Prototyping and Validation of Cognitive EW and Radar Systems

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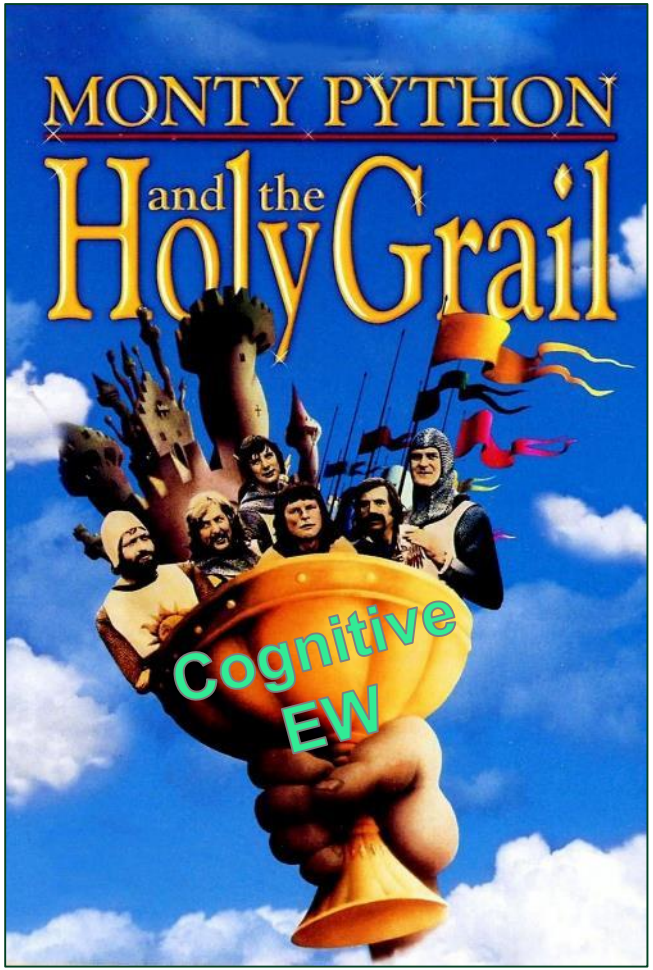
A fully reactive detection and counter-measure development is the **holy grail** of cognitive EW…

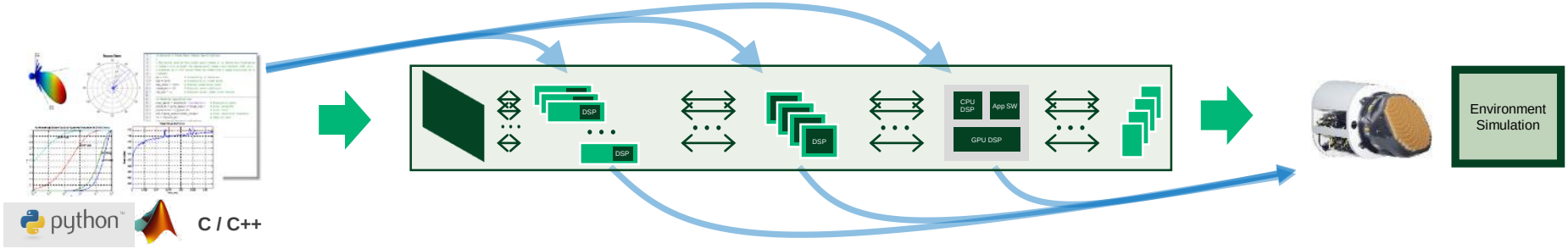


Maj John G. Casey
U.S. Air Force

Source: https://othjournal.com/2020/07/03/cognitive-electronic-warfare-a-move-towards-ems-maneuver-warfare/

Getting from the Whiteboard to Proven Concept

Software Simulation *Hardware Test Bed* *Tactical System*



Develop and simulate algorithms and system in software

Develop hardware test bed, iterate with offline processing, migrate processing to hardware

Validate algorithms against simulator and real-world scenarios, iterating as necessary

Migrate validated algorithms to mission hardware, perform integration testing/validation

Radar Design and Prototyping – Army Research Lab, Penn State University

Cognitive Radar – RF Interference Avoidance Prototyping

“Becoming an expert at traditional FPGA design languages like VHDL or Verilog takes years. Using NI LabVIEW, we can focus on the cognitive radar and spectrum sensing aspects of our algorithms without becoming FPGA experts. Being able to implement these algorithms ourselves makes it much easier, **much quicker to move from the conceptual phase to the prototype stage**.

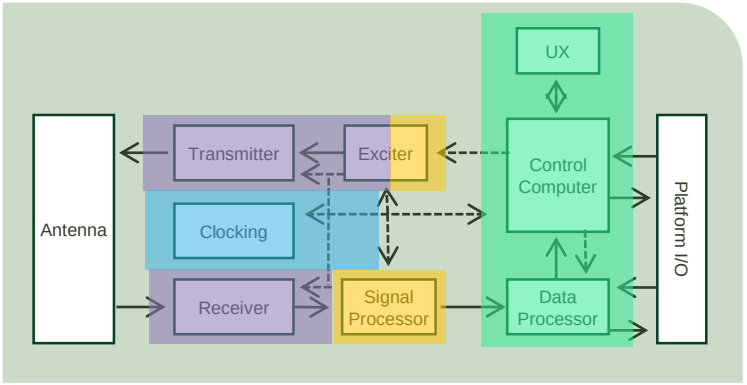
We’ve generated an RF interference emulator using NI VSTs and those allow us to test our **cognitive algorithms**. FlexRIO allows us to sense big picture instead of narrow band and we can re-tune to opportune frequency bands over a 3 GHz range now. This increase in bandwidth…allows us to more **easily avoid other RF emitters**.”

Brian Phelan, PhD

Radar Engineer, Army Research Laboratory

A COTS-based Software-defined Radar/EW Prototype

Software-Defined Radar



RF/μW Instrumentation + DSP

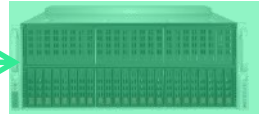
Scenario / Test Manager

Standard Model Library (ex. TMAP)

Threat Model 1

Threat Model n

COTS GPU Server



High-speed Data Bus + Sync

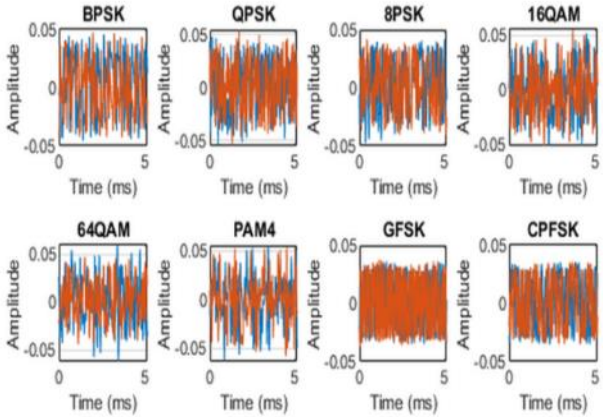
RF/Microwave Clocking FPGA/DSP CPU/GPU

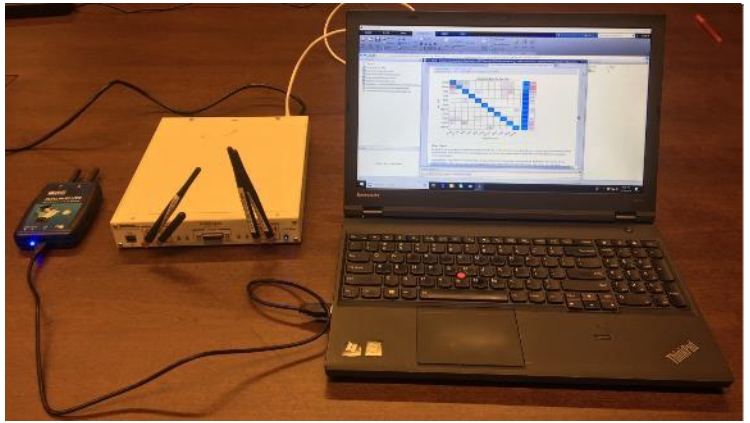
Deep Learning for Signals Intelligence

Synthetic Data + Real-World Data = Better Deep Learning Models

Generate synthetic data with impairments using MATLAB

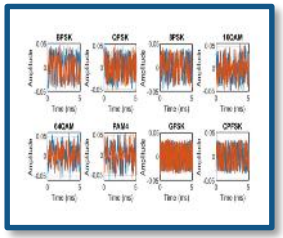
Gather real-world data over-the-air with NI software defined radio (SDR) hardware



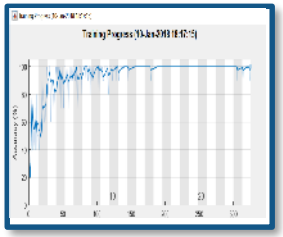


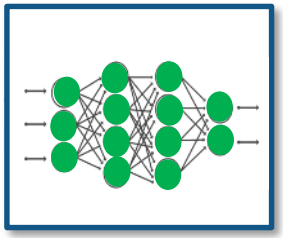
Model Development with Synthetic Signals

Train



- Noise
- Multipath fading
- Frequency offset
- Sampling rate offset

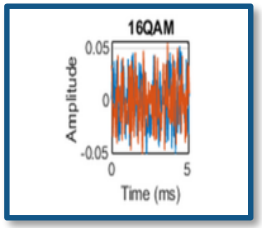


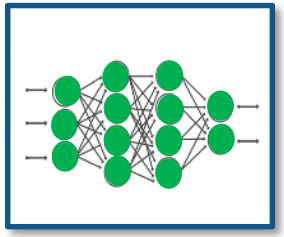


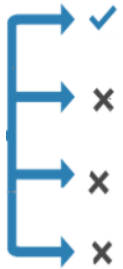
Synthesize labeled data → Add impairments → Train Network → Trained Model

Test

New Signal → Pre-Trained Model → Classification

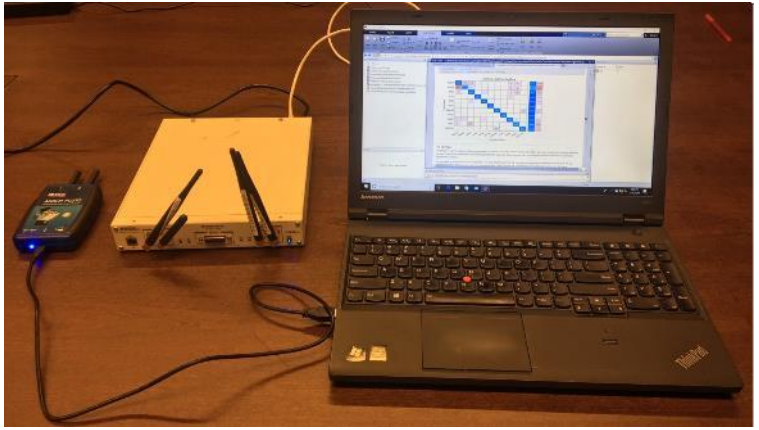


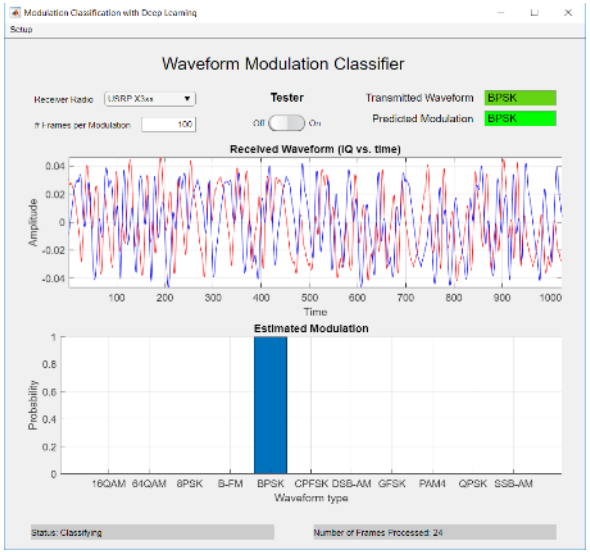


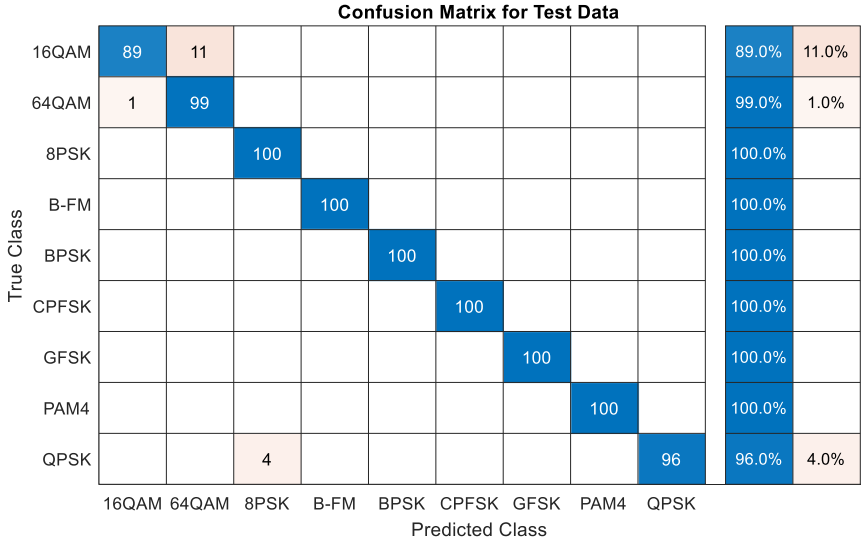


Over-the-air Test with SDR

- Generate OTA test signals using any source
- Connect MATLAB to NI SDR to receive signals
  - USRP-29xx or Ettus B2xx, N2xx, and X3xx
- Process real-time data in MATLAB

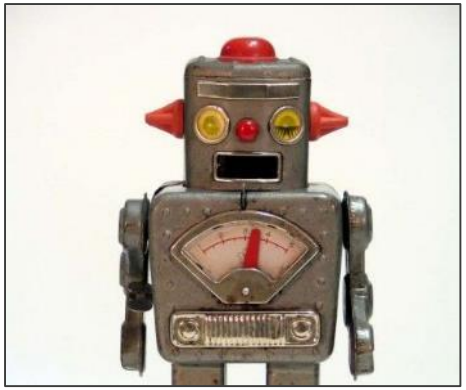






How do you test an EW system?

Legacy System



vs.

Cognitive System

<u>Traditional Approach</u> …doesn't work for <u>Cognitive Systems</u>

1. Define test scenarios ⟶ Infinite possible scenarios
2. Simulate threat environment ⟶ Handles unknown threats
3. Assess system response ⟶ Unpredictable behavior

How do you test if a 10-year-old is good at chess?

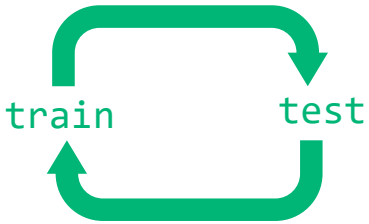
Quiz them on the best next move for every potential board configuration (estimated around 10^{45}) to achieve **100% test coverage**?

Not realistic or feasible.

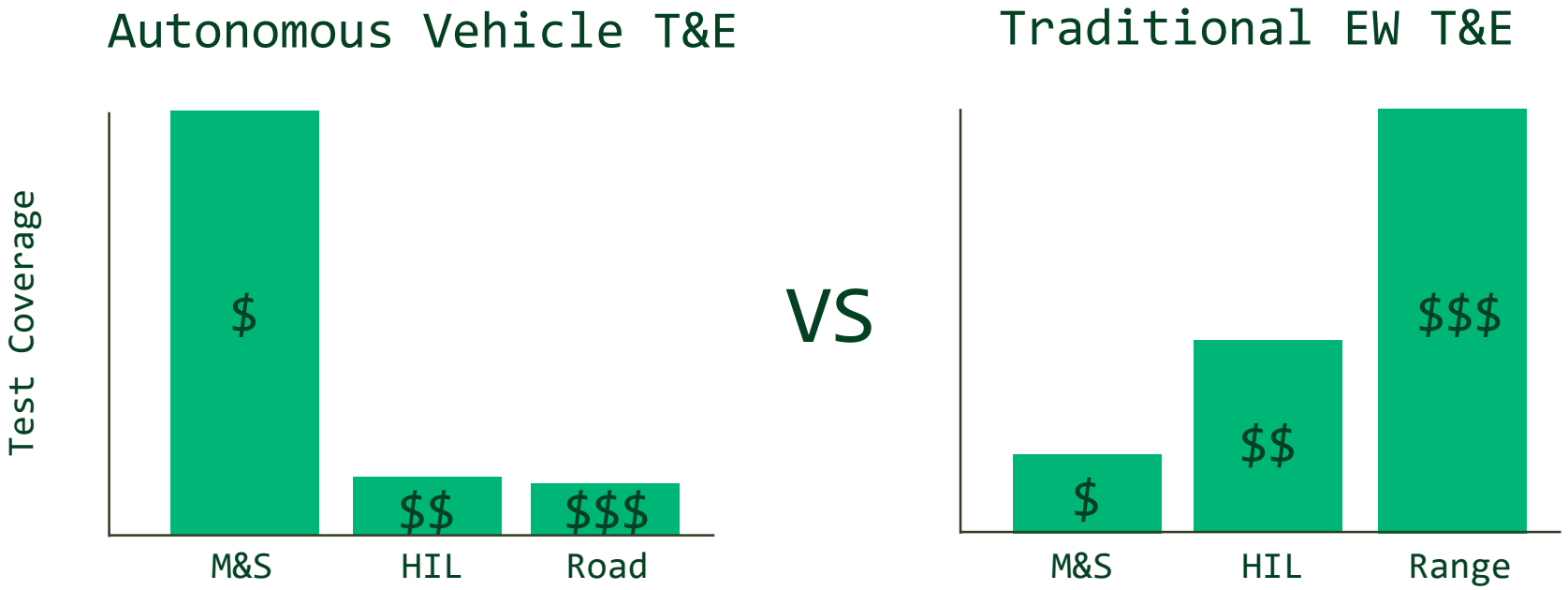
How do you test if a 10-year-old is good at chess?

Play lots of matches until they consistently beat their opponent?

They continue to learn and improve with each match!



What can we learn from Automotive?



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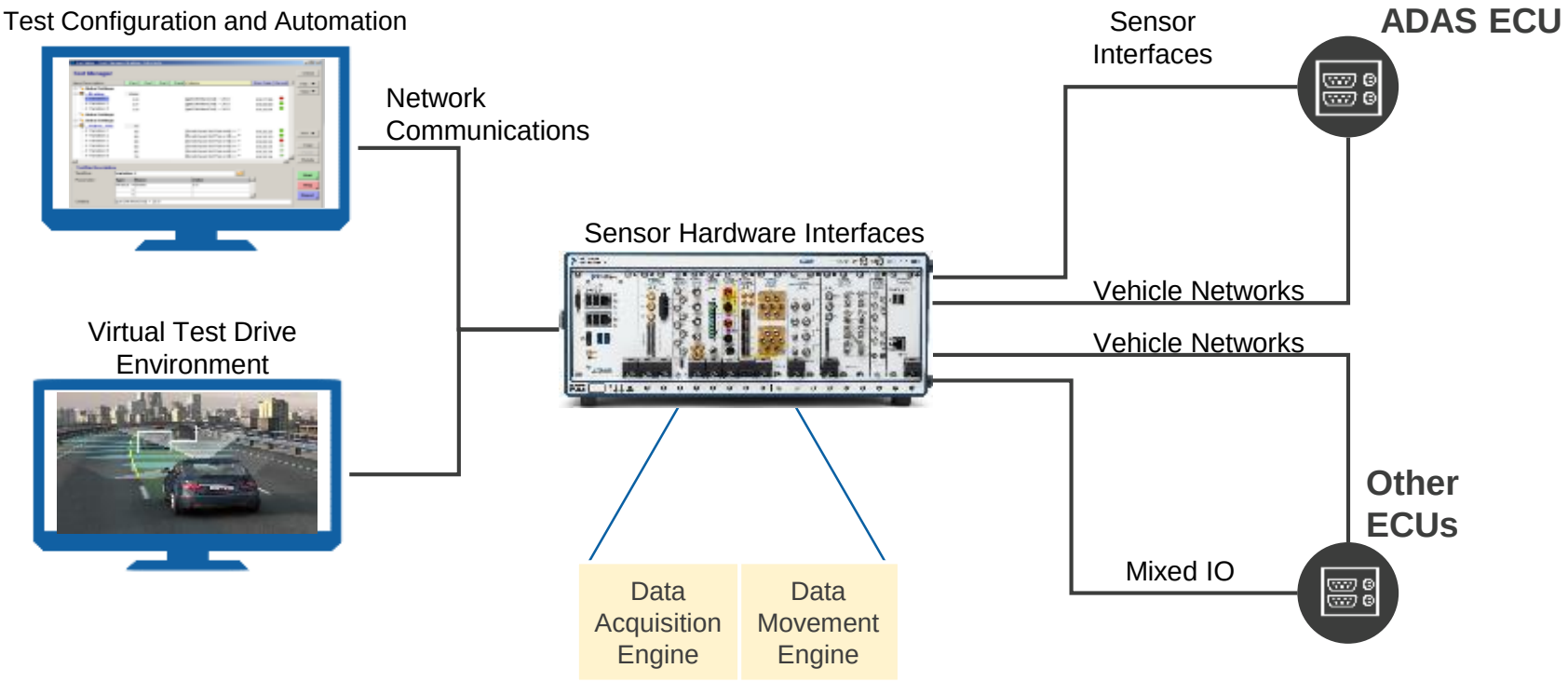
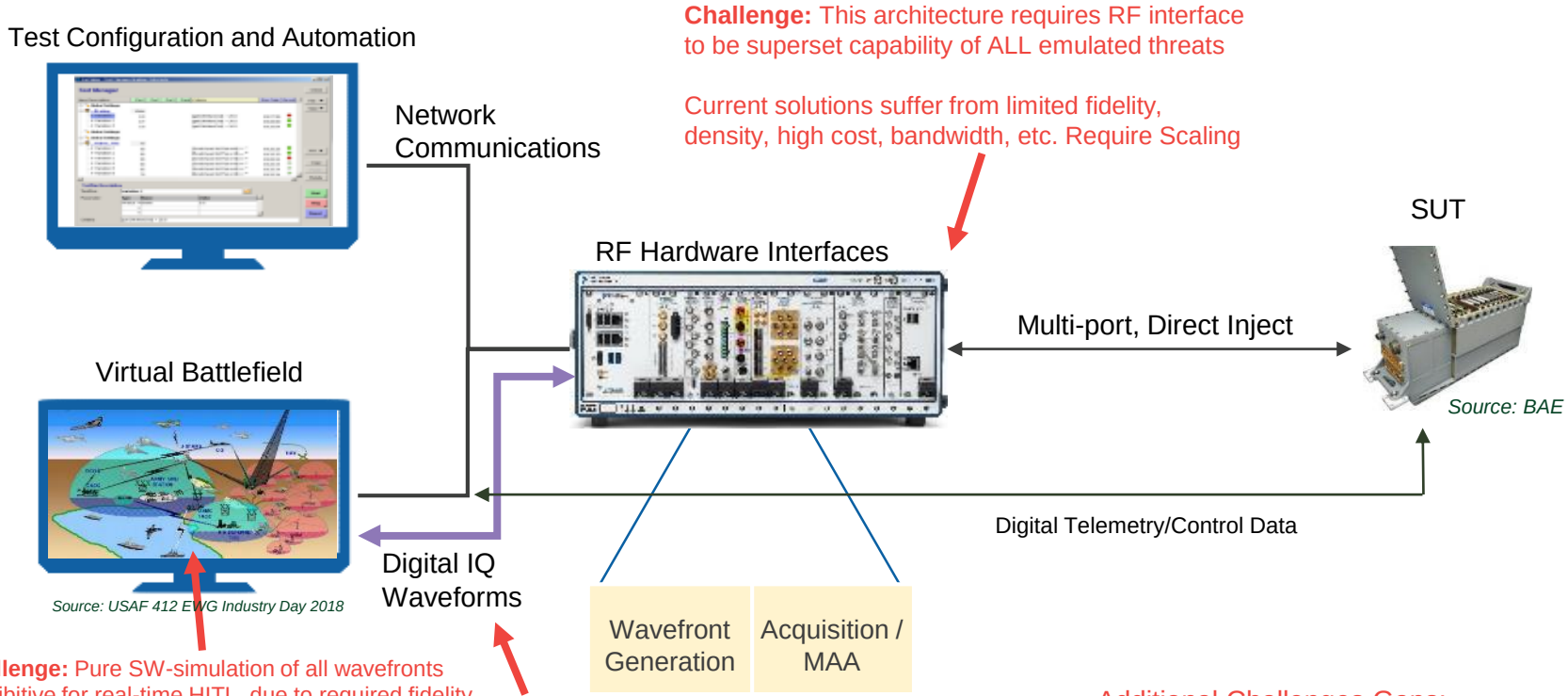


ADAS = Advanced Driver-Assistance System
ECU = Electronic Control Unit

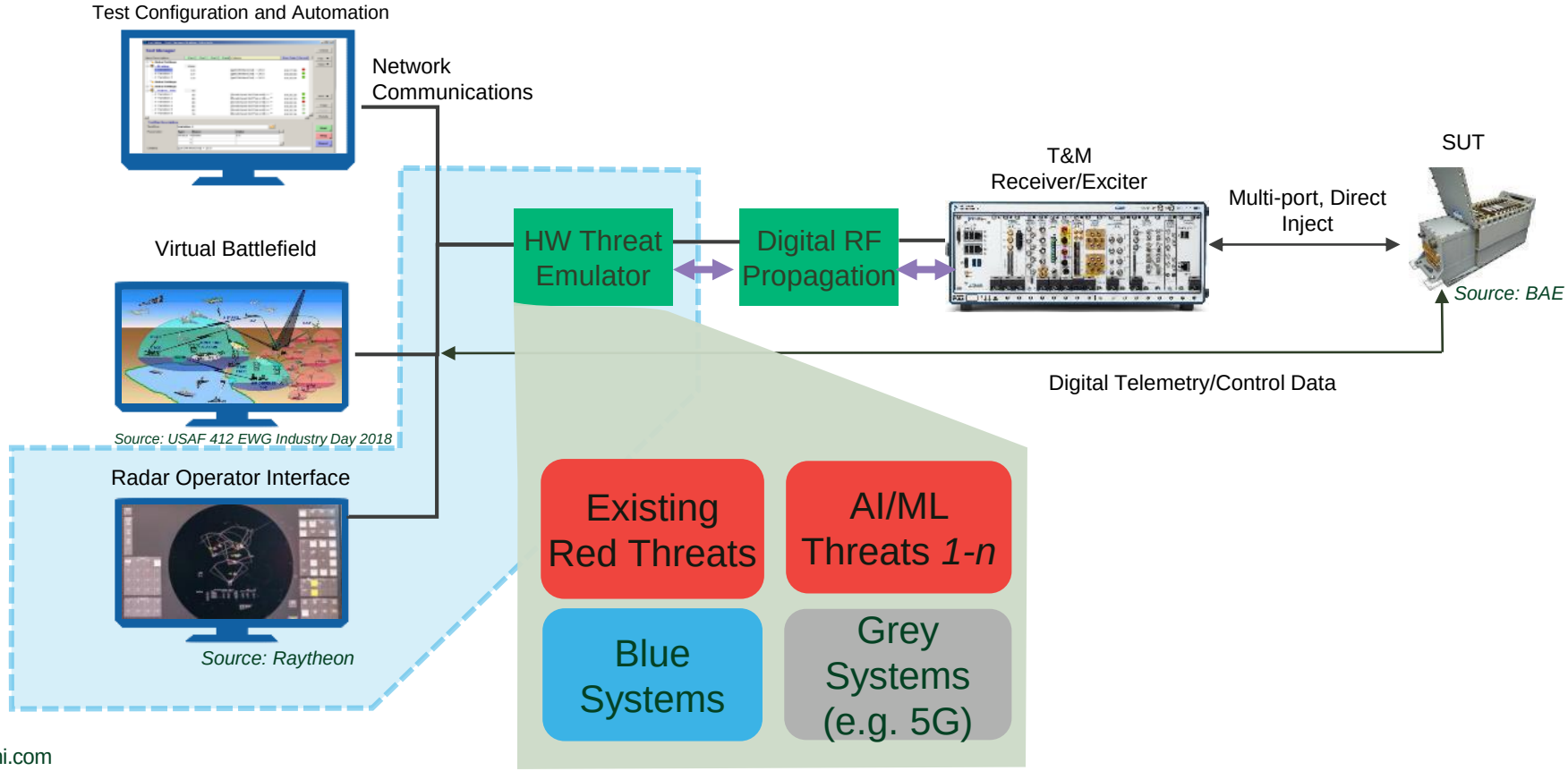
How well does this map to Cognitive EW?



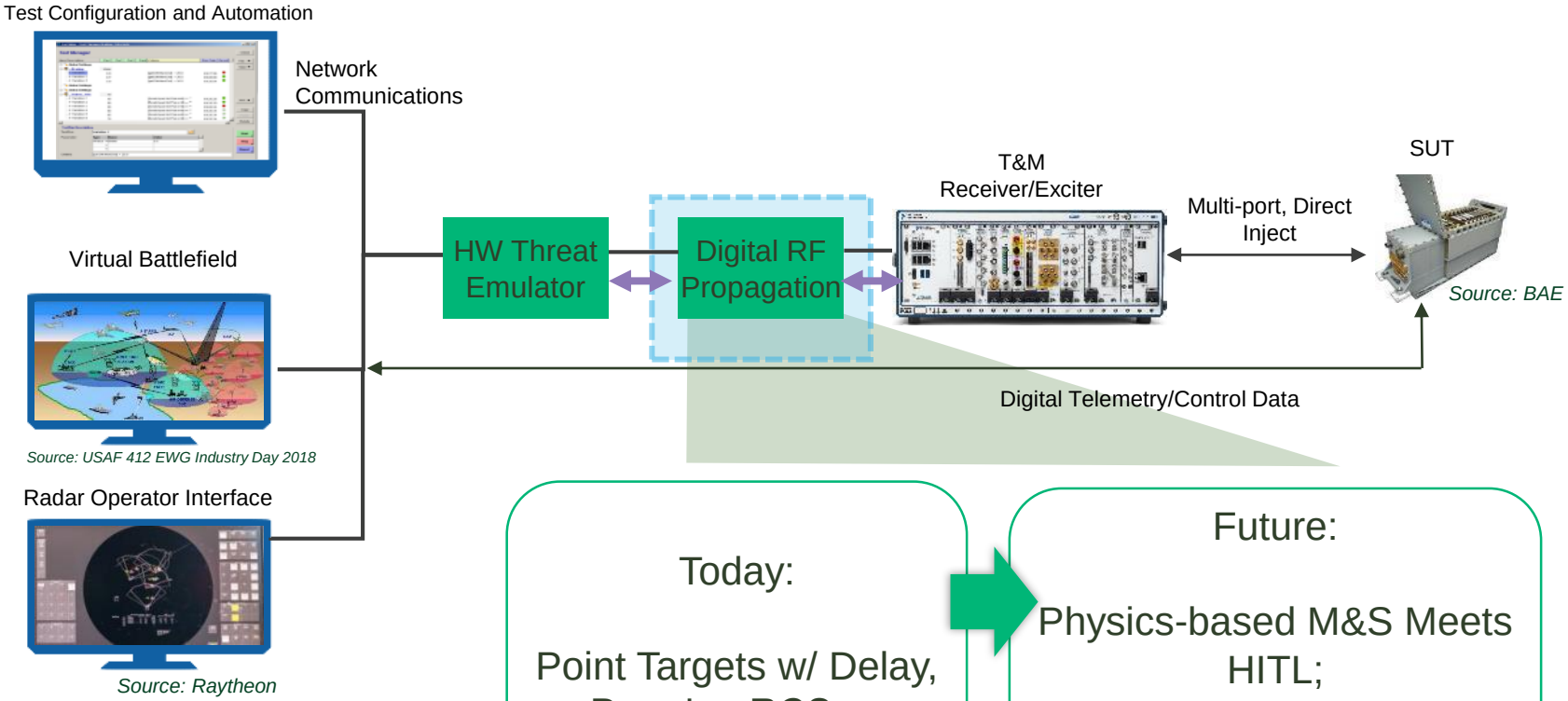
Additional Challenges Gaps:

- Lack of access to validated red/blue models
- Lack of shared, high-fidelity "real-world" data
- Etc…

HITL Test Infrastructure for Electronic Warfare Systems



Simulating RF Propagation: Push towards Higher Fidelity



A Higher-level Workflow for Cognitive EW T&E

A vision for Cognitive EW T&E

- Platform Capabilities
- System Requirements
- Prior Mission Data
- Known Adversary Capabilities / Behaviors
- Regulatory Requirements

Requirements

Test case Parameterization
Thousands to millions of engagements

Prioritization
Based on risk: impact & likelihood

Assignment
Based on function and required fidelity
M&S -> HITL -> OAR/LVC

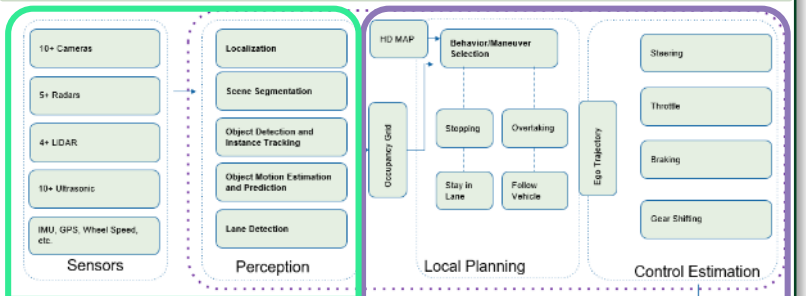
Execution
Leveraging Shared Scenario Generator / Manager

Iterate
Interesting results seed new test cases

Assessment
Establish "level of trust"

Results

Need to establish ruleset



Ex. Assign to HITL "Sensor-in-the- Loop"

Ex. Assign to M&S or "Processor-in-the-Loop"

Need to adopt continuous test construct

	M&S	HITL	OAR
Threat	TMAP Models	Digital Twin (Model Standardization)	Digital Twin
Environment	Propagation Models	Environment Simulator	Environment Simulator? (LVC)
SUT	Blue Models	Tactical HW & Digital Twin	Tactical HW

Challenge: How do MoD/DoDs and contractors work together to realize this kind of workflow?

Q&A

Thanks for your attention!

Please feel free to contact me with any further questions: jeremy.twaits@ni.com