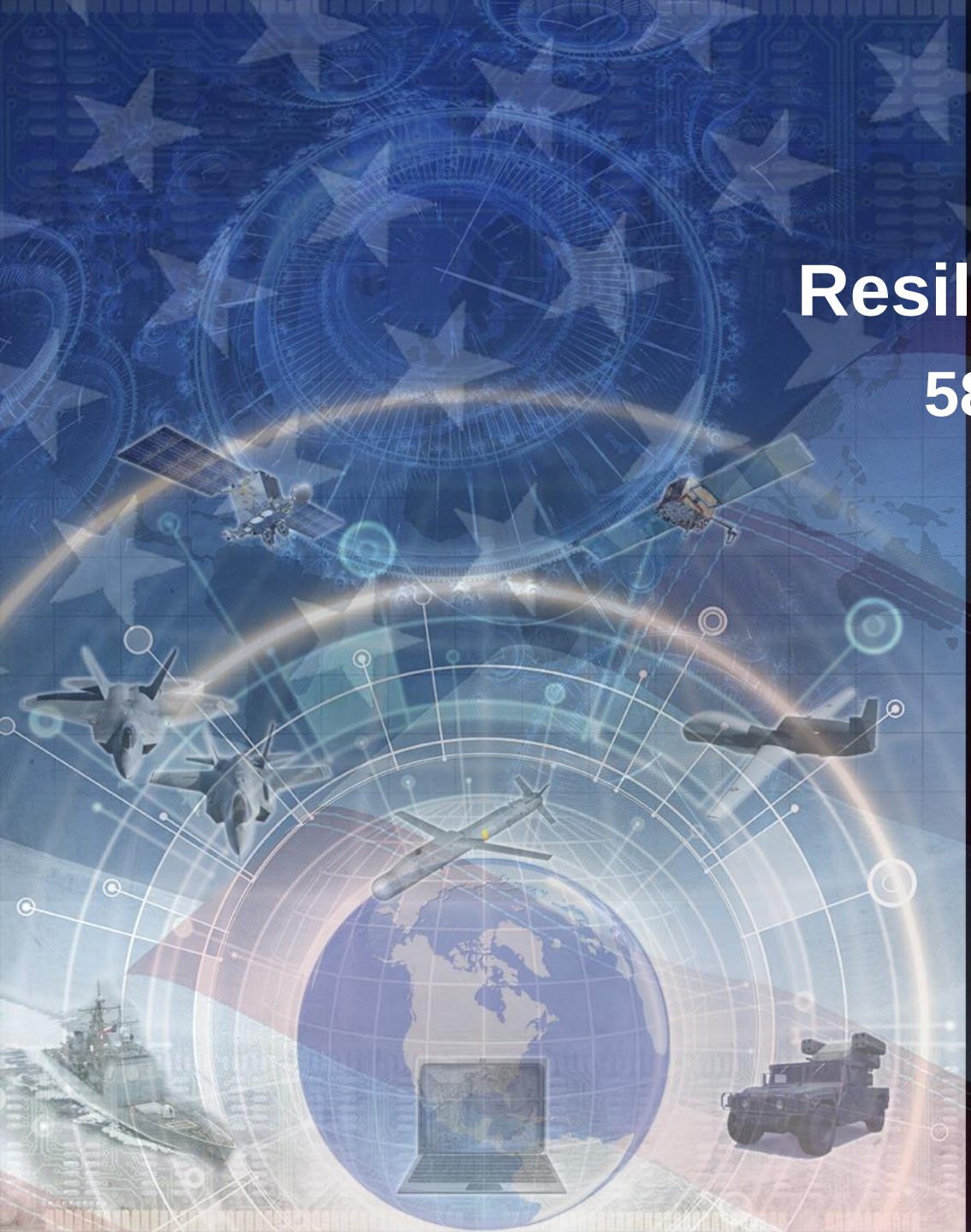

Resilient pvT Activities

58th Meeting of CGSIC

24 September 2018

Kevin Skey

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Homeland Security Systems Engineering and Development Institute

National Cybersecurity FFRDC

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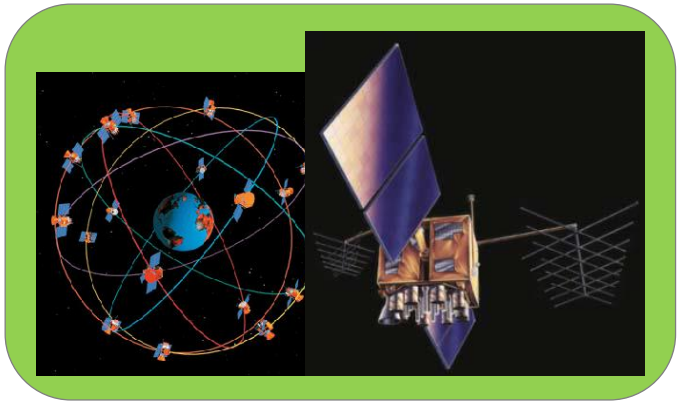
PNT Reference Implementation Laboratory (PNT RIL)

- **Objective**
  - Support for Sponsor missions by developing approaches, technologies and test techniques that increase resiliency of PNT capabilities through Robustness, Redundancy/Diversity and Recognition/Removal of Threats

- **Tools, References, Testbeds**
  - Modeling and Simulation Environments
  - COTS and custom GNSS simulators
  - SDR-Based GNSS Reference Receiver
  - Sensor Fusion
  - PNT Situational Awareness
  - Precise Time/Frequency Distribution
  - Antenna Systems
  - UE Test and Evaluation
  - System Verification and Validation



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Resilient pvT Activities

- **Near-term DHS S&T reference products for improved robustness and detection of GPS anomalies in stationary timing applications**
  - Defense-in-Depth
- **Internally developed PVT Assurance approach to enable effective use of GNSS and other sources**
  - Advanced Navigation and Timing Strategy for Enhanced Robustness and Resilience (ANTSERR)
  - Inferring PVT Assurance
- **Global Navigation Satellite System Test Architecture (GNSSTA)**

Resiliency – Risk Management (RM)

- **From Presidential Policy Directive (PPD-21):** The term **"resilience"** means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents

  https://www.dhs.gov/what-security-and-resilience

PPD-21 RM Examples	PNT Specific RM Examples
Developing a business continuity plan	Operations contingency planning – practices and procedures for GPS disruptions
Having a generator for back-up power	Alternate PVT sources – Clocks, inertial, GNSS, vision-aided, communication systems, RADAR, compass, etc.
Using building materials that are more durable	Antennas, protection algorithms, security engineering (IA), Cyber protections, adaptable system architectures

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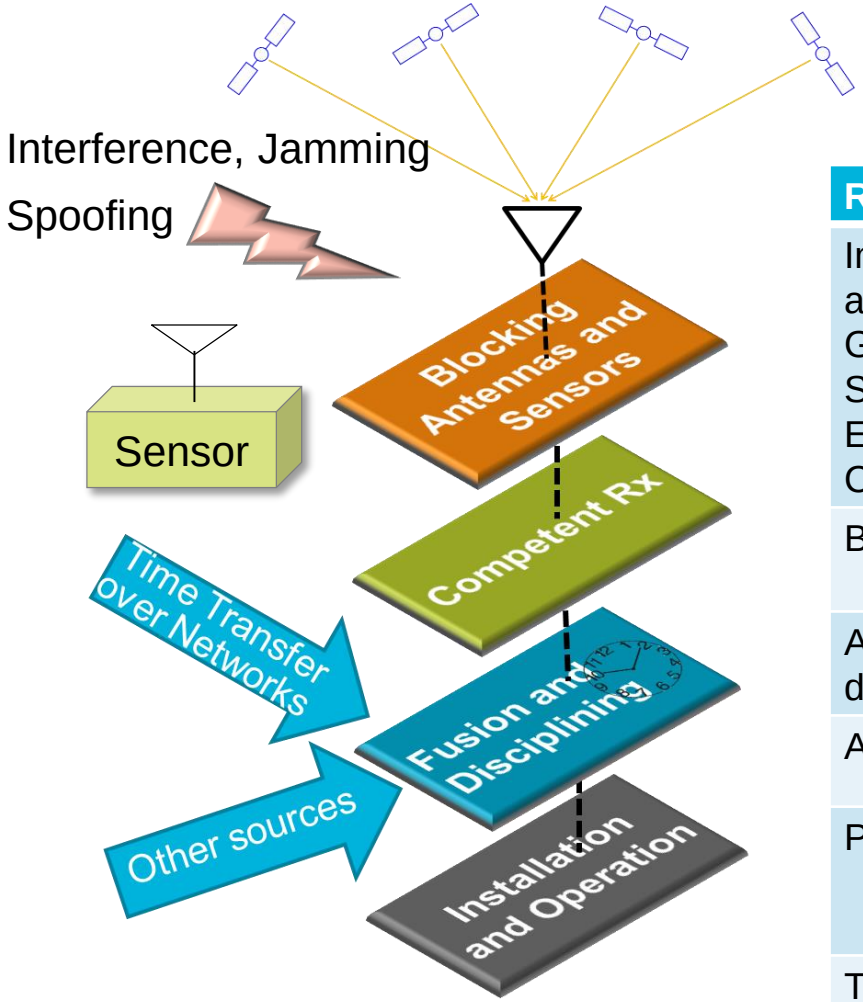
Near-Term DHS S&T References for Improved Stationary Timing Applications



Reference	
Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure	https://www.navcen.uscg.gov
Blocking Antenna	HSSEDI Total Horizon Antenna Reference Design
Anti-Measurement Spoof detection	HSSEDI Epsilon: PVT-based spoof detection algorithms
Anti-Data Spoofing	IS-GPS-200H
Power Detection	HSSEDI Interference detection mitigation applique (GIDMA)
Threat Environment recordings	Recording from DHS GET-CI Sept 2017

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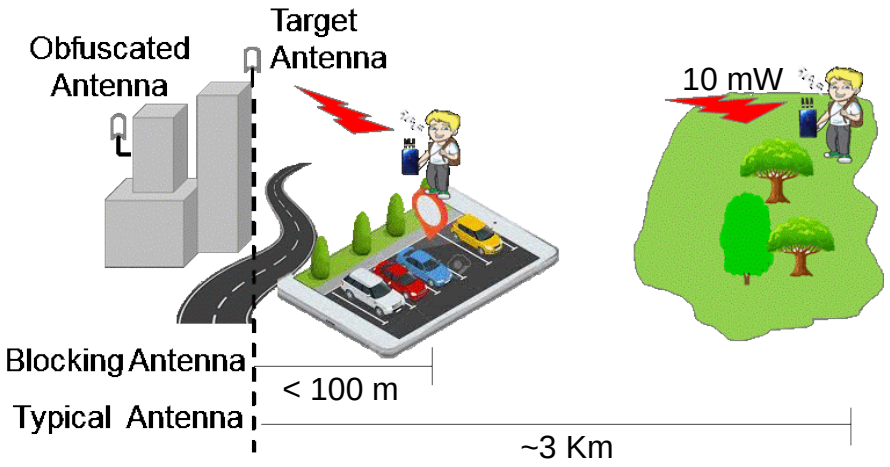
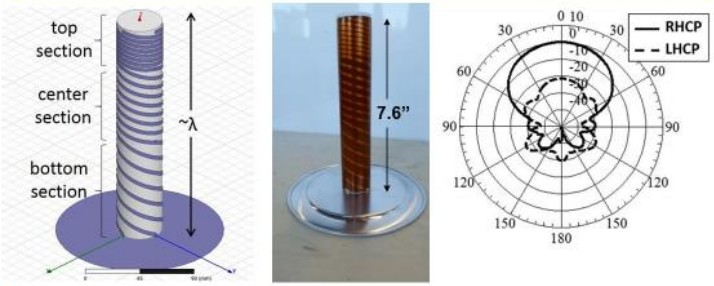
Blocking Antenna Reference for Timing Applications

- **For timing receivers, a decrease in satellite visibility can increase robustness**
- **Horizon-nulling reduces threat effectiveness by attenuating interference and spoofing at or below horizon by factor of 1000**
  - Provides ~60° beamwidth
- **Adversary must get closer or transmit with more power**



Increases chance of exposing emitter

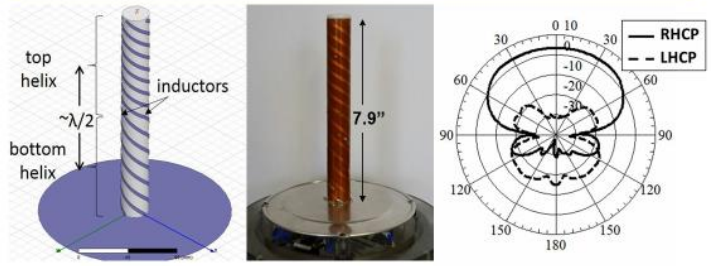
Three Section Helix



- 60 degree HPBW (measured in anechoic chamber)
  - HPBW narrows when mounted on a rooftop
- 38 dB RHCP zenith to horizon ratio
- 37 dB LHCP zenith to horizon ratio

Zenith to horizon ratio changes in real environments

Single Frequency Inductor Helix



- 100 degree HPBW
- 30 dB RHCP zenith to horizon ratio
- 34 dB LHCP zenith to horizon ratio

HSSEDI

E. Lundberg, I. McMichael; Novel Timing Antennas for Improved GNSS Resilience; ITM/PTTI 31 January 2018

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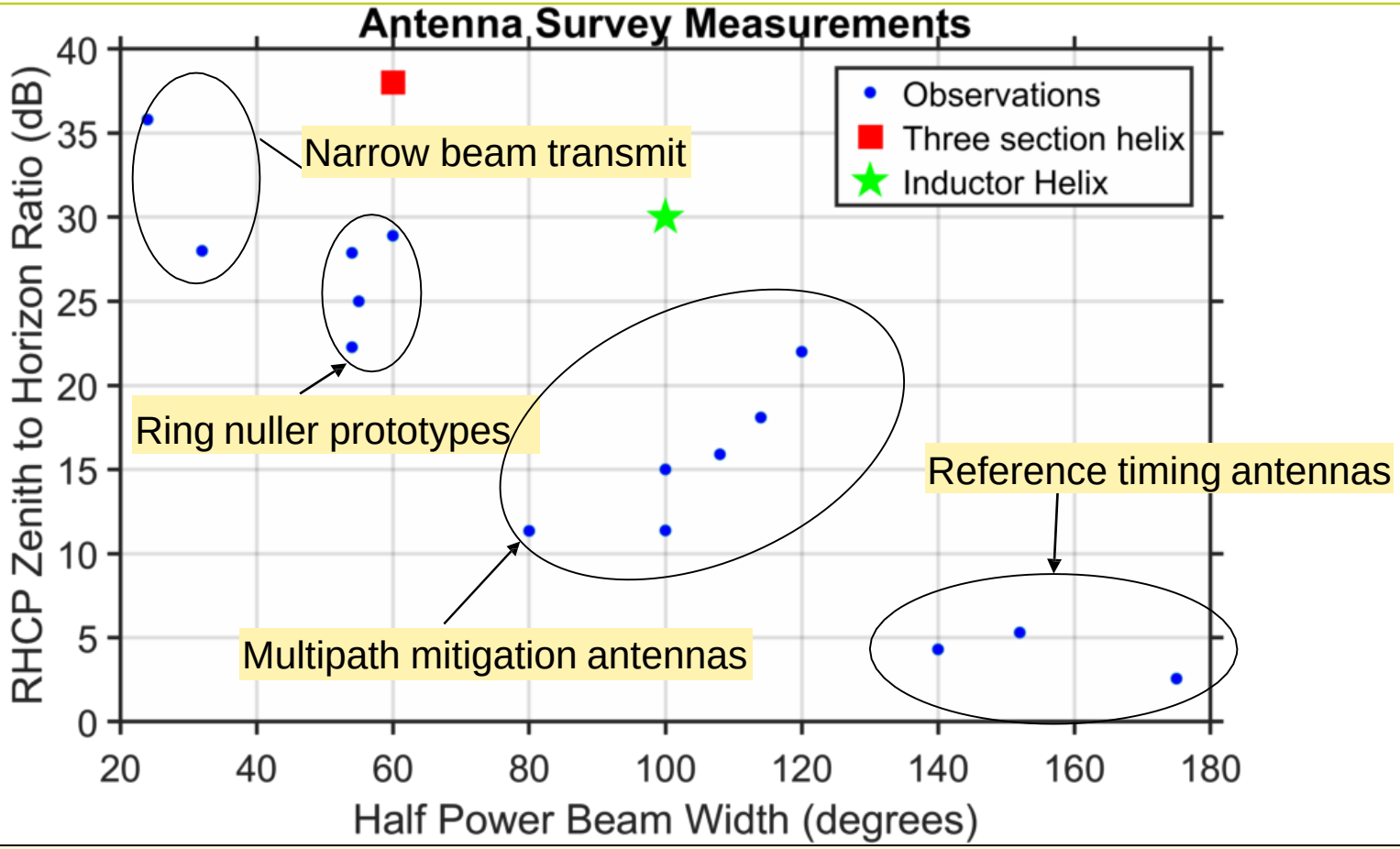
Antenna Technology Comparison



At lower cost, a fixed gain horizon nulling antenna can provide substantial interference attenuation for fixed site timing receivers

- A 60 degree half power beamwidth is sufficient to provide visibility to at least 2 satellites for all of earth's landmass 99% of the time

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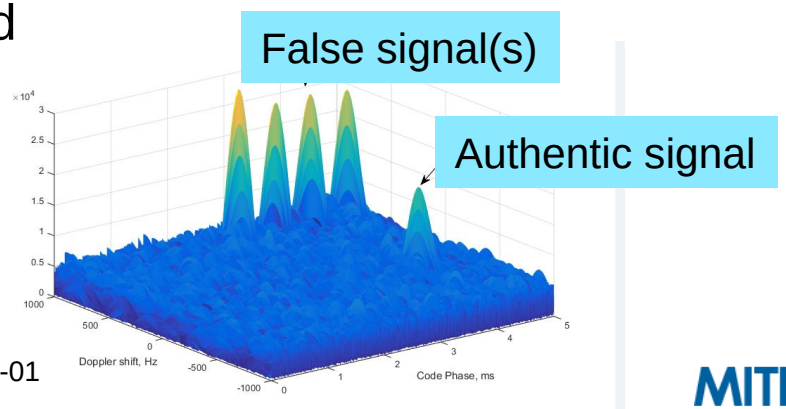
Epsilon PVT Spoof Detection Algorithms

- **Light weight spoof detection algorithms for stationary receivers**
  - Uses common GPS receiver outputs as a means to augment existing equipment
  - First step towards more powerful algorithms
- **Monitors position, velocity, and clock effects**
- **Extensively tested in simulation, laboratory and field**
- **Range of resources available**
  - Theoretical foundations, Python implementation of algorithms, threshold tuning methodology, test results
- **Evaluation software system: uses common COTS receiver to show detection behavior to aid in application development**
  - Receiver and Epsilon output visualized



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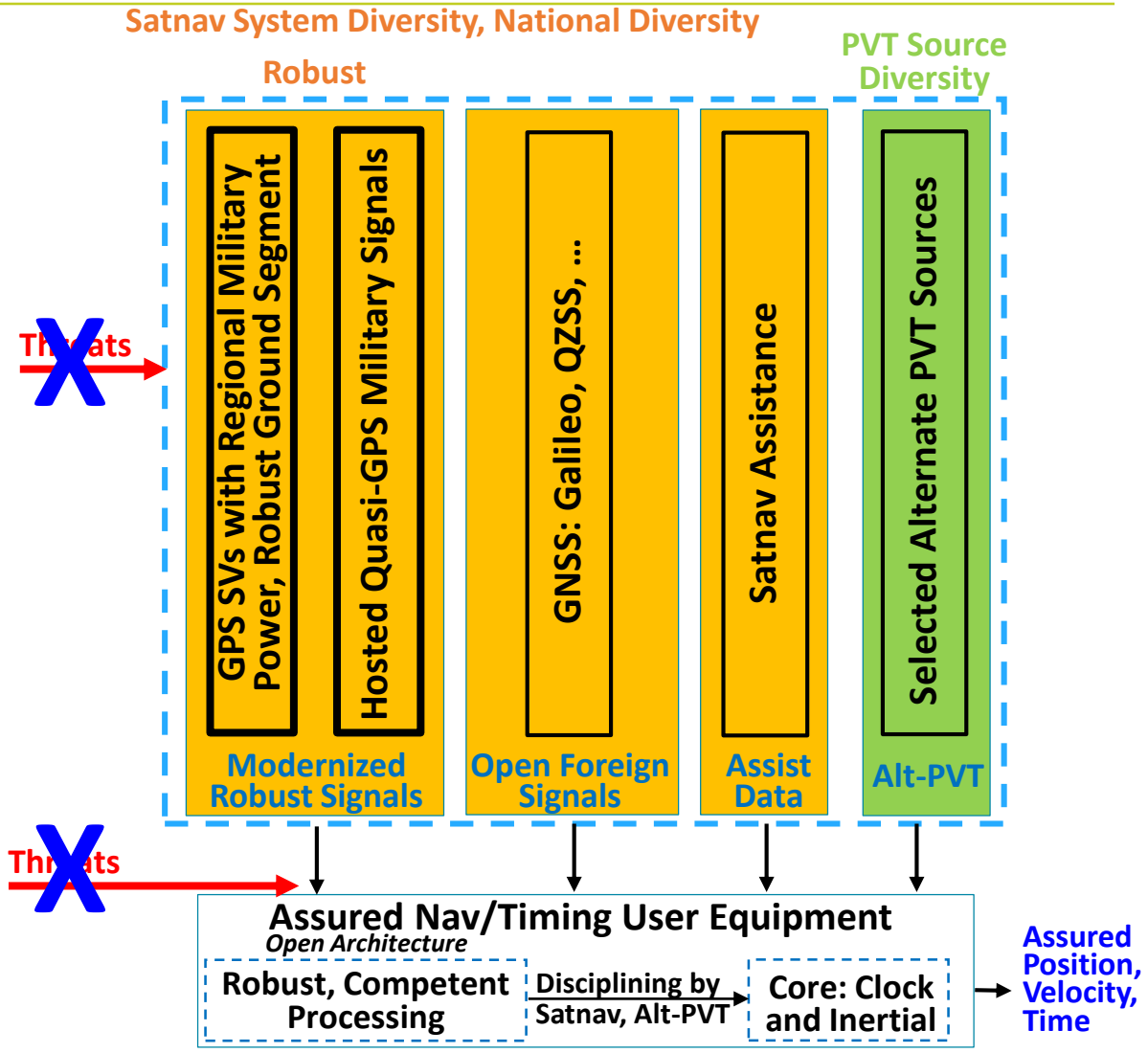
Advanced Navigation and Timing Strategy for Enhanced Robustness and Resilience (ANTSERR)

- Transition from GPS User Equipment to Assured Navigation and Timing (NT) User Equipment
- Implement Satnav User Equipment Competency
- Enhance and Develop Satnav Infrastructure
- Recognize and Remove Threats
- Take Complementary Actions to Address Policies, Processes, Legislation, etc.



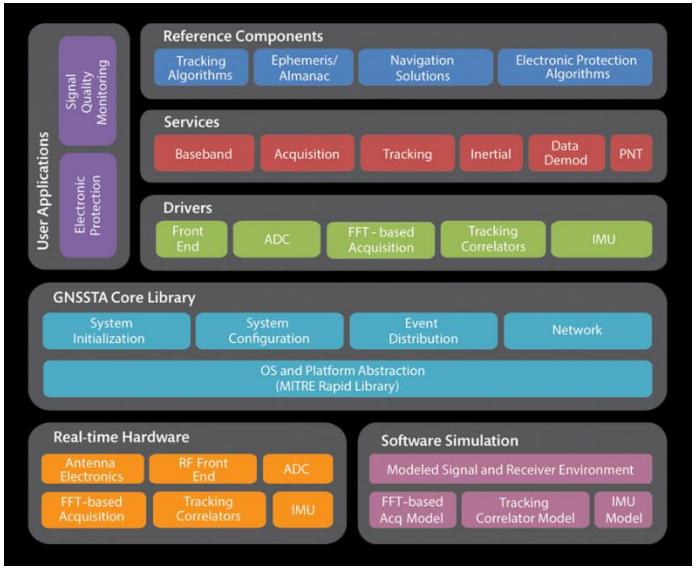
Global Navigation Satellite System Test Architecture (GNSSTA)

Sponsored by SMC/GPU and AFRL/RYWN

gnssta@mitre.org

GNSSTA is a software defined radio (SDR) framework for experimenting with PVT receiver technology. The GNSSTA ecosystem comprises (**A**) data generation tools and reference input data, (**B**) flexible receiver software/firmware and reference designs/components, and data logging, visualization, and (**C**) analysis tools to jump-start research activities.

- **Test algorithm performance**
- **Generate simulation scenarios**
- **Generate simulation *and* RF**
- **Design and develop experimental signals**
- **Design and develop new algorithms**
- **Log simulated results**
- **Prototype algorithms in Python**
- **Interact with the receiver using Python code**



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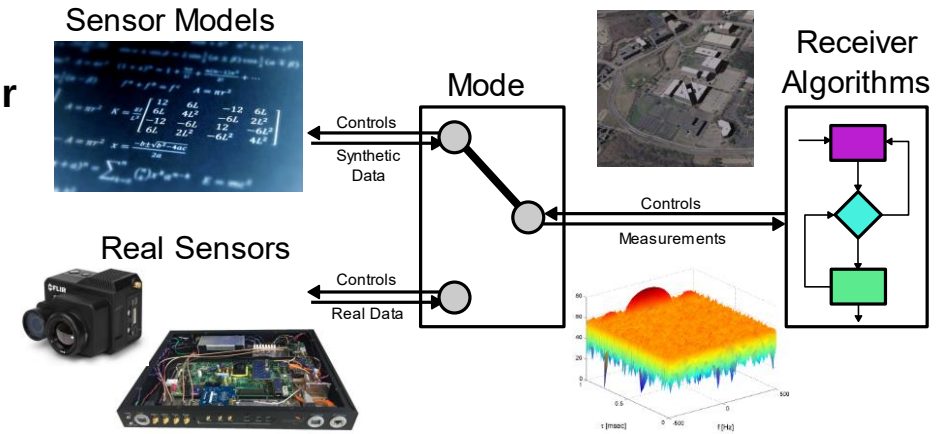
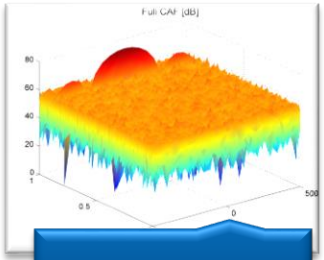
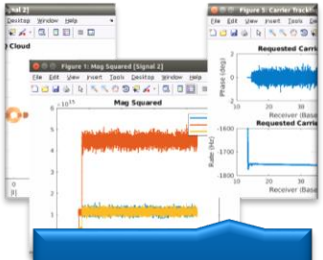
GNSSTA Use Case: Modeling and Simulation

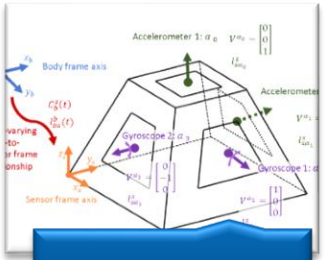
- **Architecture for simulation & real-time multi-sensor navigation M&S**
- **Compile as SWIL (laptop or Linux cluster for Monte Carlo) or HWIL (real-time receiver for benchtop or field test)**
- **Highly tunable dynamic measurement synthesis (software models/emulators)**




GNSS Acquisition


GNSS Tracking


Camera



Inertial/Clock

Barometric Altimeter

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