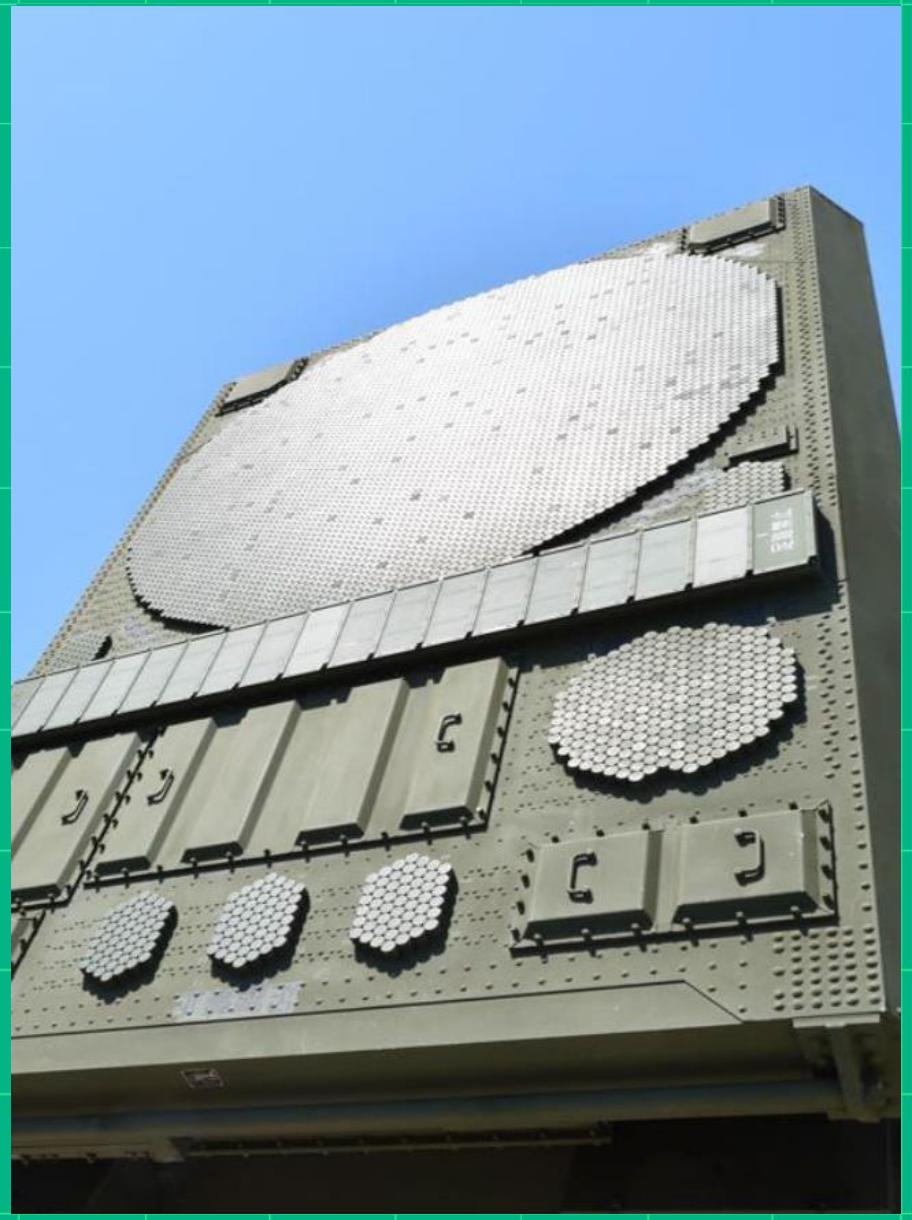
Covering the Full Radar Test Spectrum

From Digital to Analog and Component to Systems

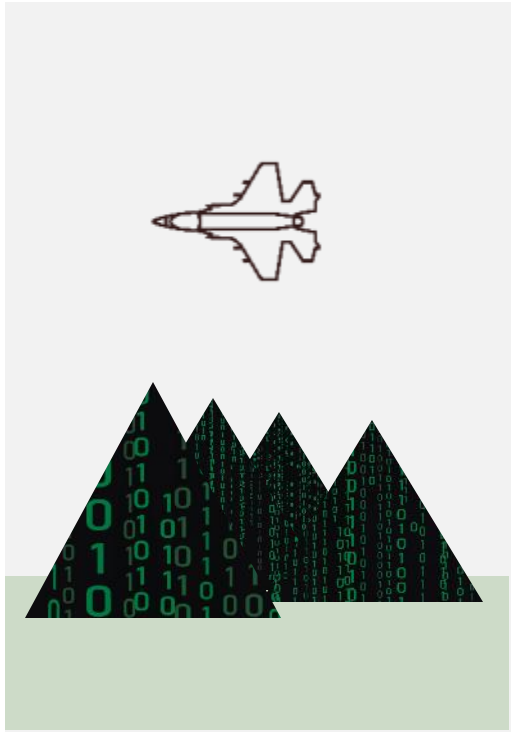
Haydn Nelson
Business Development Manager

Pang Vadysirisack
Field Applications Engineer

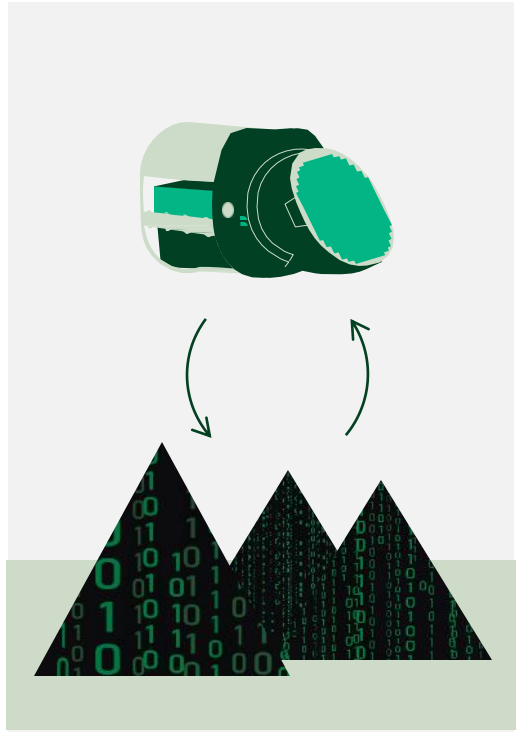


Phases of Radar Design Test & Evaluation

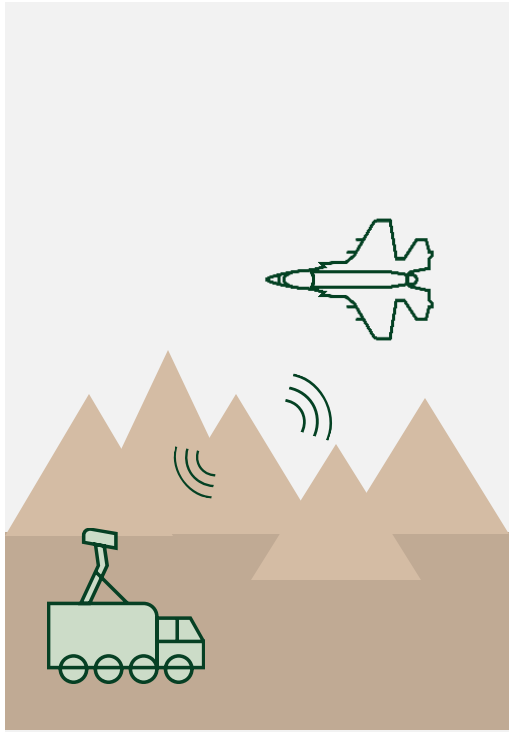
Modeling & Simulation
Digitally Simulated System



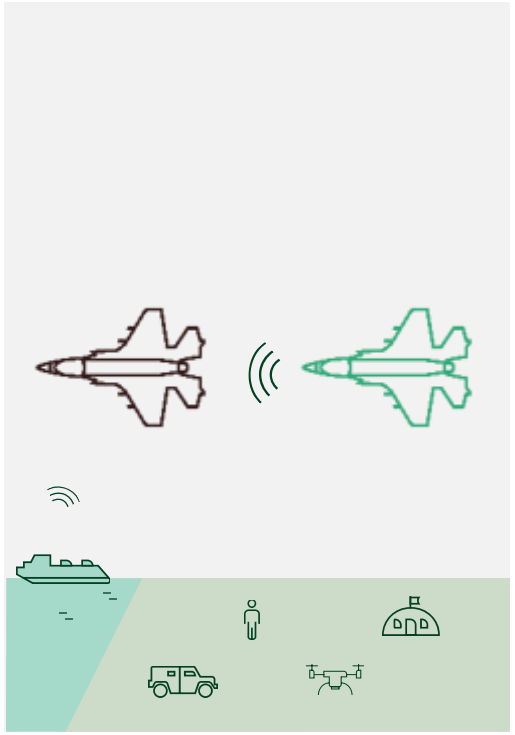
Integration Lab
Digital & RF Hardware in the Loop Testing



Open Air Range
Controlled Engagement Scenarios



Operational Mission
Active Engagement



Covering the Full Radar Test Spectrum

From Digital to Analog and Component to Systems

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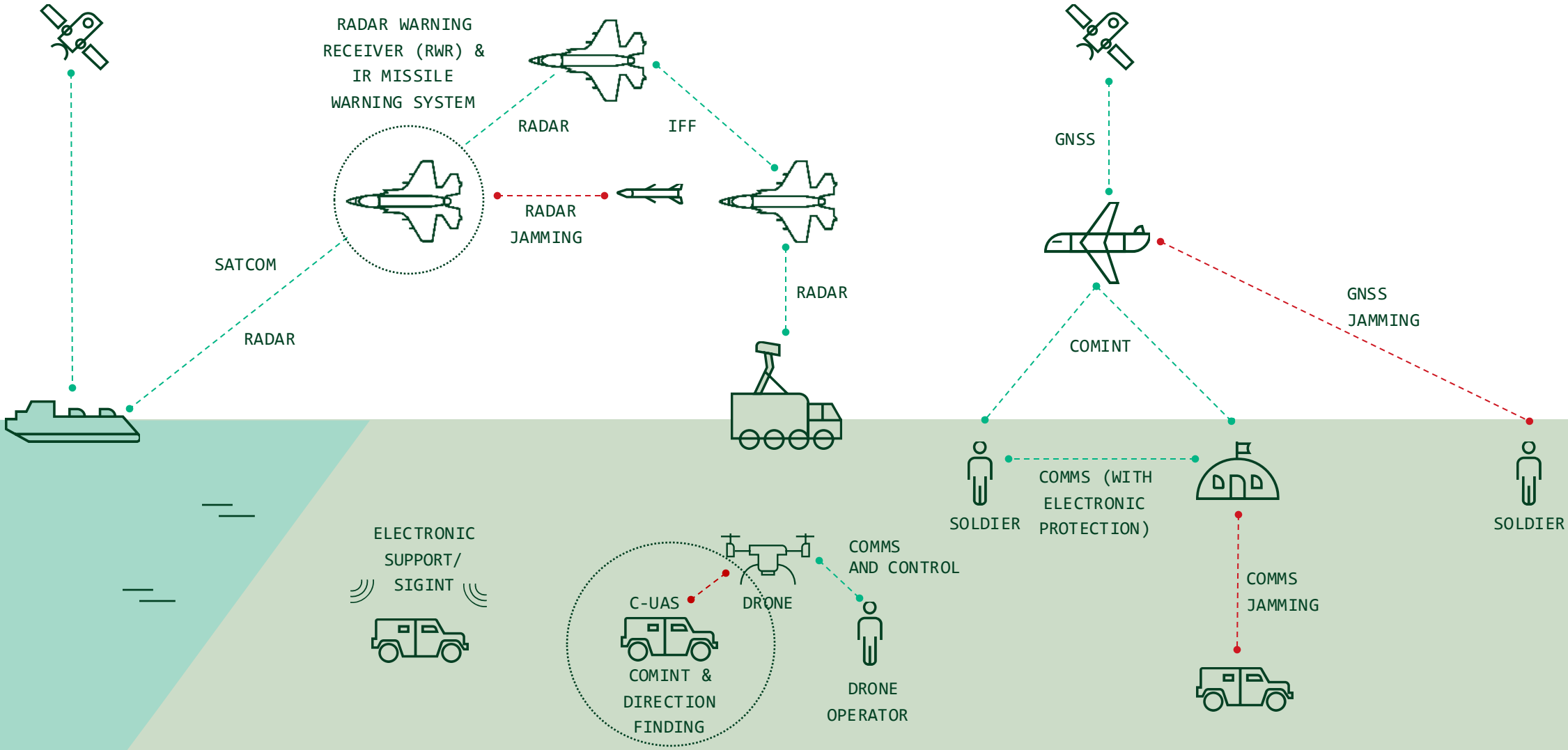
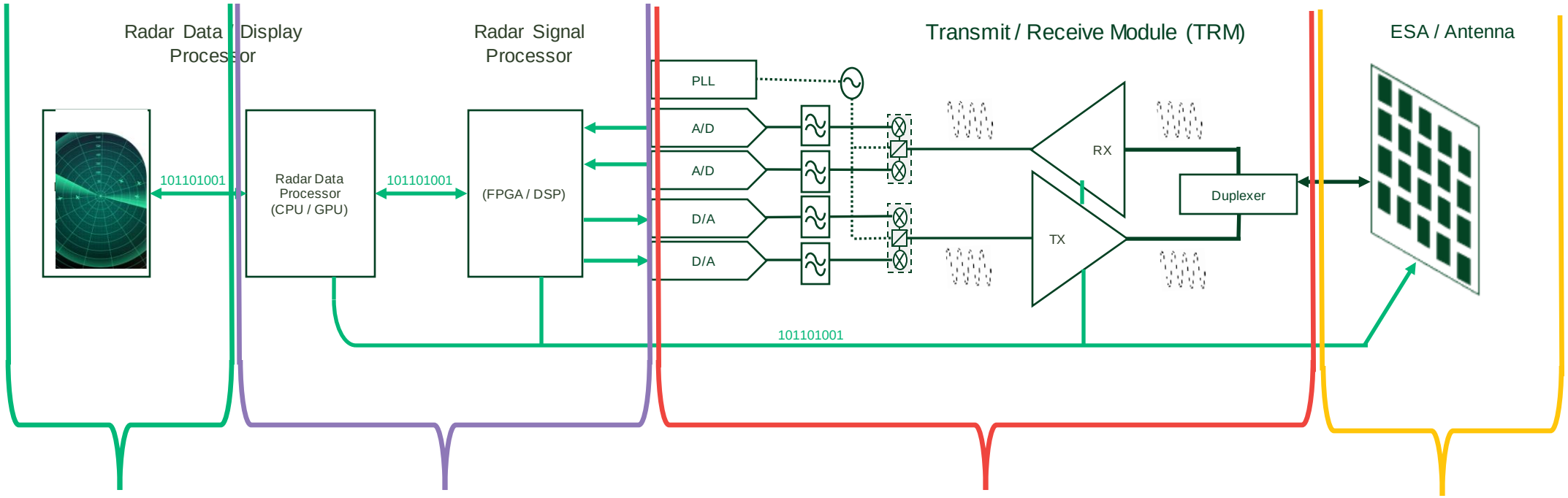
Field Applications Engineer

- Trends in Radar System Design and Test
- Radar Subsystem & Component Test Capabilities
  - Digital Radar Sub System Test
  - RF Parametric Test
- System Level Test Requirements
  - NI Radar Target Generation
    - Current deployments and new features
- NI Radar Target Generation Live Demo

The Contested & Congested Electromagnetic Battlefield



Components of a Radar System



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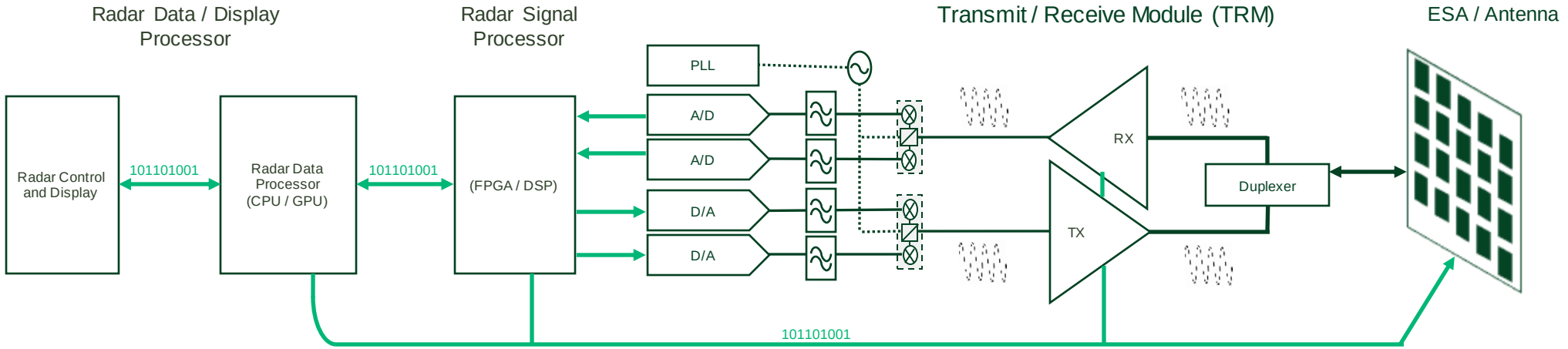
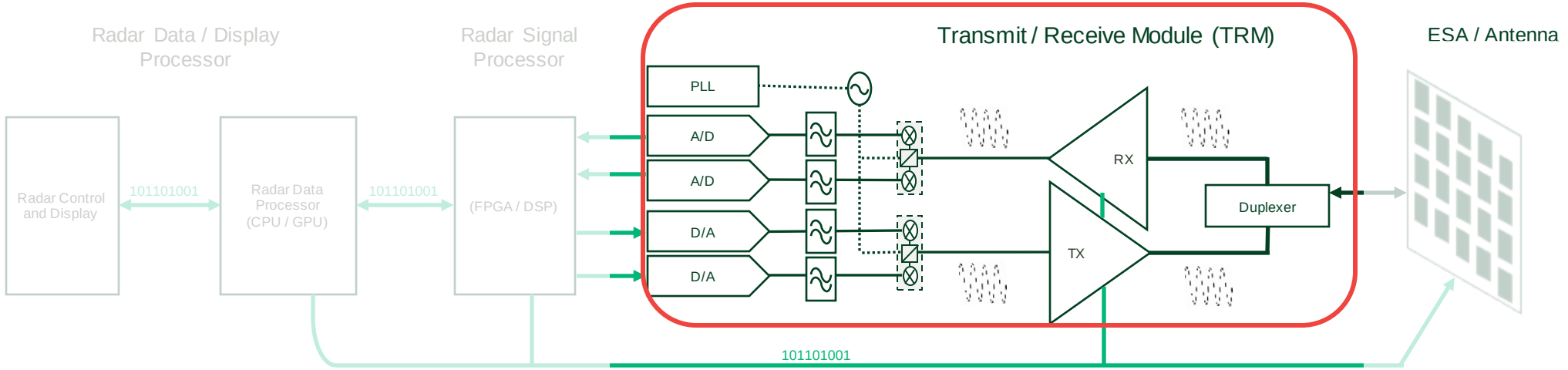


Application Test Capabilities

- System Level Hardware In the Loop Test
  - Radar Target Generation
  - RF Environment Generation
  - Multi-Channel RF Record & Playback
- RF Component and Subsystem Test
  - Pulse Profile, PAE, S-Parameters
- Digital Sub System Test
  - Digital Target Insertion
  - Sub-System Simulation

Digital Sub System Test / RF Parametric Test

Components of a Radar System



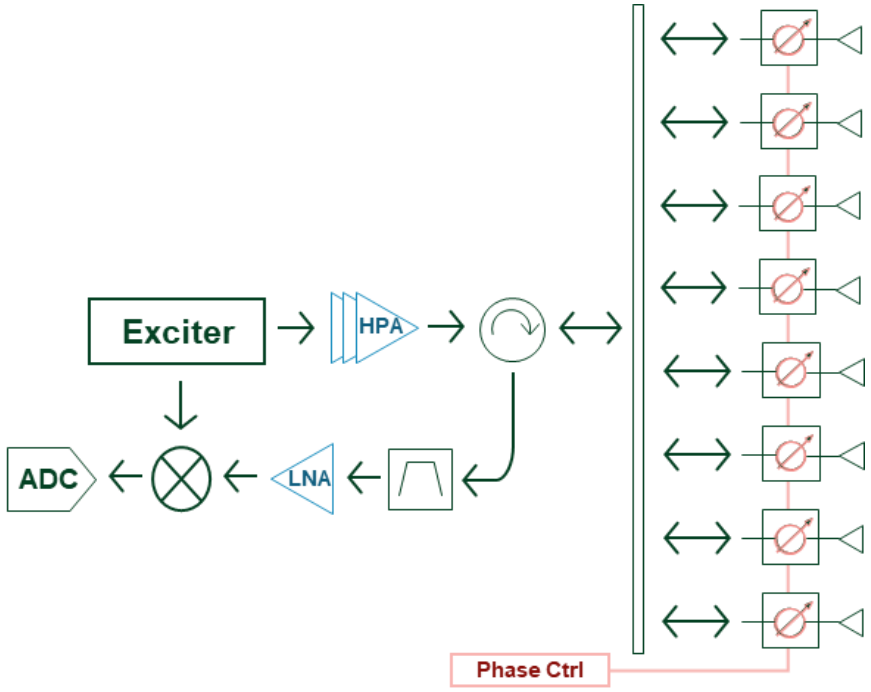
Transmit Receive module (TRM) Tests

Common Test IO Required

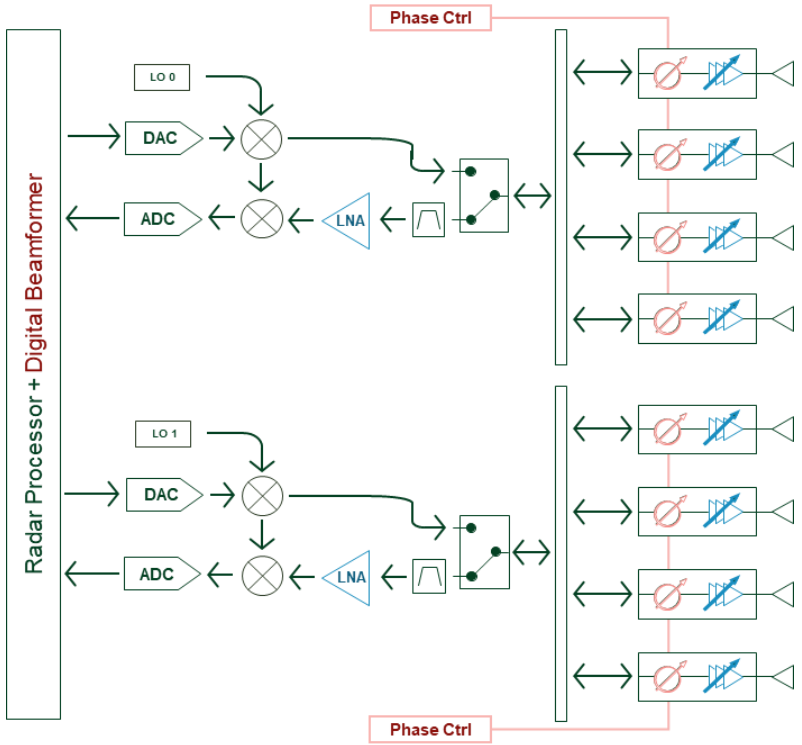
- RF Signal Generator
- RF Signal Analyzer
- High Speed Digital IO
- High Precision Power Supply
- Vector Network Analyzer

The Active Electronically Scanned Arrays (AESA)

Passive Electronically Scanned Array (**PESA**)



Active Electronically Scanned Array (**AESA**)

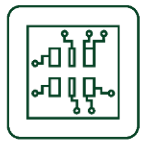


- Single Receiver/Exciter
- Per Element Phase Control for Beam Scanning
- Number of Elements Limited by centralized Gain

- Distributed Gain per Element -> Active T/R Modules
- Flexible Sub-Arrays allow for multiple beams
  - Varied frequencies and signal profiles

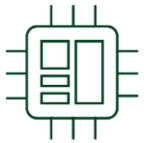
Technology Shifts and Application Evolution

Key technology shifts are leading to new mission capabilities along with new test challenges



GaN Revolution

Lower Energy Loss
Higher Voltages
More Power Per Area



Increased Integration

Integrated Digital to RF
Built in DSP
Antenna in Package

Wideband Data Converters

Increasing Bandwidths
Software Defined
Multi-Function

Modular, Multi-Element Antennas

1000’s of Active Elements
Multiple Beams
Increased Signal Fidelity

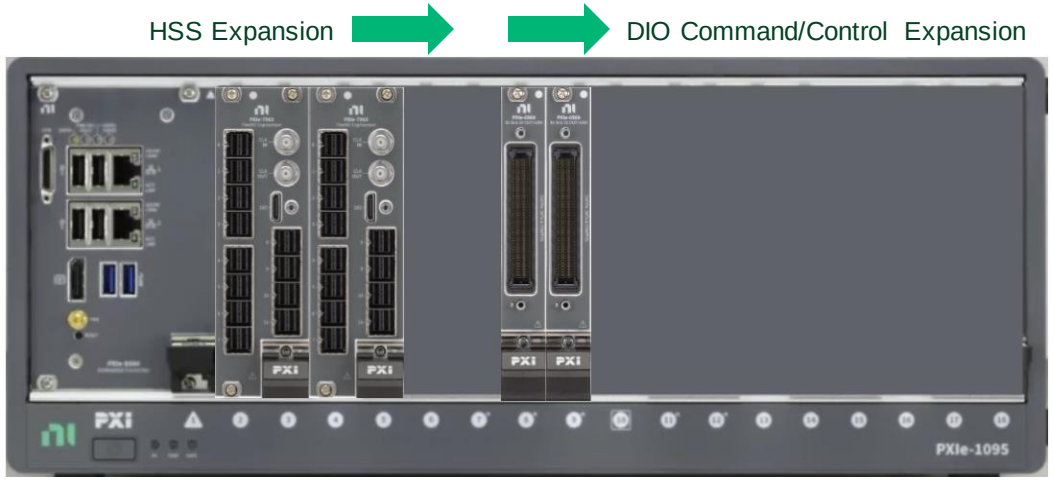
Digital AESA Digital Interfaces

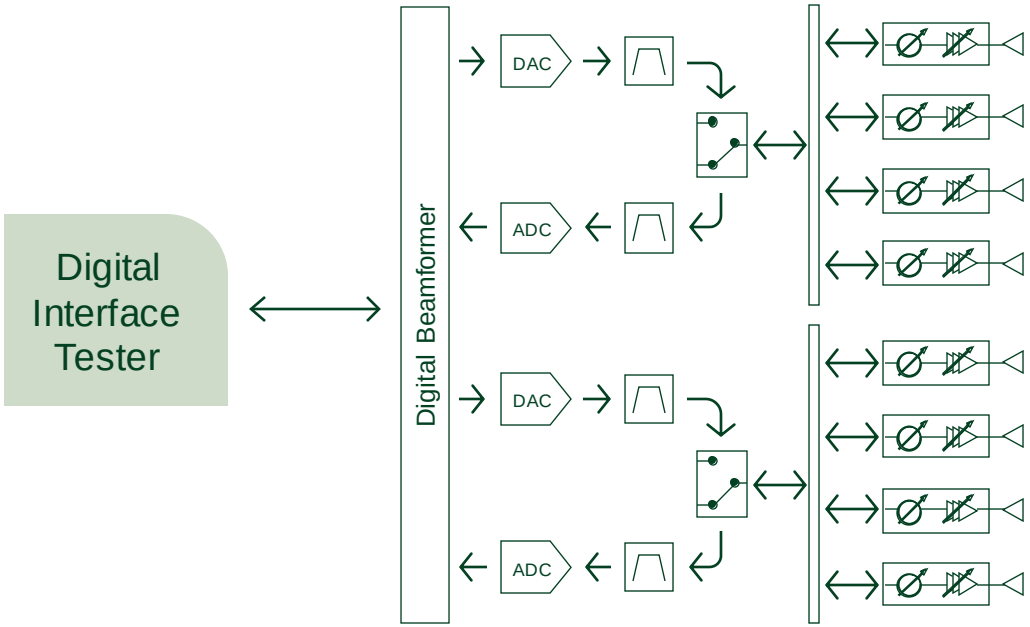
Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.

The NI Approach

PXI Platform

- Expandability
- Synchronization
- High Throughput
- Customizable FPGA Functionality





Planned
Q2 2023

2-Slot FlexRIO Coprocessor

PXIe-7903

Features

- 12 MiniSAS zHD Connectors
- 28.2 Gbps Line Rate
- External Clock Input/Output
- Xilinx Virtex UltraScale+ FPGA, VU11P
- DRAM: ~25GB/s / Bank; 2 Banks of 10GB
- PCI Express Gen 3x8

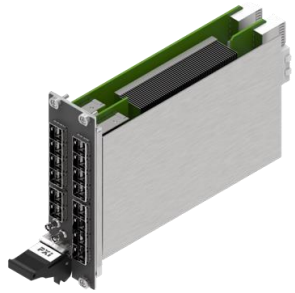
Target Applications

- Real-time Spectrum Analysis
- Comms Algorithm Prototyping
- Beamforming RF Signals
- Spectral Stitching RF Instruments

Scalable Digital Interfacing with NI FlexRIO

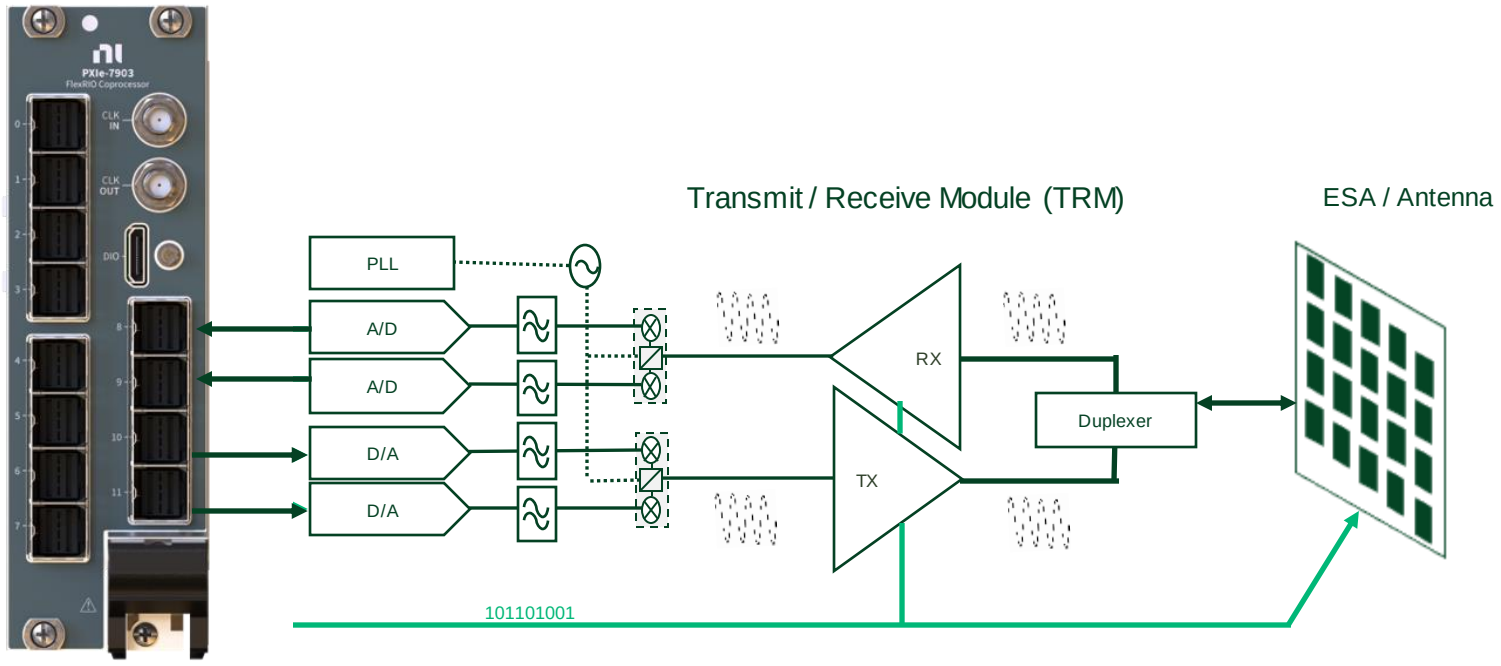
Planned Q2 2023

[High Speed Serial Product Table Link]



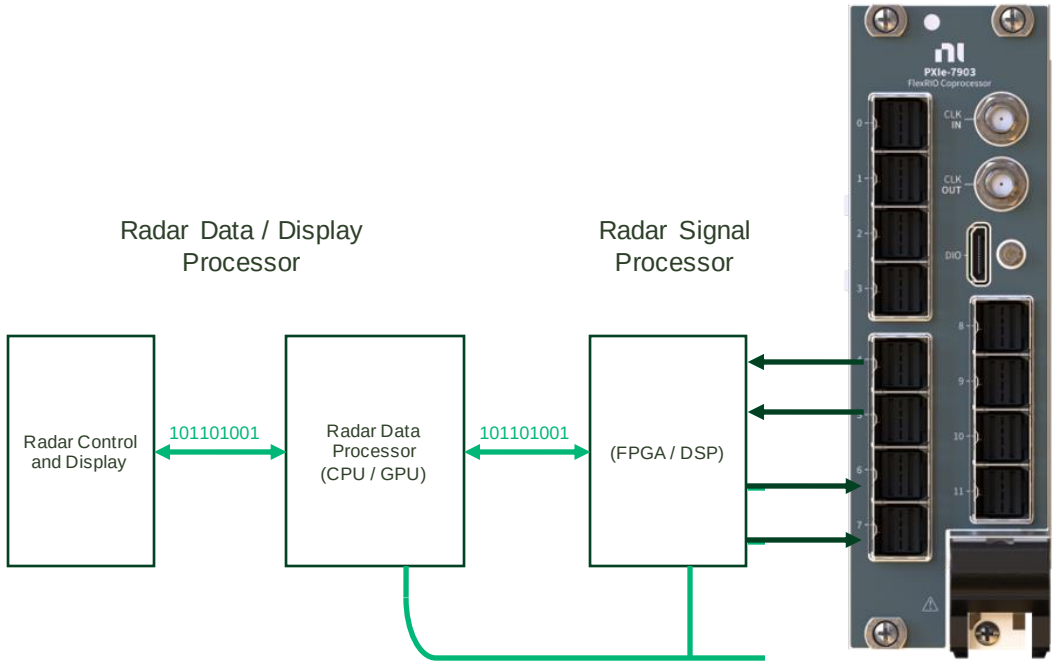
Specification	NI PXIe-6593	NI PXIe-6594	PXIe-7903
Line Rates	500 Mbps – 16.3 Gbps	500 Mbps – 28.2 Gbps	Up to 28.2 Gbps
Channels	8 RX/TX (GTH)	8 RX/TX (GTY)	48 MGTs (GTYs)
User Programmable FPGA	Kintex Ultrascale (KU040 or KU060)	Kintex Ultrascale + (KU15P)	Virtex Ultrascale+ (VU11P)
DRAM	4 GB	8 GB	16 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, Custom

Components of a Radar System



Digital TRM Test

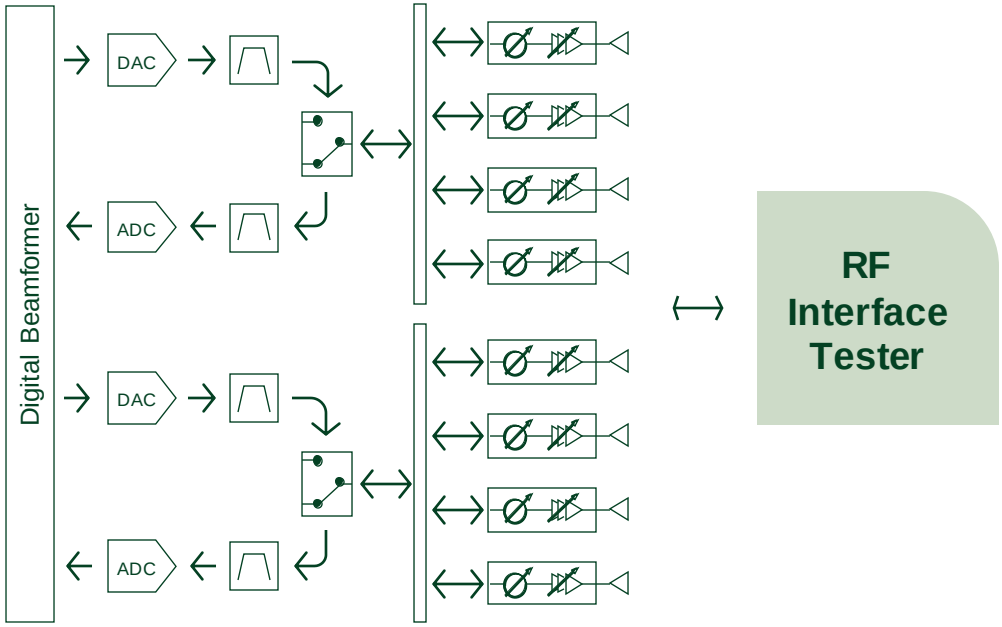
Components of a Radar System



Radar Digital Processor Test

Digital AESA - RF Interfacing & Measurements

Key Test Challenge: Provide robust and abstractable mixed I/O interfaces that can scale and adapt to evolving DUT needs while easily integrating I/O such as highspeed serial interfaces with RF instrumentation in order test functionality in an optimized and synchronous manner.



RF Interface Tester

Common Technical Challenges

High Number of RF Channels and Need for Decreased Test Times

Time/Phase Synchronization Between RF Channels

Synchronization with Digital Links

Frequency Coverage for High BW ADC/DAC's

PXIe-5842 26.5 GHz VST

Parameter	Instrument Capability
Frequency Range	50 MHz – 23 GHz (Q4 2022) 50 MHz – 26.5 GHz (H2 2023)*
Bandwidth	Up to 2 GHz (Q4 2022) Up to 4GHz (TBD)
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)
802.11be, 320 MHz EVM	Better than -49 dB

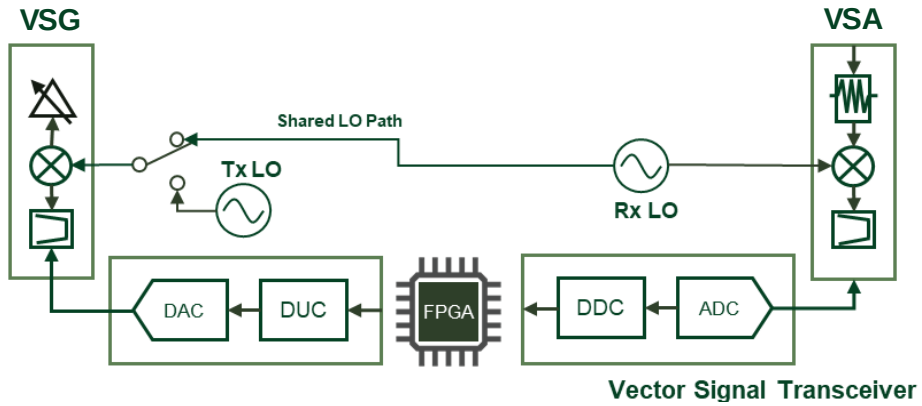
***Upgrade from 23 GHz HW to 26.5 GHz HW requires a paid upgrade service**

PXIe-5842 VST

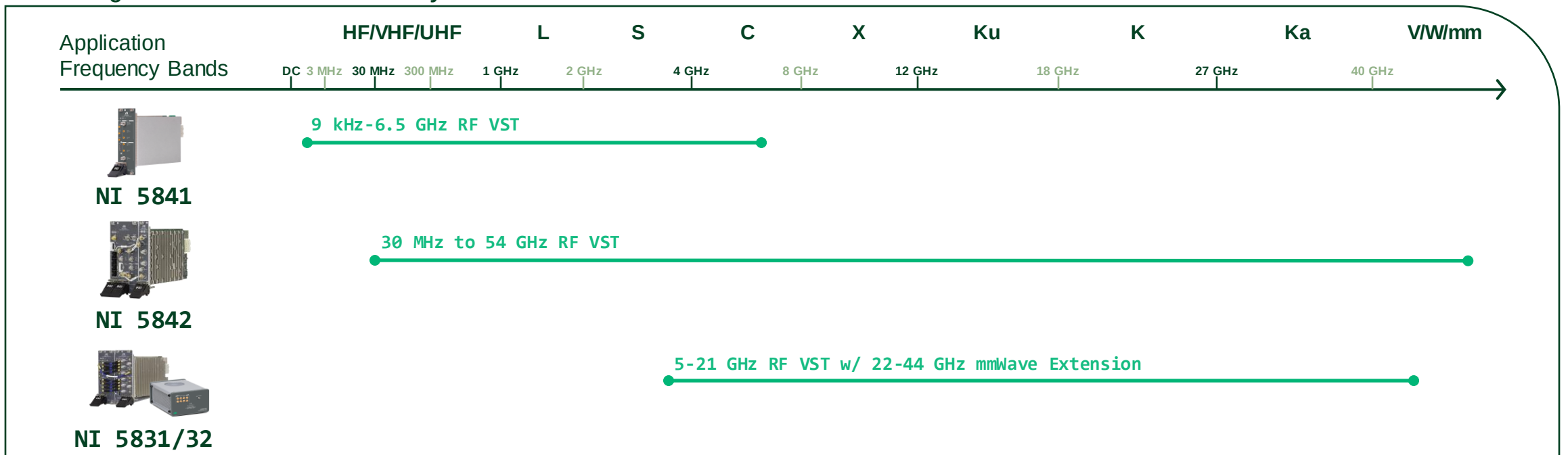
Vector Signal Transceiver

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

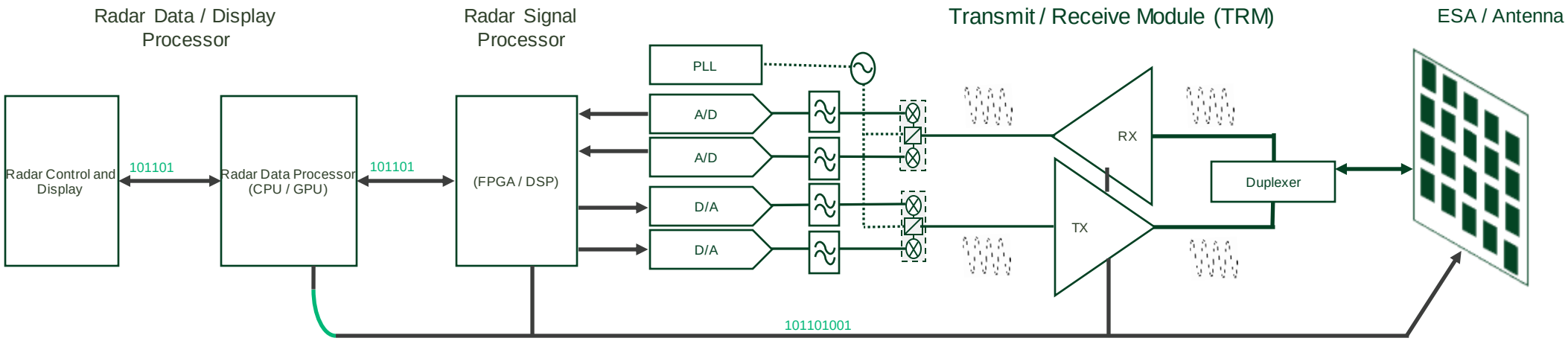
- Onboard, open FPGA
- Full rate peer to peer streaming to FPGA coprocessors



Vector Signal Transceiver Product Family



System Level Test ?



✓ Radar Processing Tested

✓ RF Subsystem Tested

✓ Digital Transmit / Receive Module Tested

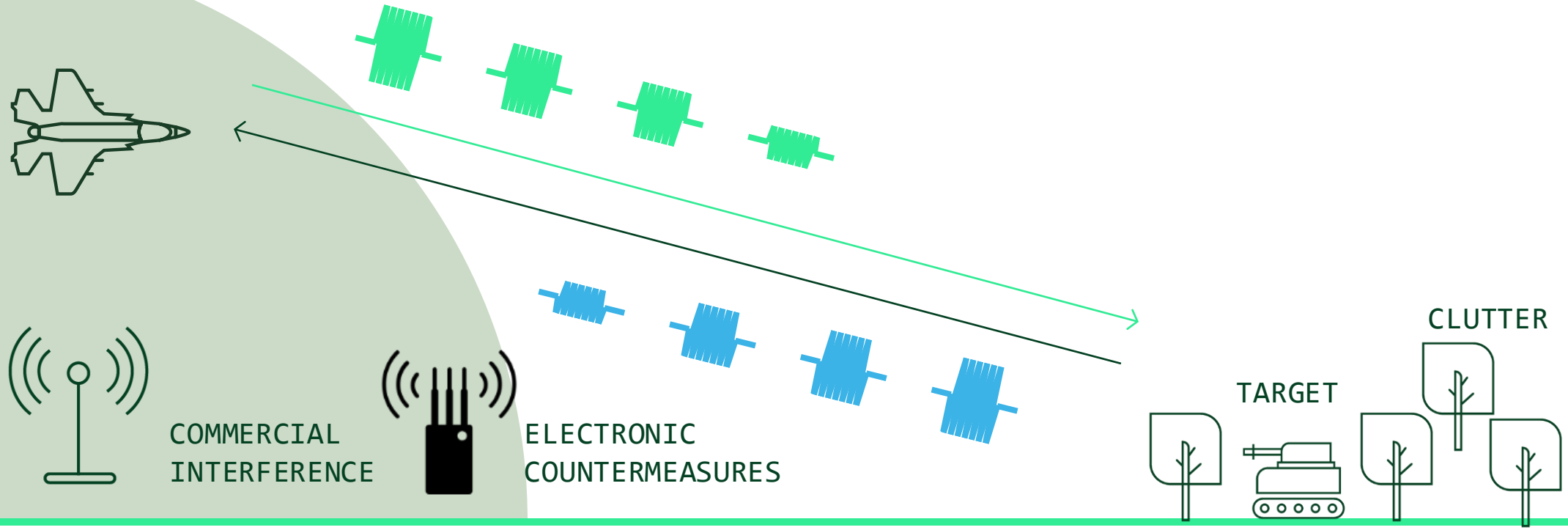
System Level Test Requirements

Radar Target Generation

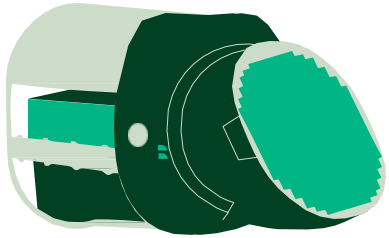
What is a Radar Target Generator?

Problem Statement

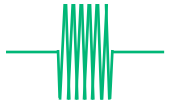
Today's military radars feature complex modes of operation, demanding more thorough testing during design to manage schedule risk and reduce probability of failure.

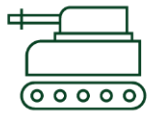


What is a Radar Target Generator?



Your Radar





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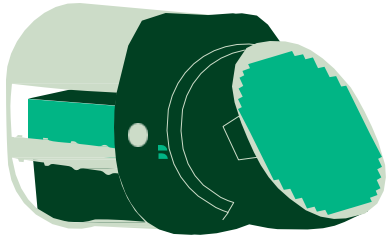

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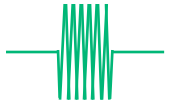
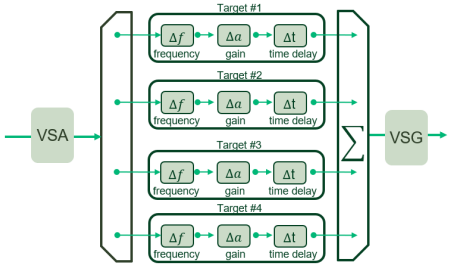
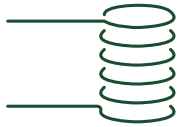




Traditional Approaches to Radar Test

Delay Lines



Strengths
- Capable of Very Low Latencies
- Cost Effective
- Robust Solutions
- Easy to Purchase & Use

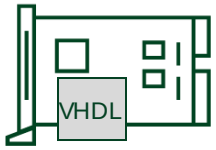
Weaknesses
- Very Limited Flexibility
- Cannot Simulate “Real World” Environmental Conditions
  - No testing of clutter, interference, ECCM techniques

COTS Target Generation

Strengths
- Hardware Tailored to Application
- Minimal NRE Required
  - Vendor has domain expertise

Weaknesses
- Very Expensive
- Less Flexibility
- Capabilities Slow to Evolve and Update
  - Reliant on Vendor to Implement New Modes

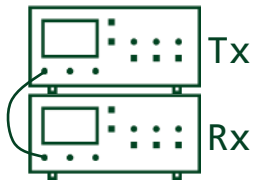
COTS FPGA DIY



Strengths
- Tailorable for Unique Requirements
- Low Capital Cost
- Capable of Low Latencies

Weaknesses
- Not Often “Test” Equipment
- Difficult to Maintain – Variable Robustness
- High NRE Cost
  - Require significant software/firmware development

Test & Measurement Solutions



Strengths
- Great Dynamic Range
- Well Calibrated with Known Support

Weaknesses
- Vendor-Defined Functionality
- Higher Latency
- Tx/Rx Usually Not Phase Coherent
- Difficult and Expensive to Scale for Multi-Channel RF
- Often Pre-Scripted/Open-Loop – Limited Closed-Loop Test

Traditional Approaches to Radar Test

Delay Lines

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COTS FPGA-Enable

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Weaknesses
- Not Often "Test" Equipment
- Difficult to Maintain – Variable Robustness
- High NRE Cost
  - Require significant software/firmware development

& Measurement Solutions

- Range
- with Known Support

- Functionality

- Tx/Rx Usually Not Phase Coherent
- Difficult and Expensive to Scale for Multi-Channel RF
- Often Pre-Scripted/Open-Loop – Limited Closed-Loop Test

NI Radar Target Generation (NI-RTG)

"A balance of the four quadrants"

Strengths
- Very Scalable & Customizable
- Proven Software Infrastructure
- Seamless Upgrade & Support for Existing Systems
- Evolves Quickly

Weaknesses
- Partners Required for Advanced IP
- Current Digital HW Not Optimized for Extremely Low Latency

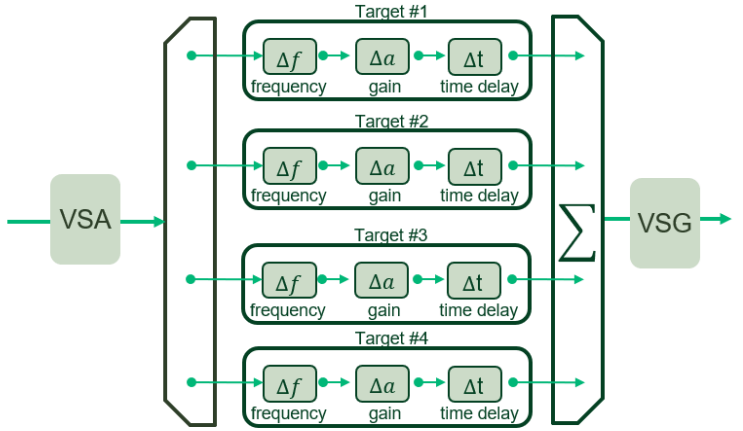
Radar Target Generation Driver

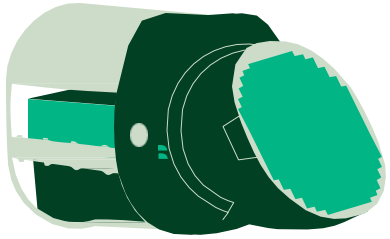
www.ni.com/radar

Features

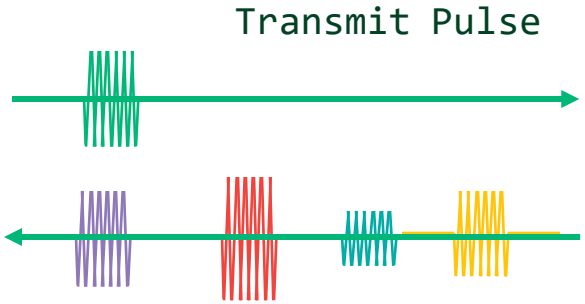
- Up to 4 Real-Time Test Targets
- Target Parameter Control *
  - Range(Time Delay): 150m – 50,000km
  - Velocity(Doppler): +/- 2MHz
  - Path Loss (Attenuation)
- **Built In Precision System Self Calibration**
  - De-embeds cable loss and time delay
- Frequency Range: 10MHz – 21Ghz
- Bandwidth: 1GHz
- Remote Procedure Call over Ethernet Protocol
- Licensed Alternative FPGA Image

Onboard IP



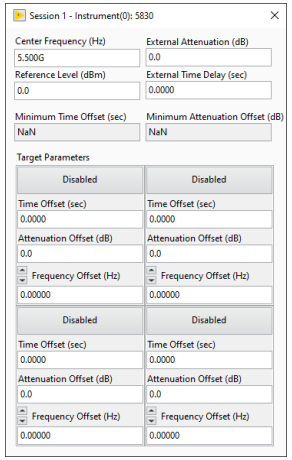


Radar Under Test



RTG Response
(Precision Test Targets)

PXIe-5830/1, PXIe-5841



Host Control
App and API

NI Radar Target Generation

Version 1.0 Features

- Up to 4 real-time test targets
- Target parameter control
  - **Range** (Time Delay): 150m – 50,000km
  - **Velocity** (Doppler): +/- 2 MHz
  - **Path Loss** (Attenuation)
- Built In precision system self calibration
  - De-embeds cable loss and time delay
- Frequency Range: 10 MHz – 21 GHz
- Bandwidth: 1 GHz
- Remote Procedure Call over Ethernet Protocol
- Licensed alternative FPGA image

Investments in NI-RTG Capabilities

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- Up to 4 real-time test targets
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  - **Range** (Time Delay): 150m – 50,000km
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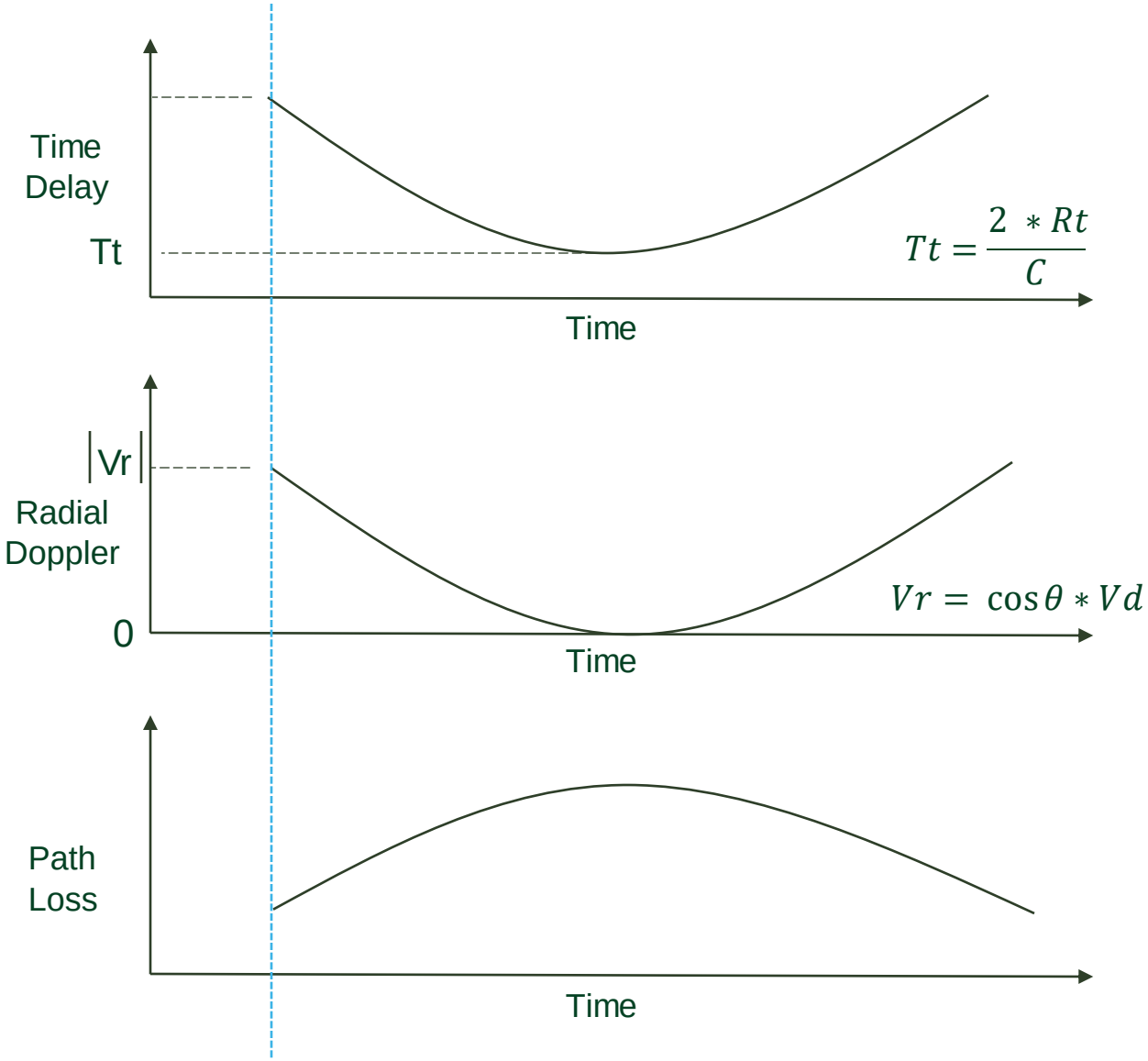
- Frequency Range: 10 MHz – 21 GHz
- Bandwidth: 1 GHz
- Remote Procedure Call over Ethernet Protocol
- Licensed alternative FPGA image

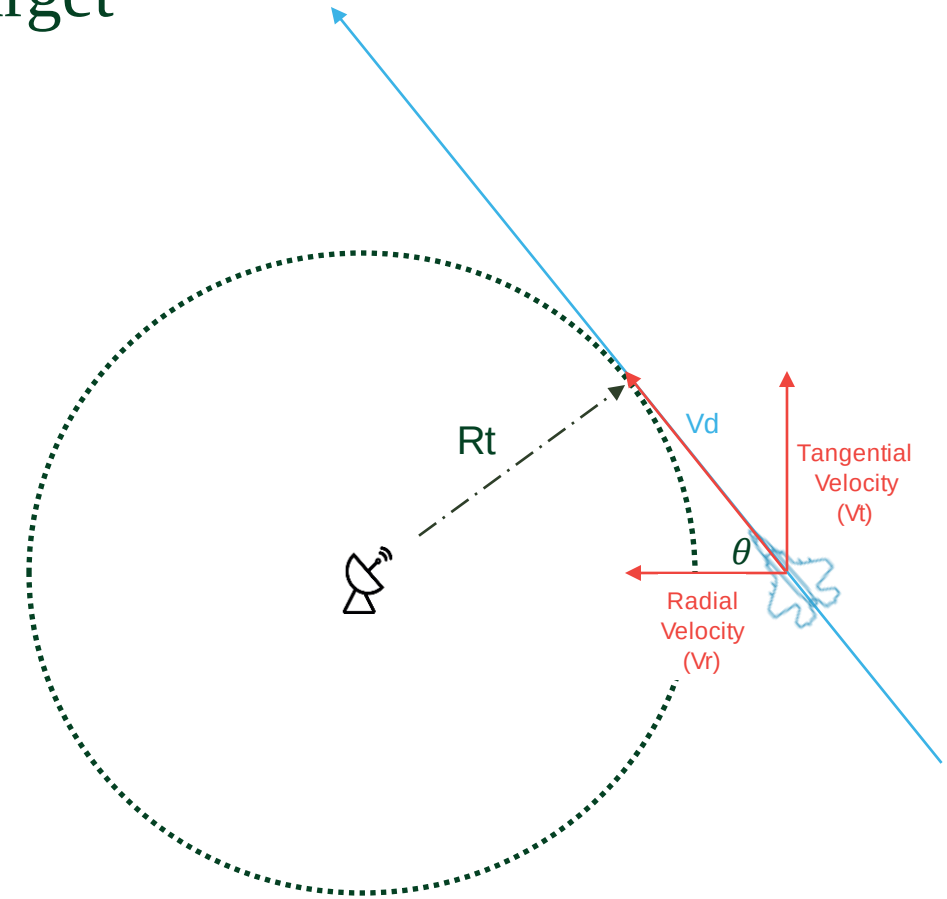
Version 1.2 Features

- All Version 1.0 features
- Interface to real-time simulator
  - Parameter streaming
- Complex pre-generated target scenario generation
  - Up to 10 million targets
  - Hardware or software timed
- **Low latency** pulse repeater
- FPGA co-processor harness
  - Ability to add customer IP and effects alongside RTG

Radar Target Generation
Dynamic Scenario Generation

Challenge of emulating a realistic moving target





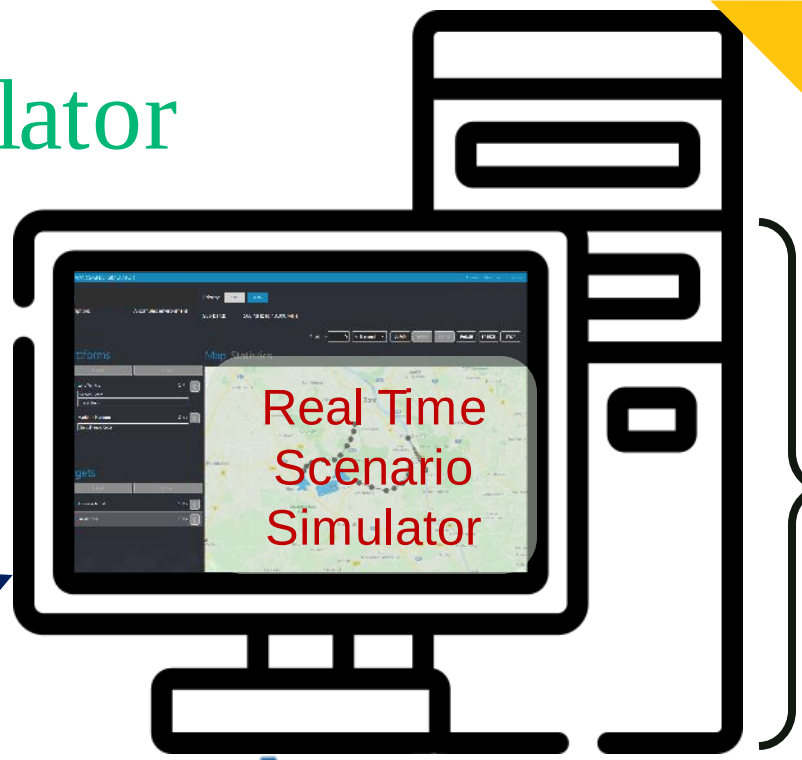
Requires precision real-time coordination of Delay, Doppler, and Path Loss to mimic real world signal propagation and geometrics

Interface with a Real Time Simulator

RTG 1.2 or higher

NI-RTG used in Real Time Scenario Simulation

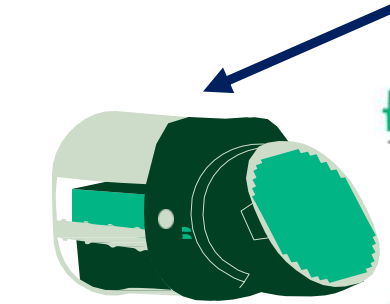
- Dynamic system simulation with hardware-in-the-loop
- HWIL test in conjunction with other system functions: EW, Comms, Navigation, etc..
- Target Parameters Applied
  - On Demand
  - Hardware Timed



Any OS

Bus Communication

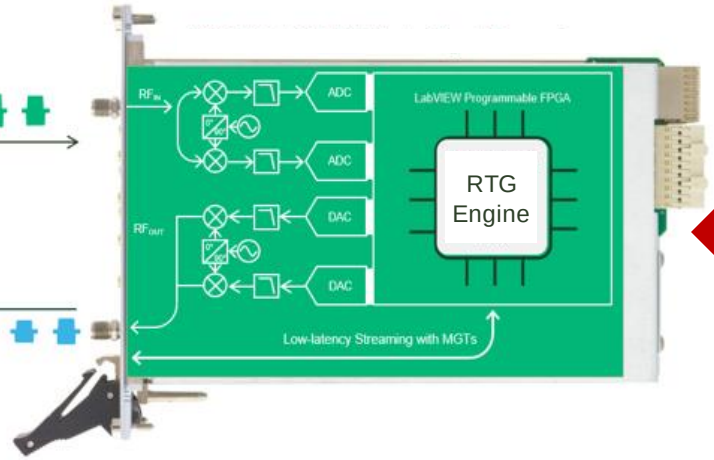
Streaming Target Parameters over Ethernet



Device(s) Under Test

TX

RX



VST Module

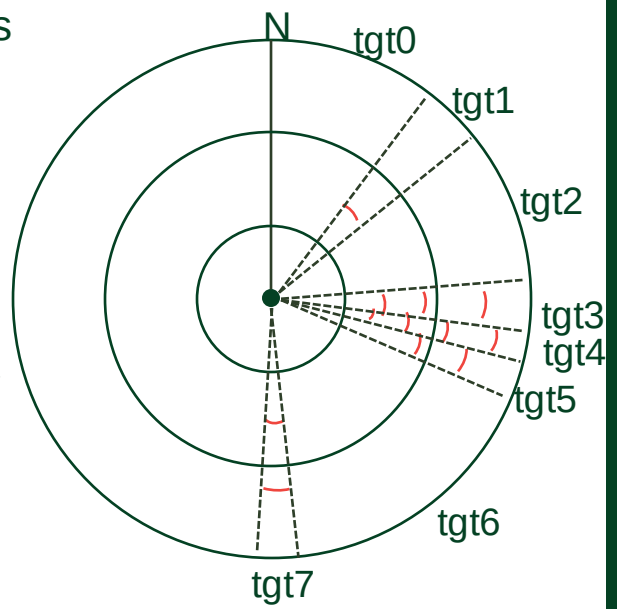
PXI Test System

Pre-Generated Target Scenarios "List Mode"

RTG 1.2 or higher

- Over 10 Million Targets
- Deterministic Timing
- Digital Triggered
- Software Triggered
- Time Reference Trig
- Synchronize to Radar
- File Driven
- Four Targets per Entry

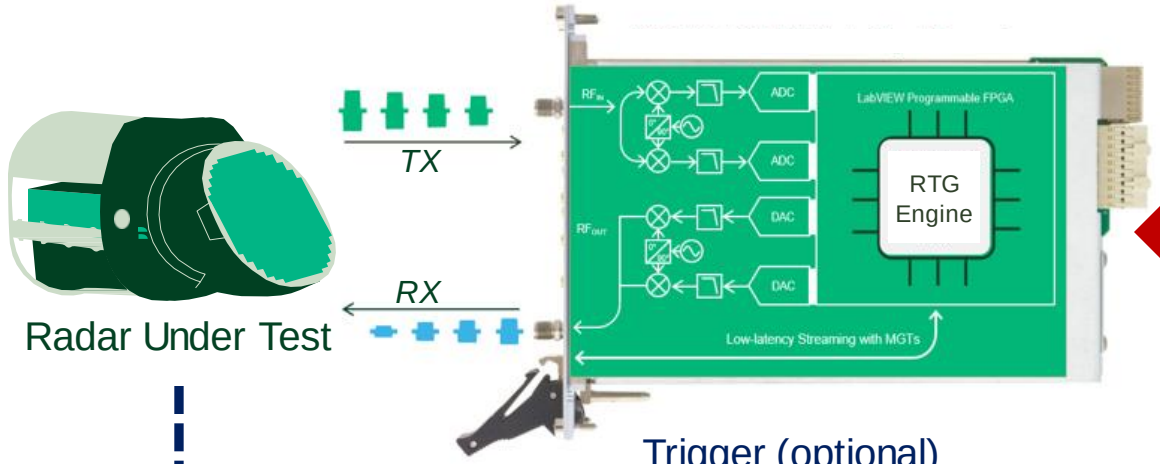
- 15KHz Update Rate



Pre-Computed Target Parameter List

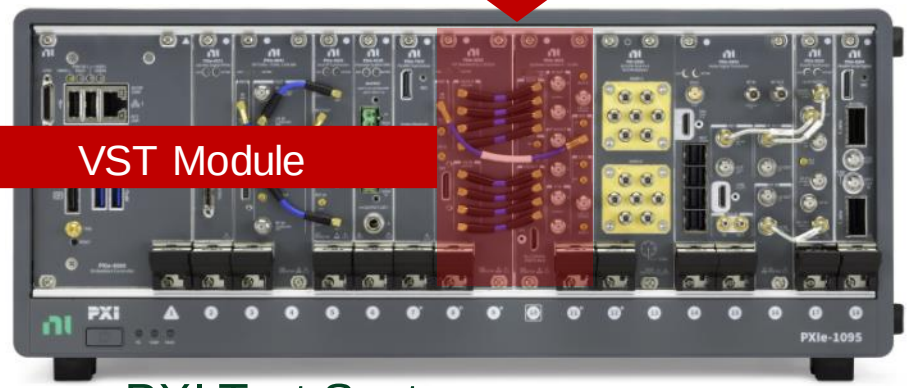
TIME or SAMPLE	# TGT	Target Parameters (Atten, Doppler, Time)			
		TGT 1	TGT 2	TGT 3	TGT 4
0 ms	0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0
234 ms	1	3.2, -2.7, 234	0, 0, 0	0, 0, 0	0, 0, 0
324 ms	0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0
Conceptual Data Structure					
872 ms	4	1.7, 2.3, 234	1.9, 3.2, 3.45	2.1, -2.1, 4.1	1.1, -3.1, 6.23
1343 ms	0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0
13187 ms	2	1.1, 2.2, 3.3	7.1, 1.7, 783	0, 0, 0	0, 0, 0

RTG file format = .CSV



Radar Under Test

VST Module



Trigger (optional)

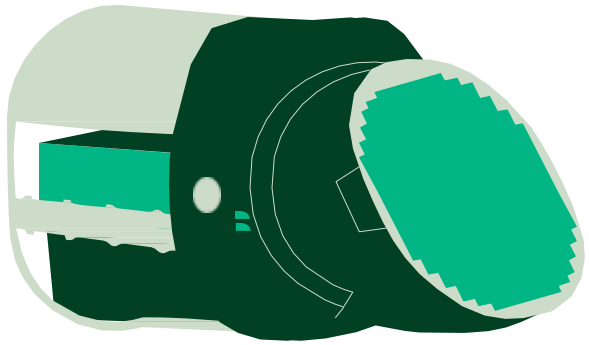
PXI Test System

**Extra PXI Cards not required*

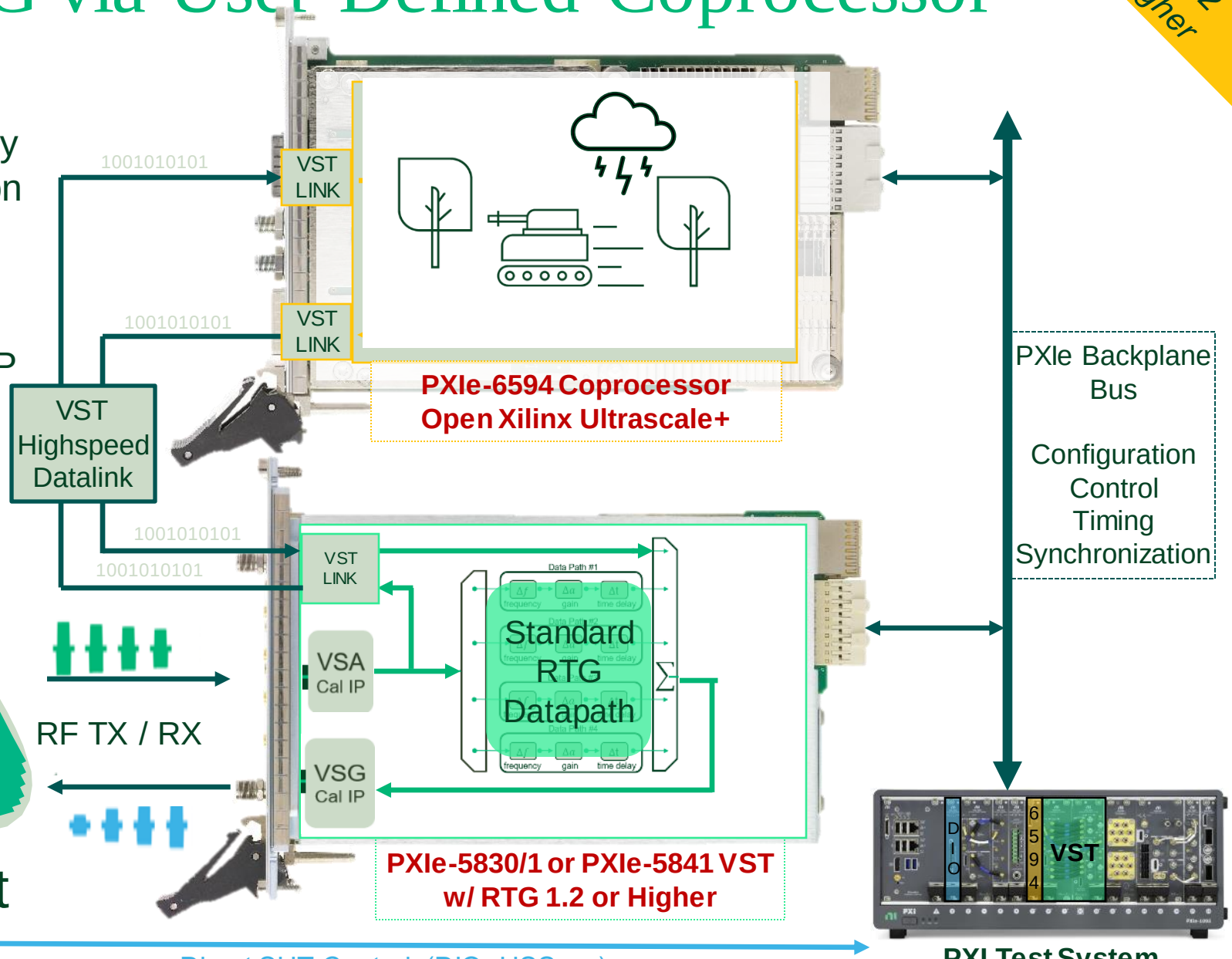
Extending NI-RTG via User-Defined Coprocessor

RTG 1.2 or higher

- NI RTG Datapath
  - Close range targets with low latency
  - Handles RTG system self calibration
  - VST Link is a known latency path
- NI RTG Coprocessor (PXIe-6594)
  - Extends NI RTG enabling custom IP integration while retaining calibration of NI RTG core



Radar Under Test



Further Investments in NI-RTG Capabilities

Enhanced Radar Test Capabilities

- High fidelity EM/RF environment simulation
- Classified & unclassified threat and terrain databases
- Customized target profiles
- Dynamic scenario simulation
- Environment parameters
  - Noise & clutter
  - Realistic flight scenarios
  - Atmospheric effects
- Others per customer feedback

NI Radar Partners

ISL INFORMATION SYSTEMS LABORATORIES, INC.

ELT ELETTRONICA GROUP

Synergent Technologies

CONSTELLI

Explore All NI Radar Test Capabilities in the Expo Hall

NI CONNECT 2023 AUSTIN

Radar Target Generation Demo