4 2022) 30 MHz – 26.5 GHz (H2 2023)*
Bandwidth	Up to 2 GHz
RF IN / OUT Flatness (2GHz)	< ±0.45 dB typ. / < ±0.4 dB typ.
RF IN / OUT Absolute Accuracy	< ±0.4 dB typ.
Max Unleveled Tx Power	+20 dBm typ. (<18 GHz)

***Upgrade from 23 GHz HW to 26.5 GHz HW requires a paid upgrade service**

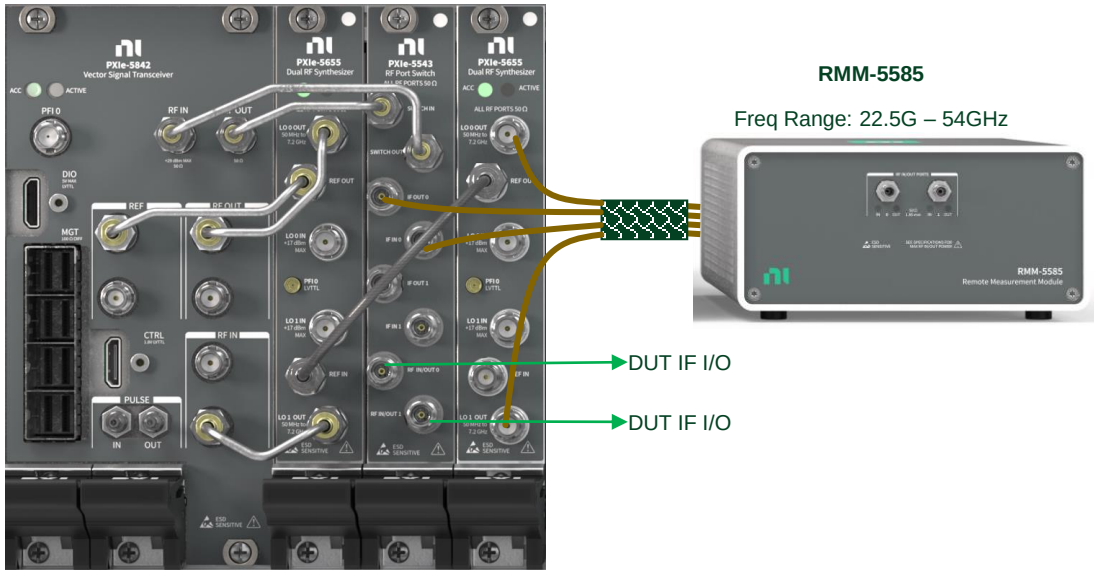
PXIe-5842 with 54GHz Freq Extension | High Level Overview

Key Features

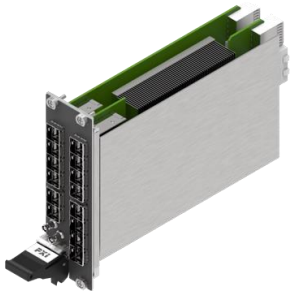
- Extended, Wideband coverage for mmWave Applications such as 5G, Satcom, Radar, and EW
- 2x Bidirectional RF ports for both mmWave and IF DUT connections
- Simultaneous operation of RF Tx & Rx ports on a single RMM-5585
- Independent frequency tuning of RF Tx & Rx ports on RMM-5585

Parameter	Instrument Capability
Frequency Range	22.5GHz – 54 GHz (RMM-5585 RF IN/OUT) 100 MHz – 23 GHz (PXIe-5543 RF IN/OUT)
Bandwidth	2 GHz
RMM RF IN/OUT Flatness (2GHz BW)	1.2 dB (39GHz)
RMM RF IN/OUT Absolute Accuracy	± 1.0 dB (39GHz)
RMM RF OUT Max Power	28 GHz: +13 dBm
5G NR,100MHz EVM	Better than -43 dB @ 47GHz

PXIe-5842 VST with 54 GHz Freq Extension



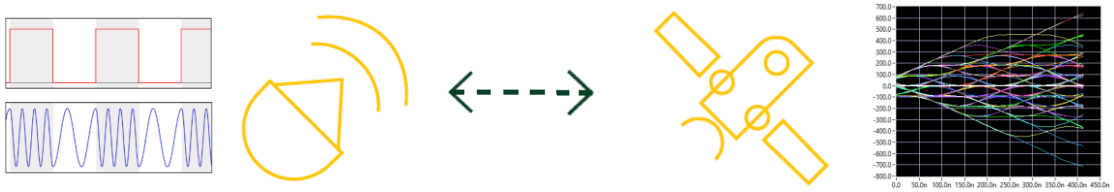
Scalable Digital Interfacing with NI FlexRIO



[High Speed Serial Product Table Link]

Specification	NI PXIe-6593	NI PXIe-6594	PXIe-7903
Line Rates	500 Mbps – 16.3 Gbps	500 Mbps – 28.2 Gbps	Up to 28.2 Gbps
Channels	8 RX/TX (GTH)	8 RX/TX (GTY)	48 MGTs (GTYs)
User Programmable FPGA	Kintex Ultrascale (KU040 or KU060)	Kintex Ultrascale + (KU15P)	Virtex Ultrascale+ (VU11P)
DRAM	4 GB	8 GB	16 GB
Host Streaming Bandwidth	7 GB/s	7 GB/s	7 GB/s
Connector	QSFP28	QSFP28	12x miniSAS zHD
Cabling Options	Copper or Optical	Copper or Optical	Copper or Optical (TBD)
Aux DIO	8 GPIO, 4 GTH (RX/TX)	8 GPIO, 4 GTY (RX/TX)	12 GPIO (MiniHDMI)
Relevant Protocols	JESD204B, 10/40 GbE, Aurora, Custom	JESD204B/C, 10/25/40/100 GbE, Aurora, Custom	100 GbE, Aurora 64b66b

NI | Datalink Reference Architecture



InstrumentStudio, MeasurementLink, & Application SW

Vector Signal Analysis

Signal Generation

Real-Time Modulation & Demodulation

NI RFmx

NI Datalinks Application Software

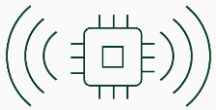
Calibrated RF Measurements(Spectrum Analysis, Pulse Analysis)
Standardized Configuration Interface to Real-Time Mission IP

NI RF Drivers

NI FlexRIO Drivers and LabVIEW FPGA

RF Instrument Control, FPGA Instrument Control,
Data Streaming configuration, Triggering and Synchronization

VST



NI Datalinks Reference IP

User IP

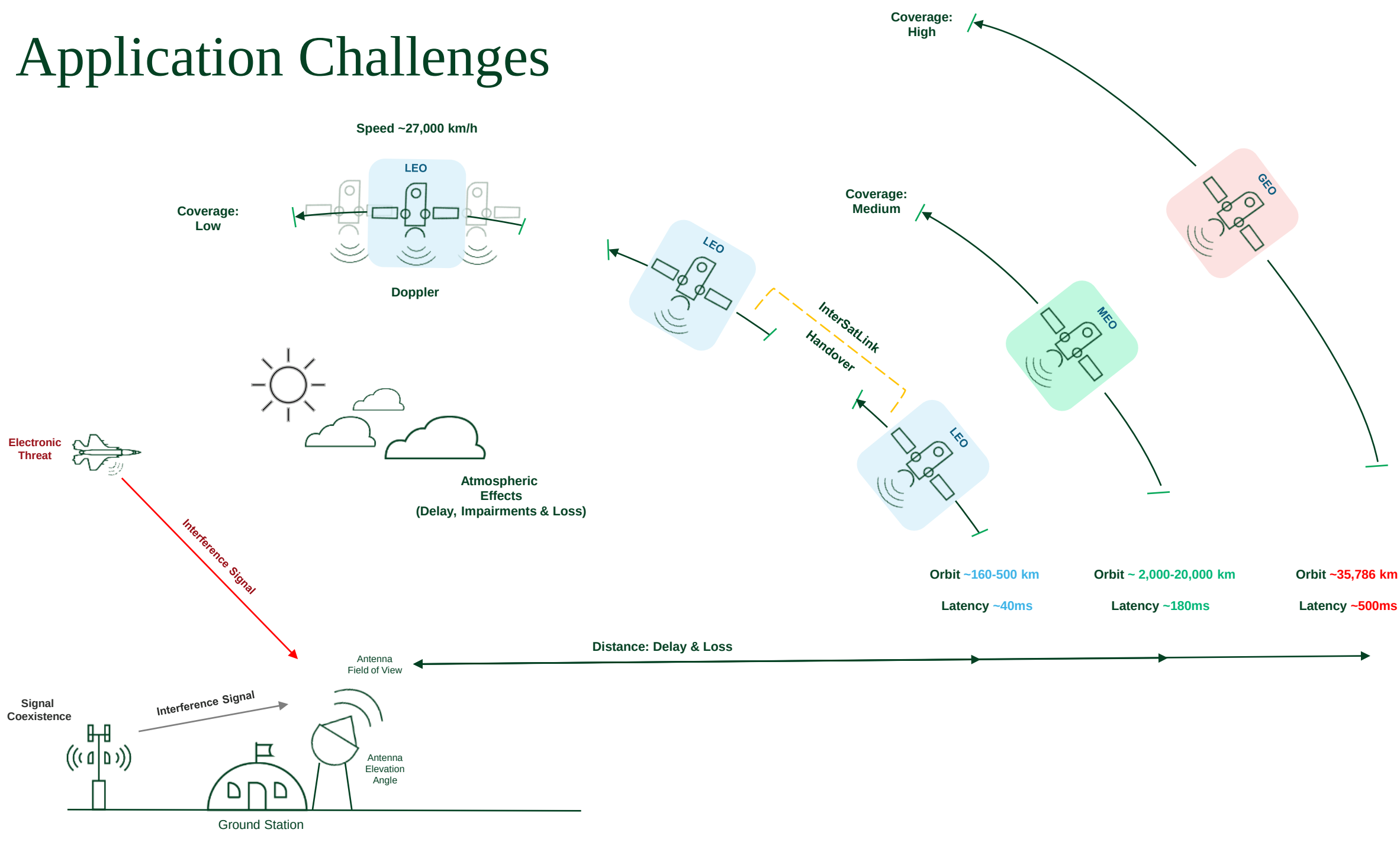
FlexRIO FPGA Coprocessor

RF Front End
- 1 Tx + 1 Rx
- Frequency: 30 MHz - 54 GHz
- IBW: 2 GHz
- Instrument Grade RF performance & Calibration
- Full BW I/Q Streaming

Core DSP
- RE-Configurable
- Peer-to-Peer Data Stream over MGT (Aurora)
- User Defined IP with VHDL import capability
- Add on stream to disk capability for I/Q data recording

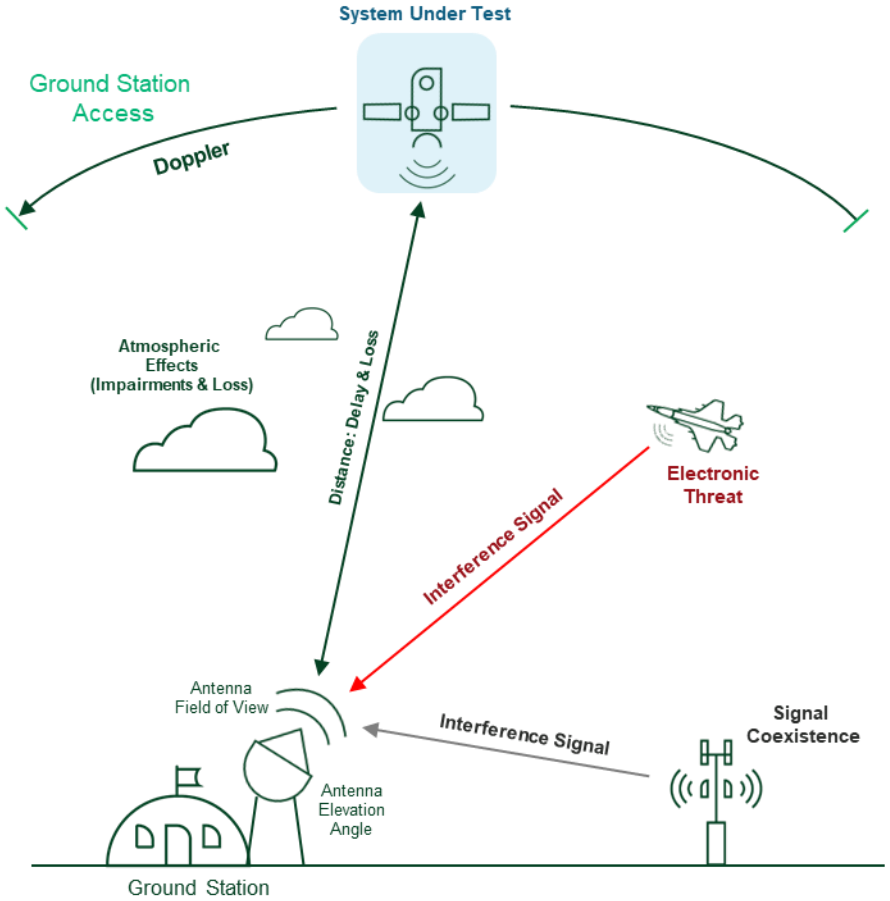
Environmental (Channel) Emulation

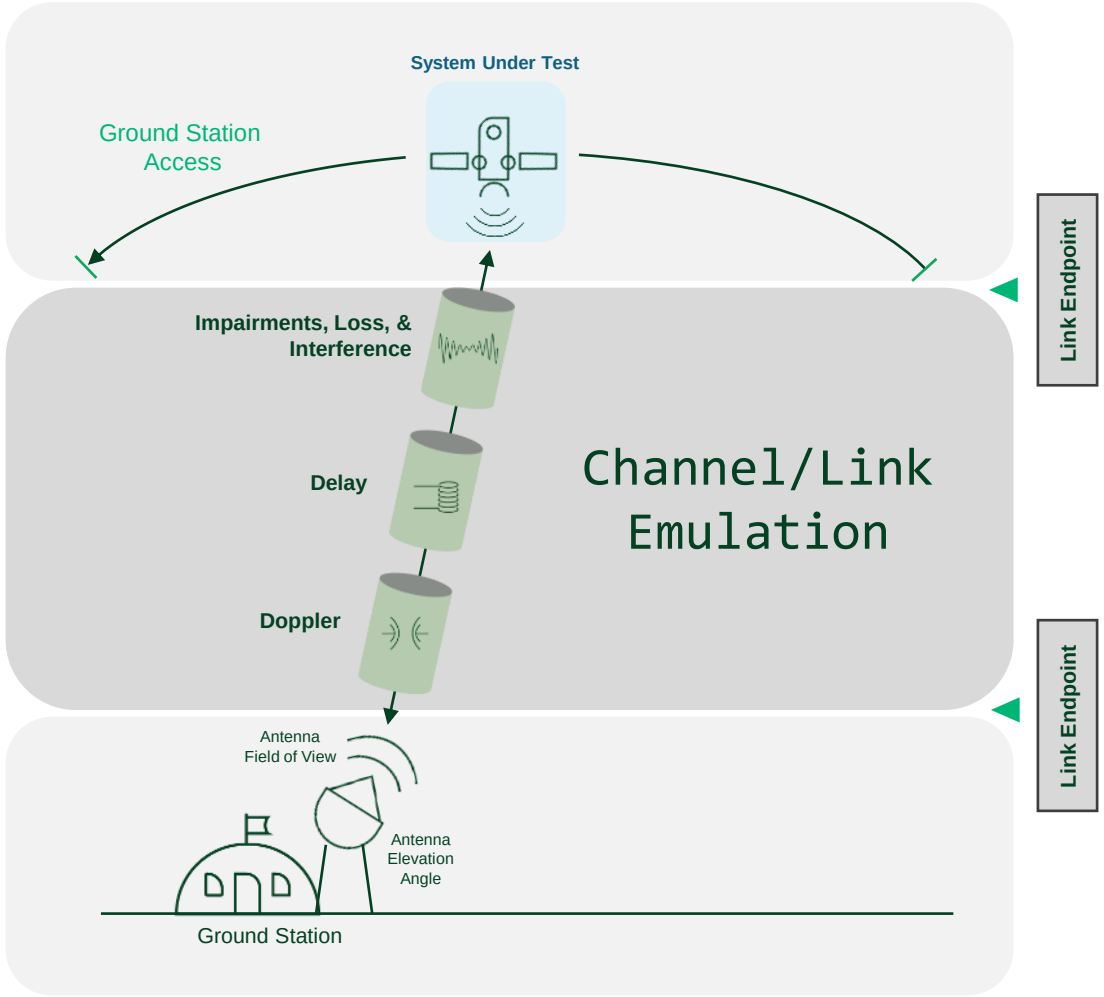
Application Challenges



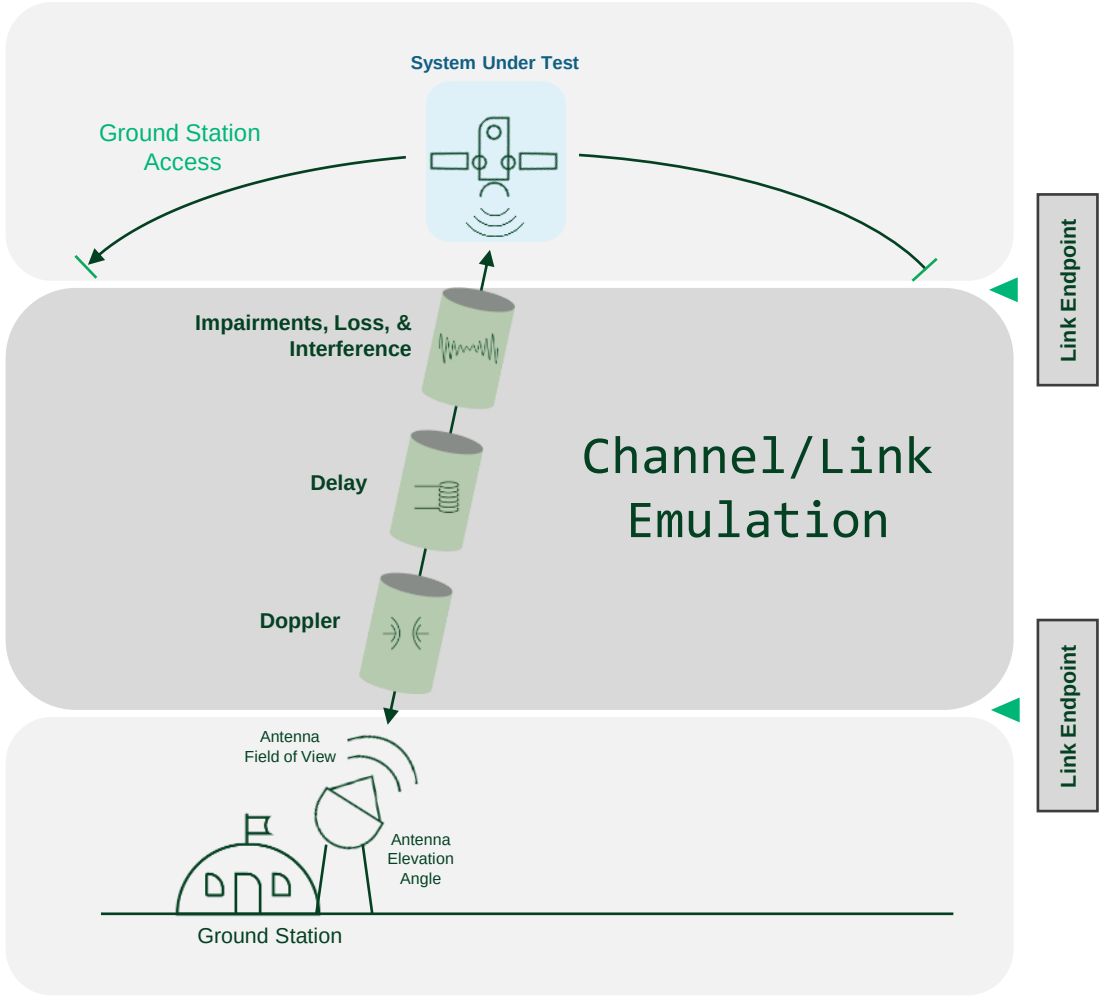
Application Challenge | Real-Time Hardware Emulation

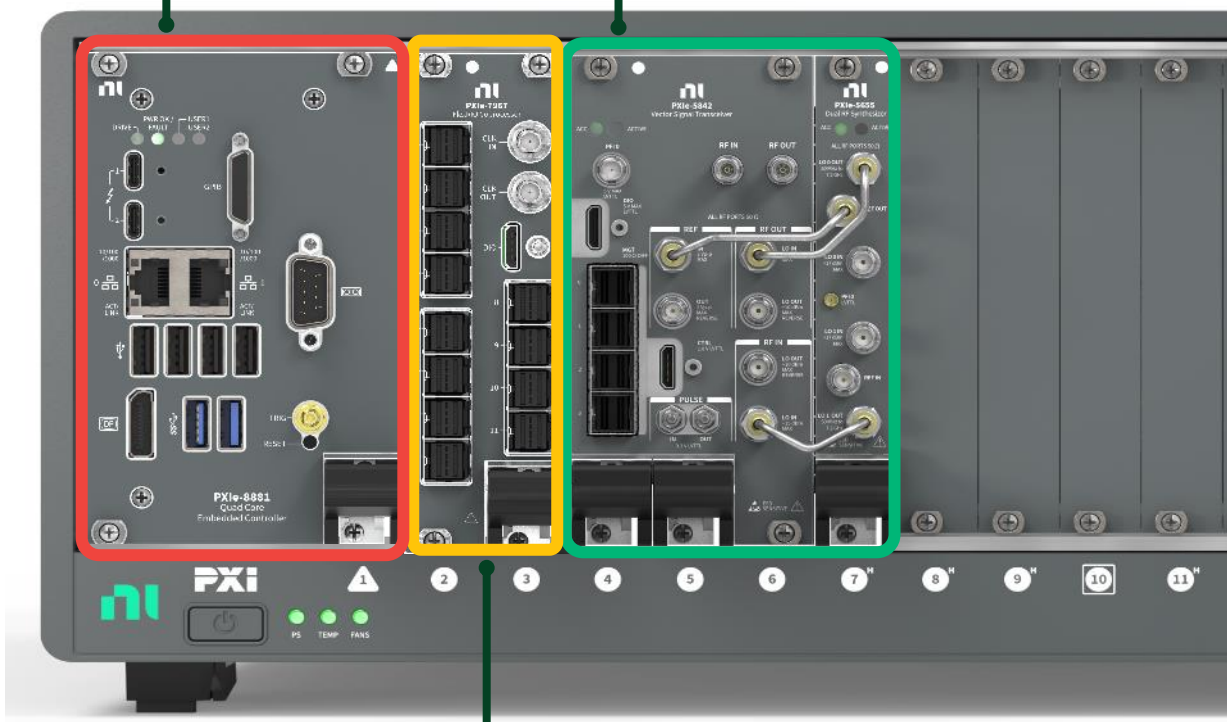
Bring real-world radio channel conditions into the lab with real-time, hardware in the loop channel emulation





Satellite Link Emulator | Hardware Architecture





Scenario Parameters (CPU)
PXI Controller PXIE-8881

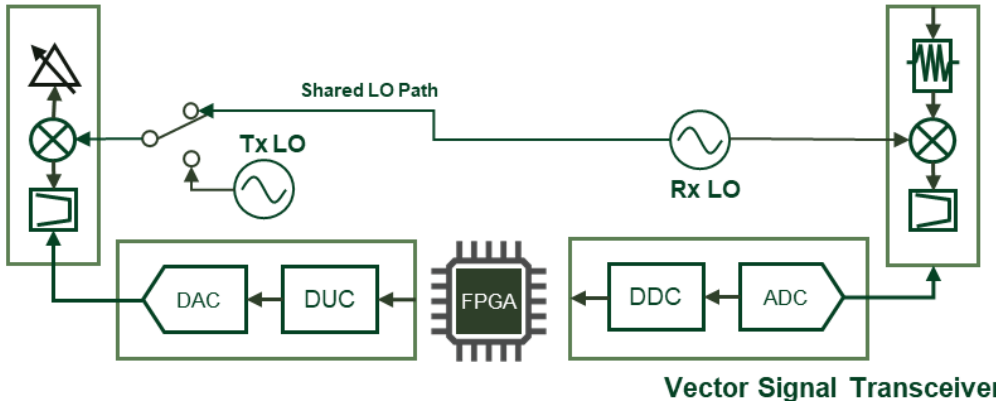
RF Link Endpoint
NI Vector Signal Transceiver
PXIe-5842

Channel / Link Emulation
NI FPGA Co-Processor
PXIe-7903

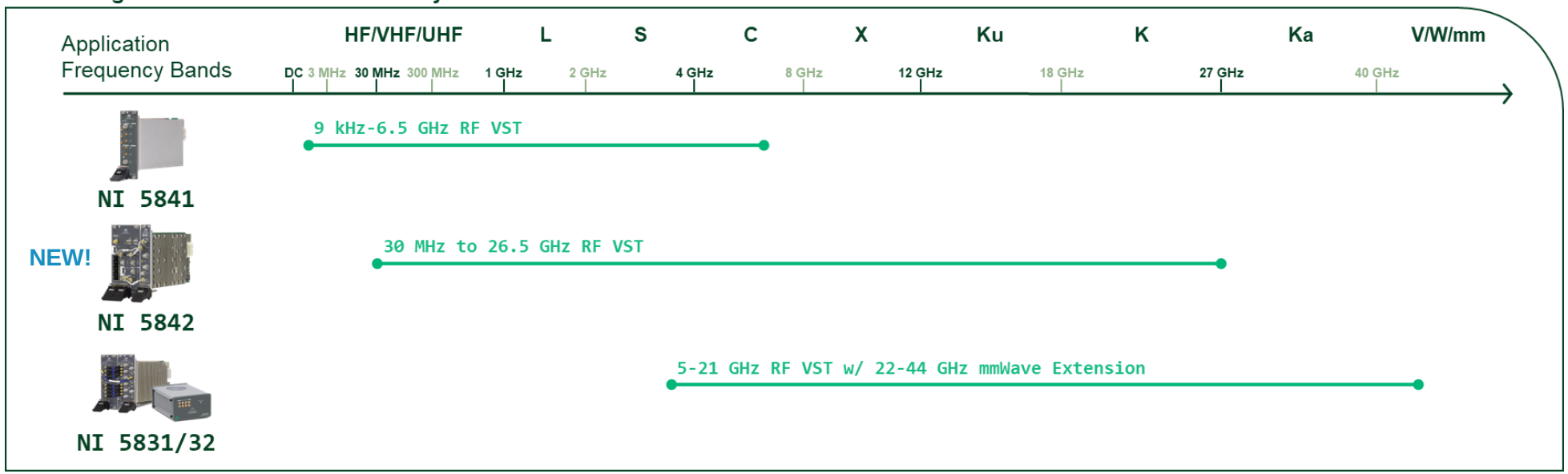
Vector Signal Transceiver

Integrated, instrument grade VSA and VSG 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



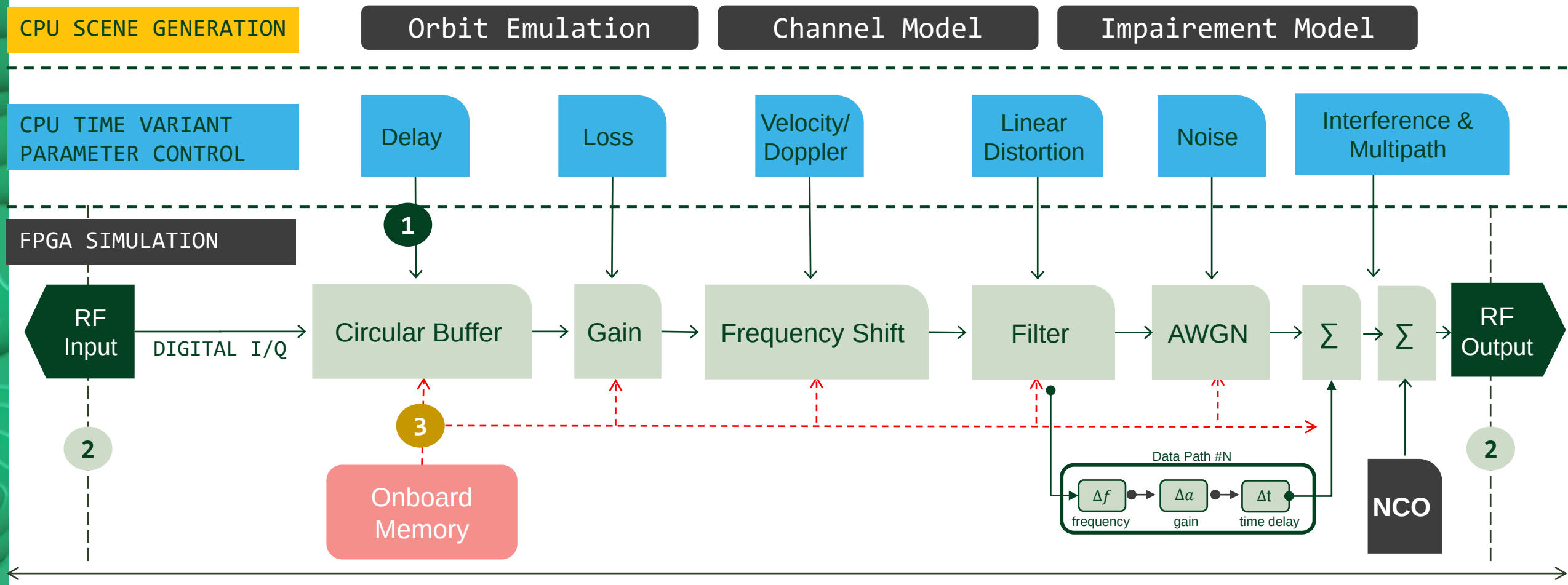
Vector Signal Transceiver Product Family



Commercial Off-The Shelf | Modularity & Density | Open Hardware & Software Standards | Heterogenous, Real-Time Compute & DSP | Wideband, High-Fidelity RF | Synchronization & RF Phase Alignment

Satellite Link Emulator | Software Architecture

ni.com

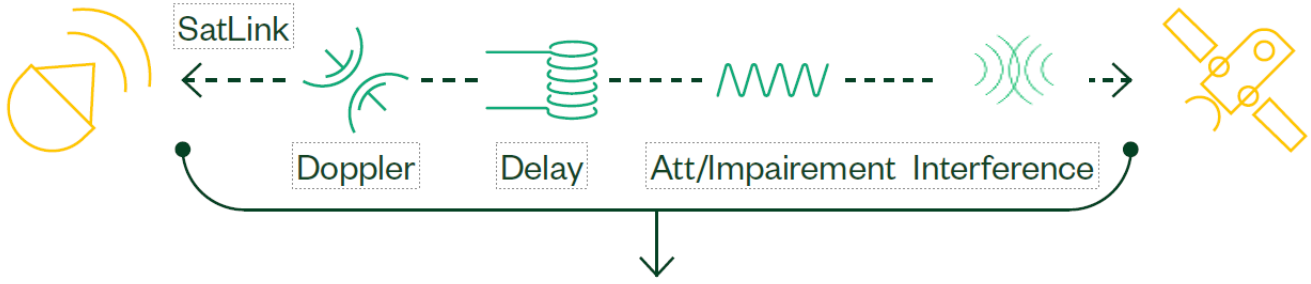


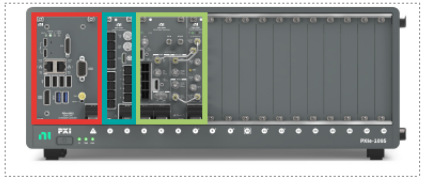
1 Use PCIe streaming at up to 7 GB/s to stream updated target parameters down to FPGA

2 Use Peer to Peer or MGT streaming to stream IQ Data from/To VST.

3 Use FPGA Onboard memory to store Scene Parameters with time dependent updates

NI | Satellite Link Emulator Reference Architecture





Scenario Generation

Orbit Emulation | Channel Model | Impairement Model

Dynamic Parameter Loading/Calibration/RF Link Settings/IQ Dsk Data Stream/RF Measurement Libraries

RF Instrument Control/FPGA Instrument Control/ Data Stream Control

Satellite Link Emulator Solution

3rd Party Simulation Software

Satellite Link Emulator Application Example (LabVIEW)

NI RF Drivers

NI FlexRIO Drivers and LabVIEW FPGA

VST

Doppler + Delay + Attenuation = User Defined Model

FPGA Co-Processor

System Under Test

RF Front End

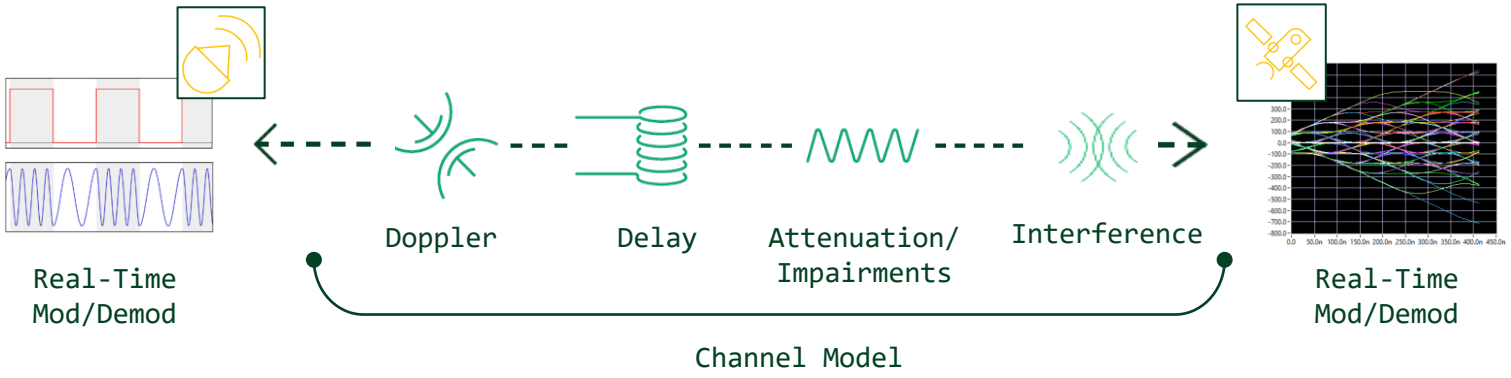
- 1Tx + 1 Rx
- Expandable Multichannel with Phase Coherency
- Frequency: 30MHz – 26GHz
- IBW:1GHz

Core DSP

- Re-Configurable
- Peer-to-Peer Data Stream or MGT (Aurora)
- User Defined IP with VHDL CLIP

Full Comms Validation Solution

NI | End-to-End Datalink Validation



InstrumentStudio, MeasurementLink, & Application SW

Signal Generation & Analysis

Scenario Emulation (Channel)

Real-Time Modulation & Demodulation

NI RFmx

NI Datalinks Application Software

Satellite Link Emulation Application Example

Calibrated RF Measurements(Spectrum Analysis, Pulse Analysis)
Standardized Configuration Interface to Real-Time Mission IP
Real-Time Orbit, Channel, Impairments, Interference Models, User Defined algorithms

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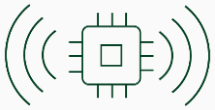

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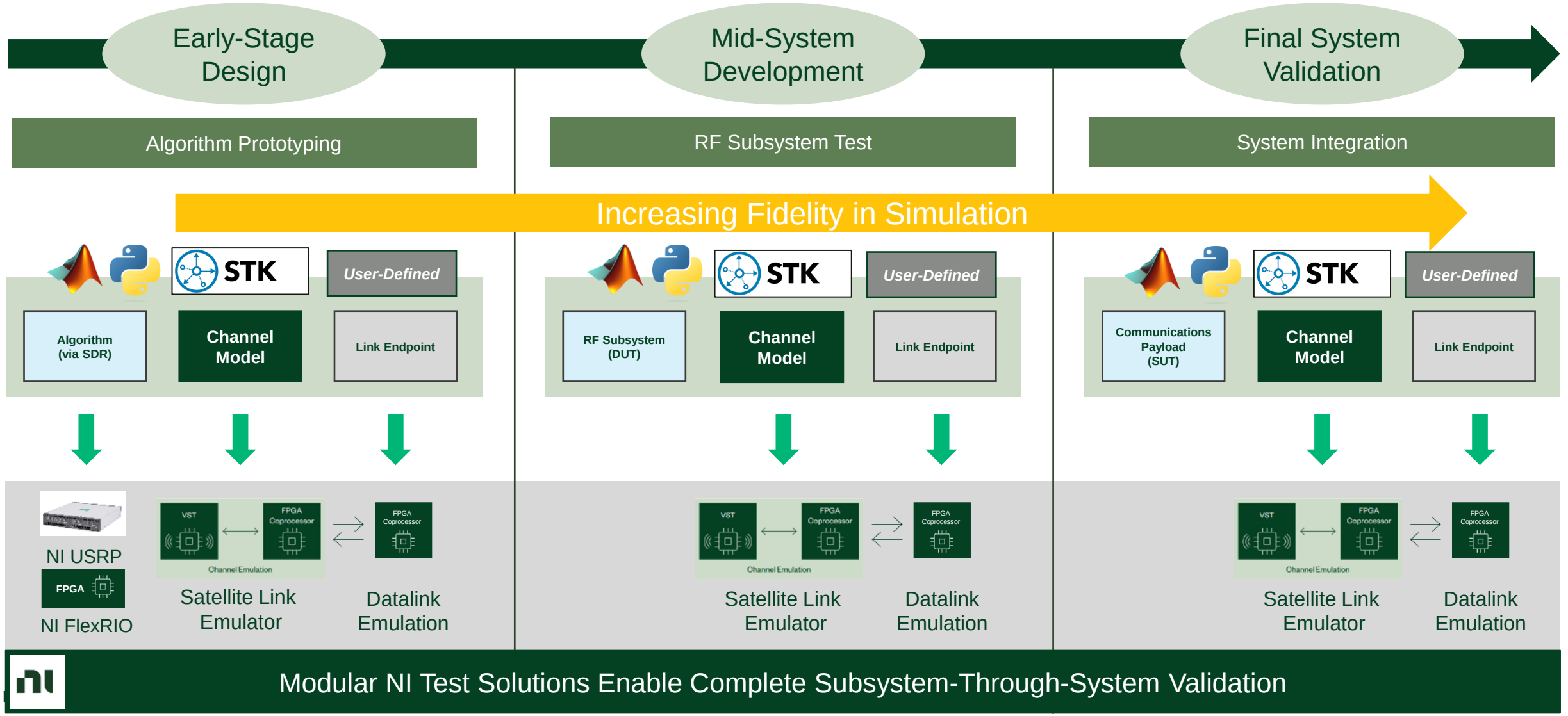
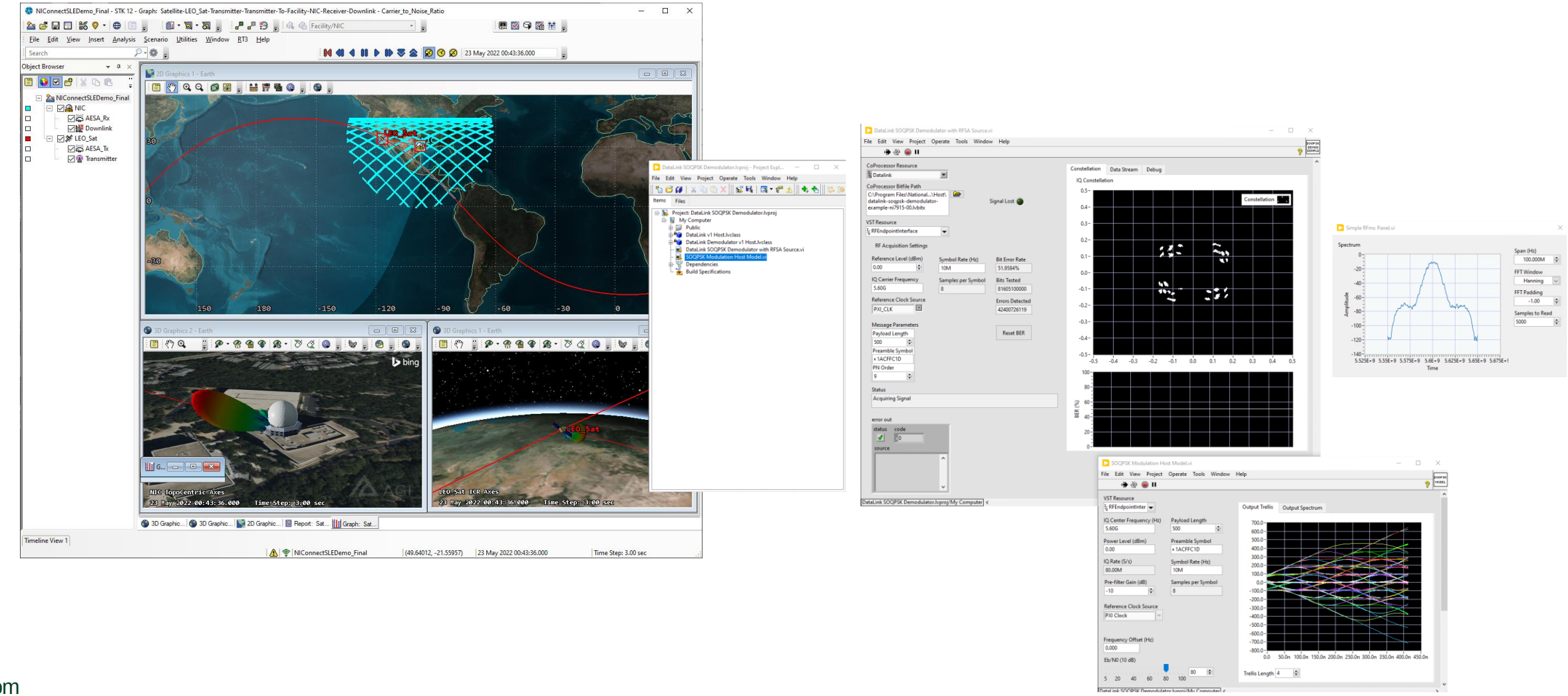
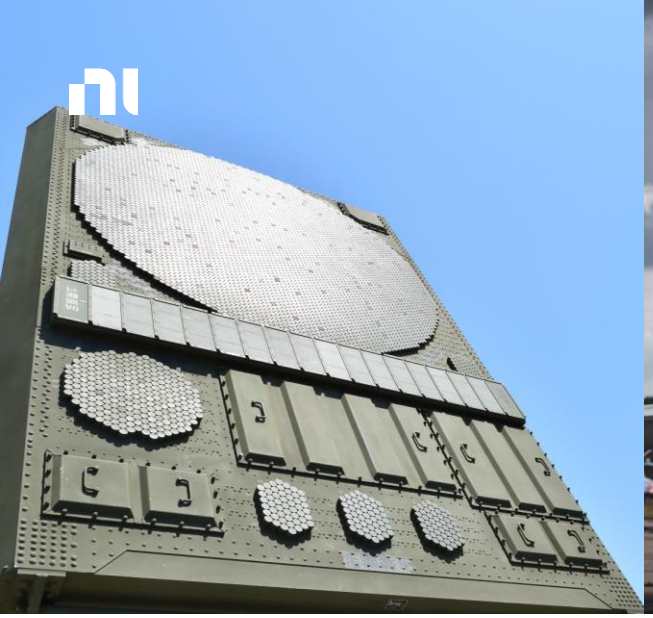
Design Workflow | Modular, Scalable Solution



Modular NI Test Solutions Enable Complete Subsystem-Through-System Validation

Datalink & SLE Reference Architecture - Demonstration






Today's modern Telemetry and Datalink Systems are increasingly mission-critical to dynamic Aerospace & Defense Applications such as Satellite Communications.

To reduce risk and get to market faster – it's crucial to combine traditional RF parametric measurements with real-time, application specific HIL validation. This includes not just the SUT in a static condition, but under the real mission parameters of the end system.

NI approaches this challenge by combining high performance RF instrumentation with scalable FPGA co-processors to provide the SUT and environment emulation needed to design, validate, and product these key systems.

- See it in action in the Aerospace and Defense Experience Lounge, or contact your NI representative for more information!

connect