Department of Transportation
Office of the Assistant Secretary for Research and Technology (OST-R)

DOT/OST-R: Karen L. Van Dyke
DOT/OST-R/FAA: James S. Aviles

Position Navigation Timing Advisory Board 28th Meeting
DOT-System-of-Systems IDM Briefing May 3, 2023

US DOT SPD-7 High-Level PNT IDM Strategy

- **Actively Detect and identify L-Band Interference Emissions**
  - Focus on In-Band and Adjacent Band Interference
  - In partnership with other Federal Departments/Agencies
- **Leverage Space, Ground, Fixed, Transportable, and Mobile**
  - Sensor Equipment Already in Operation | System-of-Systems
  - Adapt/Enhance to Cover GNSS Interference
- **Joint Federal, State and Local – Civil, Military**
  - Establish Multi-Federal-State MOA & CONOPS
- **State and Local Law Enforcement Involvement**
  - Focused for Critical Ports and Infrastructure Protection

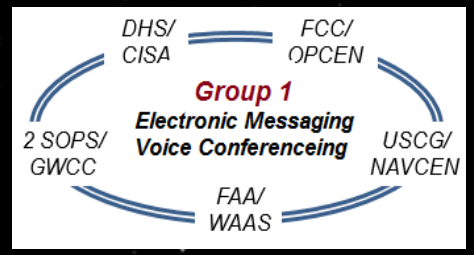
US DOT SPD-7 PNT IDM High Level Requirements

- **# 1 Implement Federal Interagency PNT IDM Capability**
  - Implementation Efforts Started in FY2022
- **# 2 Coordinated with DoD and DHS and Other Agencies**
  - Two Major Coordination Activities On-Going for MOA, CONOPS and SOPs
- **# 3 Facilitate State, Local & Commercial Implementation**
  - Next Major Phase to Kick-Off in FY2023
- **# 4 Must Cover Safety, Security and Scientific Purposes**
  - Partnering with Aviation Cyber Initiative PNT Activities
- **# 5 Must Cover In Band and Adjacent Band Emissions**
  - Technologies and Processes Developed for Implementation Readiness
- **# 6 Leverage Fixed-Mobile Assets & Sensor Technology Innovations**
  - Two Leverage Activities Initiated
- **# 7 Use Open Architecture and Modular Frameworks**
  - Next Key Activity to Start Planning in FY2023
- **# 8 Establish Multi-Layer Space, Airborne, Terrestrial & Cyber**
  - Layers Established in FY2022 – Initiated Airborne / Terrestrial – Space / Cyber will follow
- **# 9 Centralize Reporting-Coordination for Regulatory Enforcement**
  - Initiated MOA Revisions – CONOPS Developments – Common Operational Tools

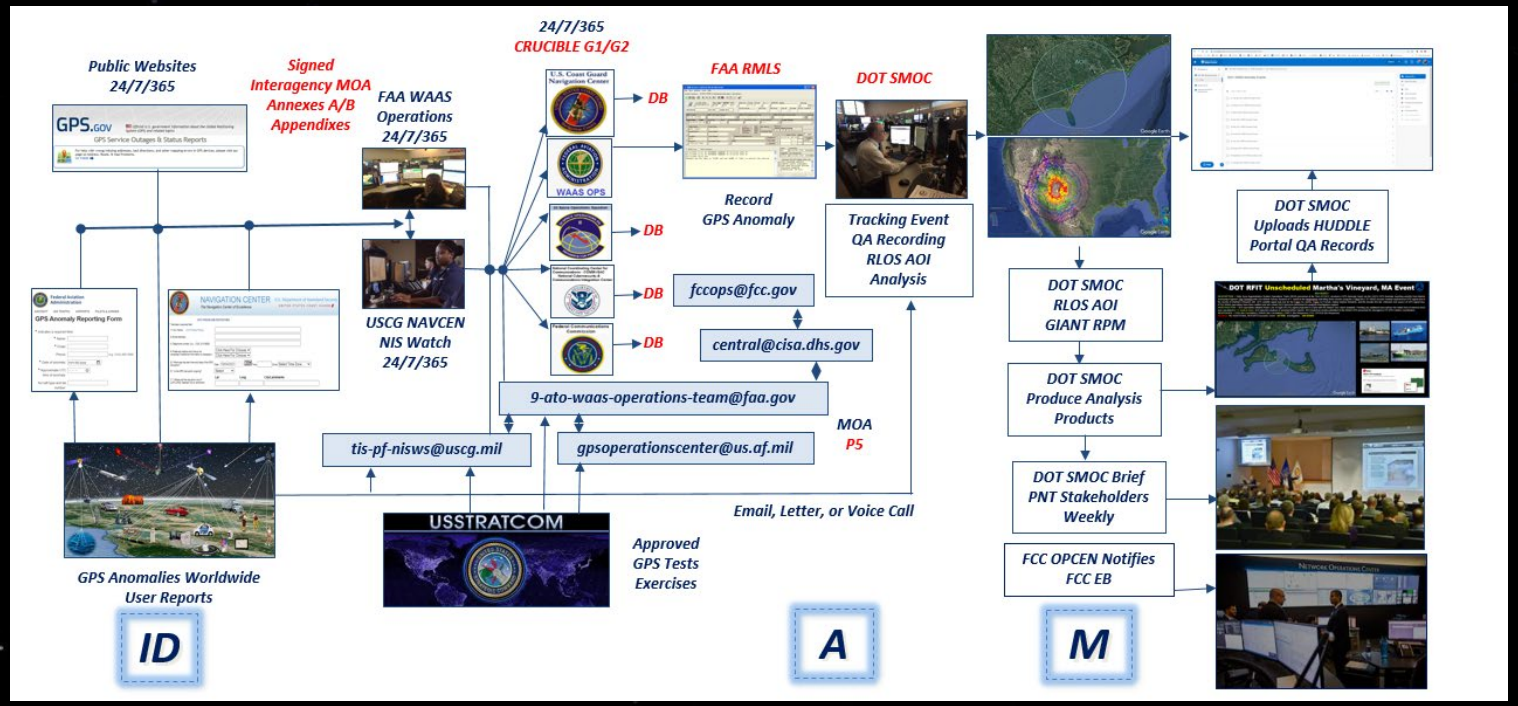
Early Path-finders
- NGA Monitor Stations
- Volpe Wake Vortex Installations
- FAA WAAS/NSTB Network
- ADS-B Ground Base Transceiver (GBT) Network
- PIRT OLSON Network
- Airport Facilities, e.g. Glide Slope/Localizers
- Mobile/LEO Platform
- CISA National Critical Function Sites

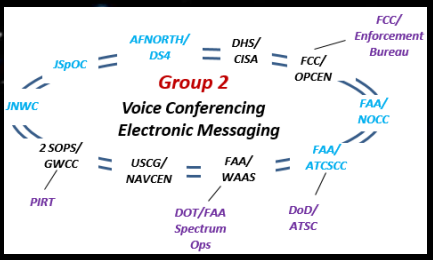
Interagency Present PNT IDM Capability Posture

- **Federal Government CBL IDM Present Posture** = Reliant on User Identification, Detection and Reporting of GNSS Interference, Based on Subjective User Assessment of Operational Disruptions or Impacts.



INITIAL - TRIGGERS START OF THE CRUCIBLE **GROUP 1** CONFERENCING AND INFORMATION SHARING BETWEEN THE FIVE (P5) 24/7/365 OPERATIONS CENTERS



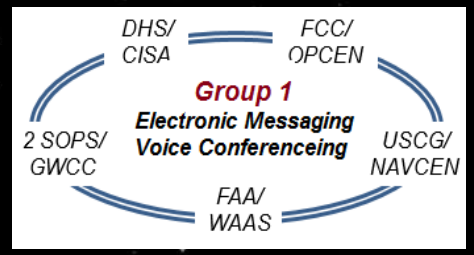


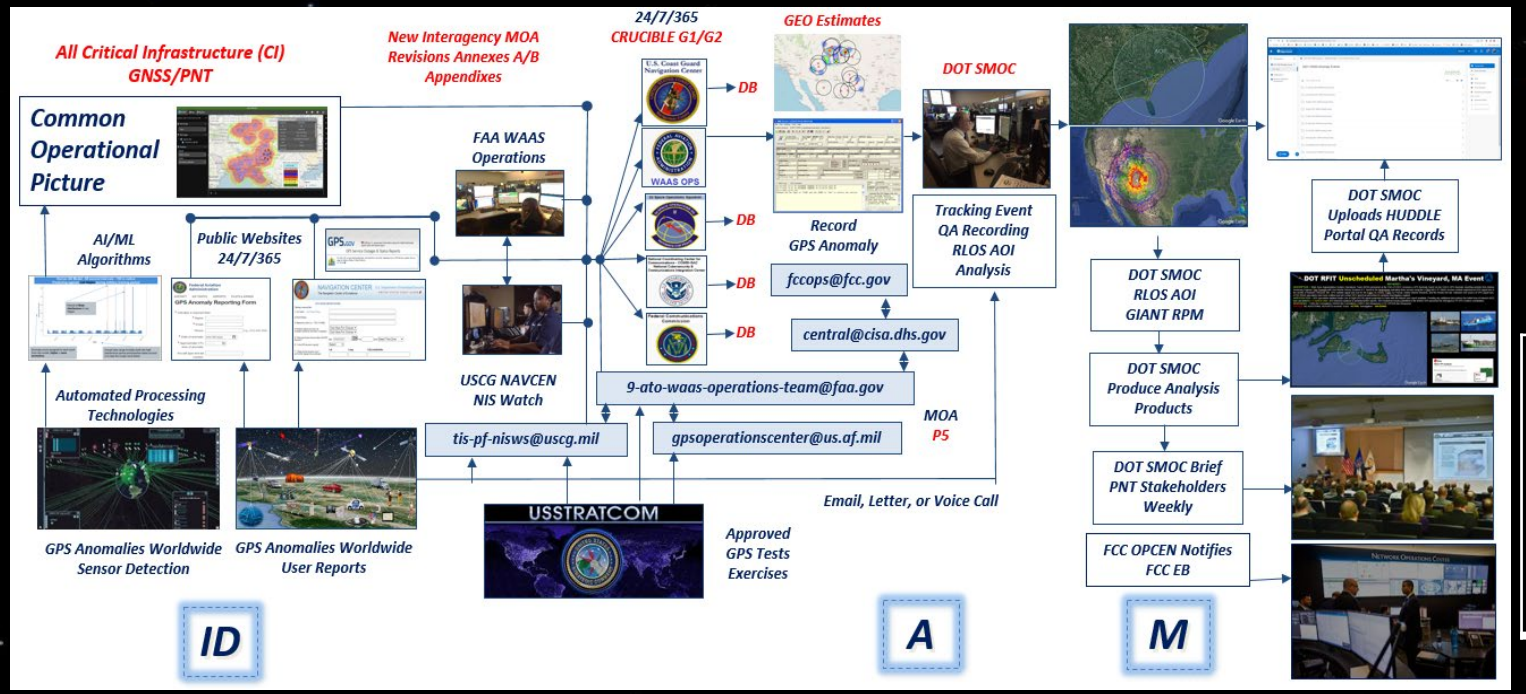
PERSISTENT - ELEVATES TO CRUCIBLE **GROUP 2** CONFERENCING AND INFORMATION SHARING BETWEEN ADDITIONAL OPERATIONS CENTERS AND SUBJECT EXPERTS

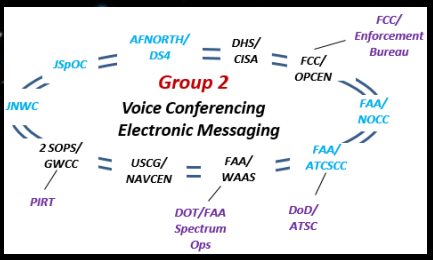
- **Joint IDM Technology Implementation Initiative** = Independent Dedicated Technology for Automated Monitoring of GPS Interference Signals by Chartered Federal Interagency Partners to Improve Faster Resolution of CBL Incidents.

Interagency Future PNT IDM Automated Posture

- **Federal Government IDM Future Posture** = Implement Automated Identification, Detection and Reporting of GNSS Interference, Based on System-of-System Measurements Validate Subjective User Assessment of Operational Disruptions or Impacts.





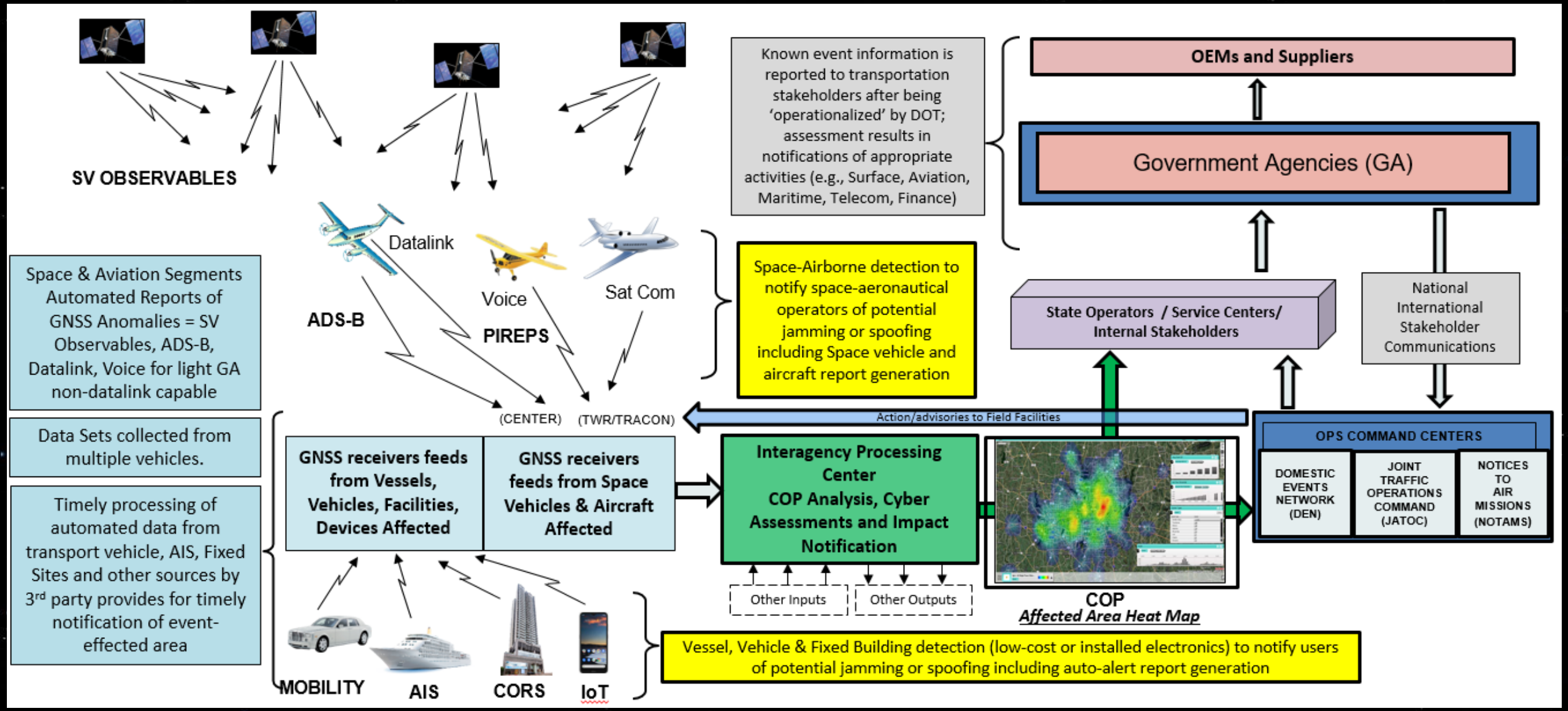


INITIAL - TRIGGERS START OF THE CRUCIBLE **GROUP 1** CONFERENCING AND INFORMATION SHARING BETWEEN THE FIVE (P5) 24/7/365 OPERATIONS CENTERS

PERSISTENT - ELEVATES TO CRUCIBLE **GROUP 2** CONFERENCING AND INFORMATION SHARING BETWEEN ADDITIONAL OPERATIONS CENTERS AND SUBJECT EXPERTS

- **Common Visualization Environment** = Common Operational Picture from Technology and Automated Monitoring of GPS Interference Signals Available to All Chartered Federal Interagency Partners for Common Situational Awareness.

Interagency PNT IDM Joint Concept of Operations



DIU Unique Mission Strategic Goals

DoD DIU MISSION

DEFENSE INNOVATION UNIT

DIU is a Fast-Moving, Cross-DoD Organization Focused Exclusively on Commercial Companies to Solve National Security Problems.

Elements of DIU Mission

- **Accelerate** DoD adoption of commercial technology
- **Transform** Military capacity and capabilities
- **Strengthen** the national security innovation base

Key DIU Differentiators

- **Unique project lifecycle** from curation to transition
- **Joint force** & mandate to scale value across DoD
- Broad and deep **integration** into key tech ecosystems

Accelerating Commercial Technology for National Security

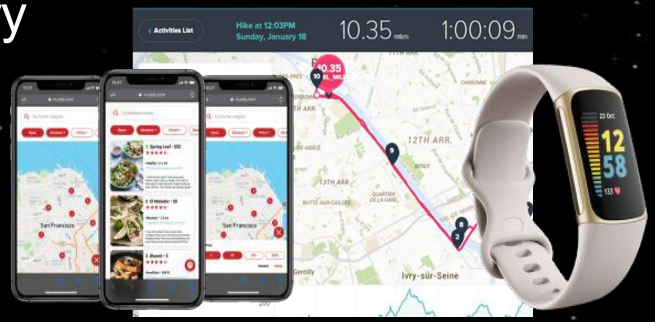
Harmonious Rook

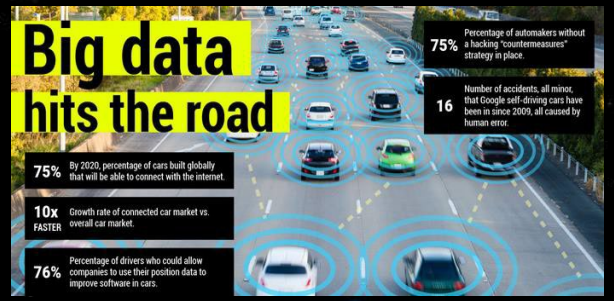
Discovery, Classification and Attribution with PAI Analytics

January, 2023

DIU Harmonious Rook = Ideal for DOT's PNT IDM

- **Turn the Vulnerability Into a Solution:**
  - Billions of distributed, networked GNSS devices act as sensor discovery for PNT disruptions
  - Inform the use of custom, hardware centric solutions with timely classification and attribution
- **End-to-End Unclassified Workflow:**
  - Maximize discretion for sharing and dissemination with civil agencies, allies and public
- **Domain agnostic datasets:**
  - Broad coverage, classification of events, and confidence in reporting (AIS, ADS-B, IoT, SIGINT); Multi-source-Multi-Vote
- **Mixture of rule-based and ML analytics:**
  - Performance verification unsupervised clustering models
- **Actionable insight to both the analyst and the operator:**
  - Operator View: Can I expect degraded PNT on this mission?
  - Analyst View: Is there a new anomaly in my AOI?

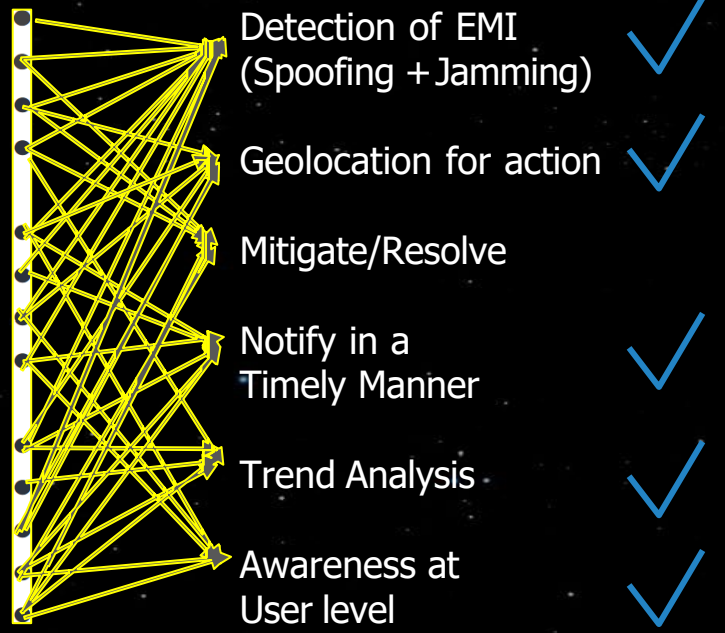




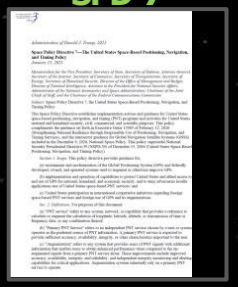
US DOT SPD-7 PNT IDM Requirements Mapping

Shared Common PNT Disruption Requirements to:

- Verify Integrity of GPS Environment
- Detect, mitigate, and increase resilience
- Identify, locate, and mitigate GPS Disruption
- Detect, Mitigate, and increase resilience to GPS manipulation
- Detect + Report GPS manipulation
- Provide timely reports of GPS manipulation
- Take action to mitigate GPS disruption
- All users must report all EMI, regardless of severity, intensity and duration
- Report, Track, Analyze, Resolve EMI
- Verification + Characterization
- Geolocation + Identification
- Resolve at lowest level
- Ensure agencies tracking EMI trends

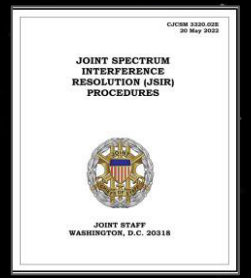


SPD-7



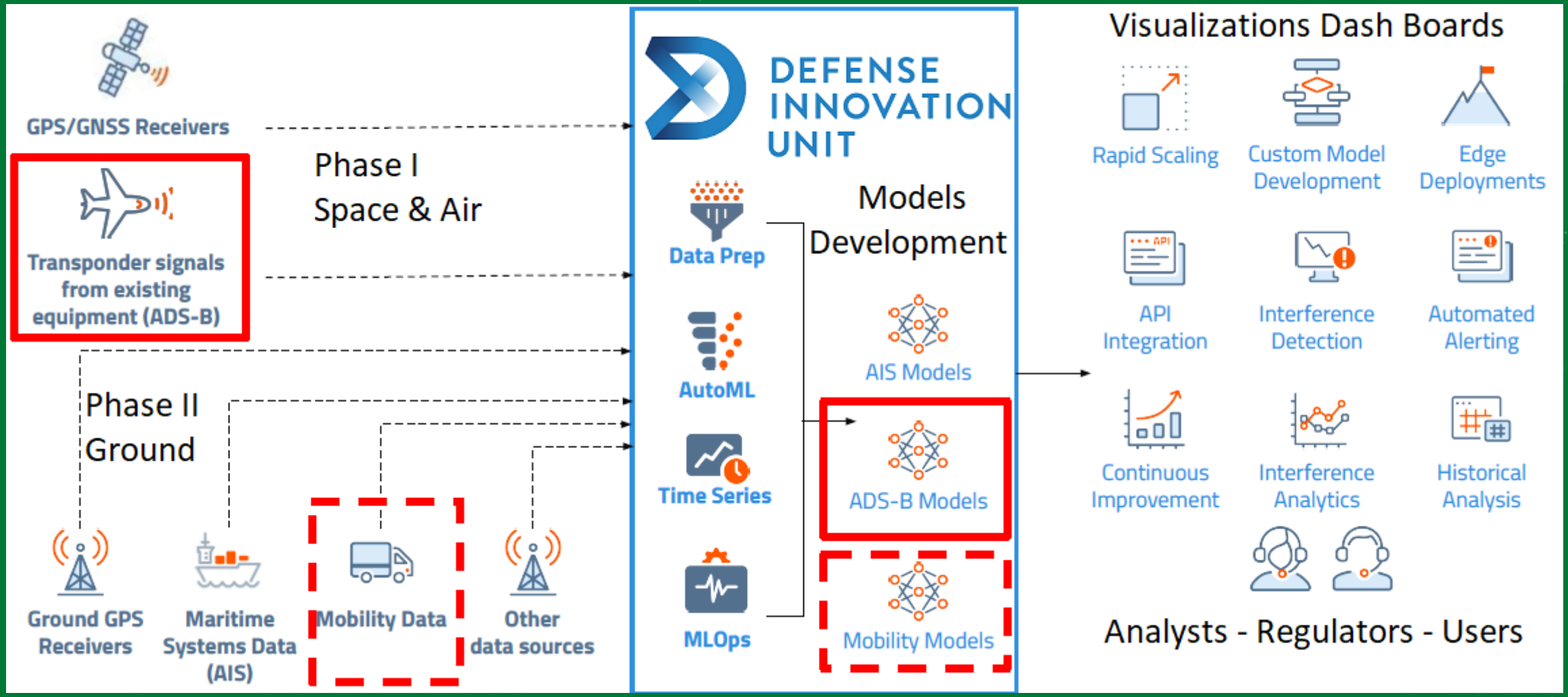
EO 13905

CJCSM 3320.02E



US DOT-DOD Joint Harmonious Rook PNT IDM Initiative

Initiating the Interagency Automated Processing Fusion Center

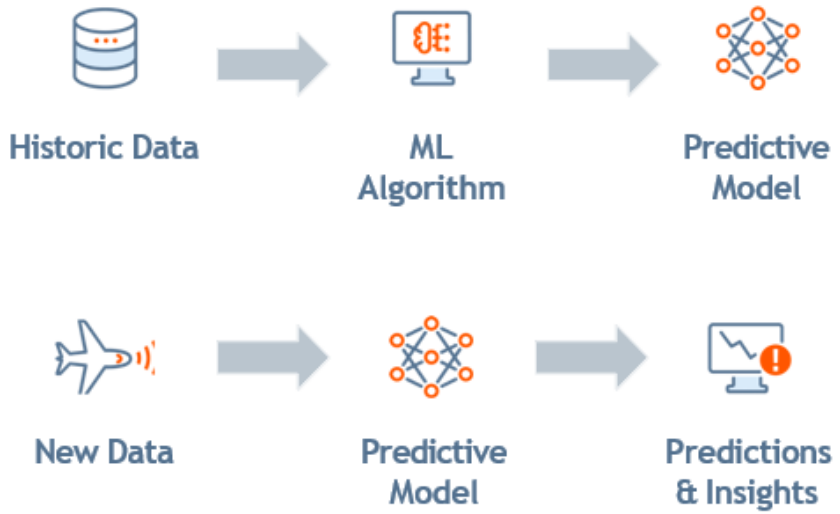


Predicting GNSS Interference

Detecting/Predicting Interference & Related PNT Issues well suited for ML

Machine Learning

Systems that build models that learn from the past to predict the present/future



Why is GNSS Interference a good problem for ML?

- Lots of **historic data**
- Lots of structured data
- **Time-consuming** for human review
- Known outcomes to optimize to
- Looking for trends, patterns, insights from this **mass structured data**

All of these apply to detecting GNSS interference (to varying degrees)

Key Takeaway

Using machine learning to predict GNSS interference is a more sophisticated and proactive approach (beyond rules-based methods) that can be validated against known occurrences

Harmonious Rook – Domestic Prototype

DIU/DOT Prototype with Data Robot

Phase I IOC concluded that there was meaningful signal in ADS-B data for detecting GNSS interference using machine learning. Phase II is focusing on refining that modeling effort, incorporating additional data, and predicting the approximate location of the emitter

PHASE II Initial Operational Capability (IOC) Sprints

1: Data Curation

Build out core **data infrastructure** for scalable and rapid interference detection

2. Refine ADS-B Model

Improve existing **detection methods** for Global Navigation Satellite System (GNSS) Interference

3. Ground Domain Model

Identify and incorporate additional **terrestrial GPS** data (e.g., Cell phone, Vehicle, CORS)

4. Refine Geolocation

Predict the **approximate location** of the Radio Frequency Interference (RFI) emitter

Accelerating Commercial Technology for National Security

Harmonious Rook Test and Evaluation Approach

Quantifying Success in PNT SA

The team has approached the problem using **unsupervised machine learning** where anomaly detection, without a target to train to, identifies anomalous events in data. In order to validate the approach of using anomaly detection models, the DataRobot team will work along a 'validation funnel' to increase the certainty on model performance:

1. **Train:** Build the model from incidents of reported, prolonged GNSS interference as provided by a Subject Matter Expert (SME))
2. **Test:** Test the model in areas of suspected GNSS interference to validate expected results
3. **Negative Sampling:** Test the model in areas of unlikely GNSS interference to validate expected results
4. **Validate:** Validate the model in areas and time windows where satellite-based radio frequency (RF) collection identified GNSS interference (HawkEye360 collections)

Train/Test Data Purchased (by month)?			Event coverage	
Month	Aerial	Terrestrial	Identified by SME	HE360 # ellipses
Dec. 2021	X	X	Charlotte	N/A
Jan. 2022	✓	X	Denver	N/A
Aug. 2022	✓	X		6
Sept. 2022	✓	X		6
Oct. 2022	✓	✓	LaGuardia, Dallas	406
Nov. 2022	✓	✓		450
Dec. 2022	✓	✓		1524
Jan. 2023	✓	✓	Longview, TX	1341
Feb. 2023	✓	X		*TBD*
Mar. 2023	✓ *1st - 15th	X		NAVFEST

Sprint 1 – Data Curation, Assessment, and Procurement

Due Diligence on Datasets vs. various metrics of interest

Sprint 1 of IOC Phase II focused primarily on identifying and thoroughly evaluating various GNSS data sources against criteria such as cost, geographic coverage, time-coverage, data robustness, value to modeling, geolocation accuracy, time-frequency of data updates, and ability to scale beyond the IOC. Two datasets were recommended for modeling:

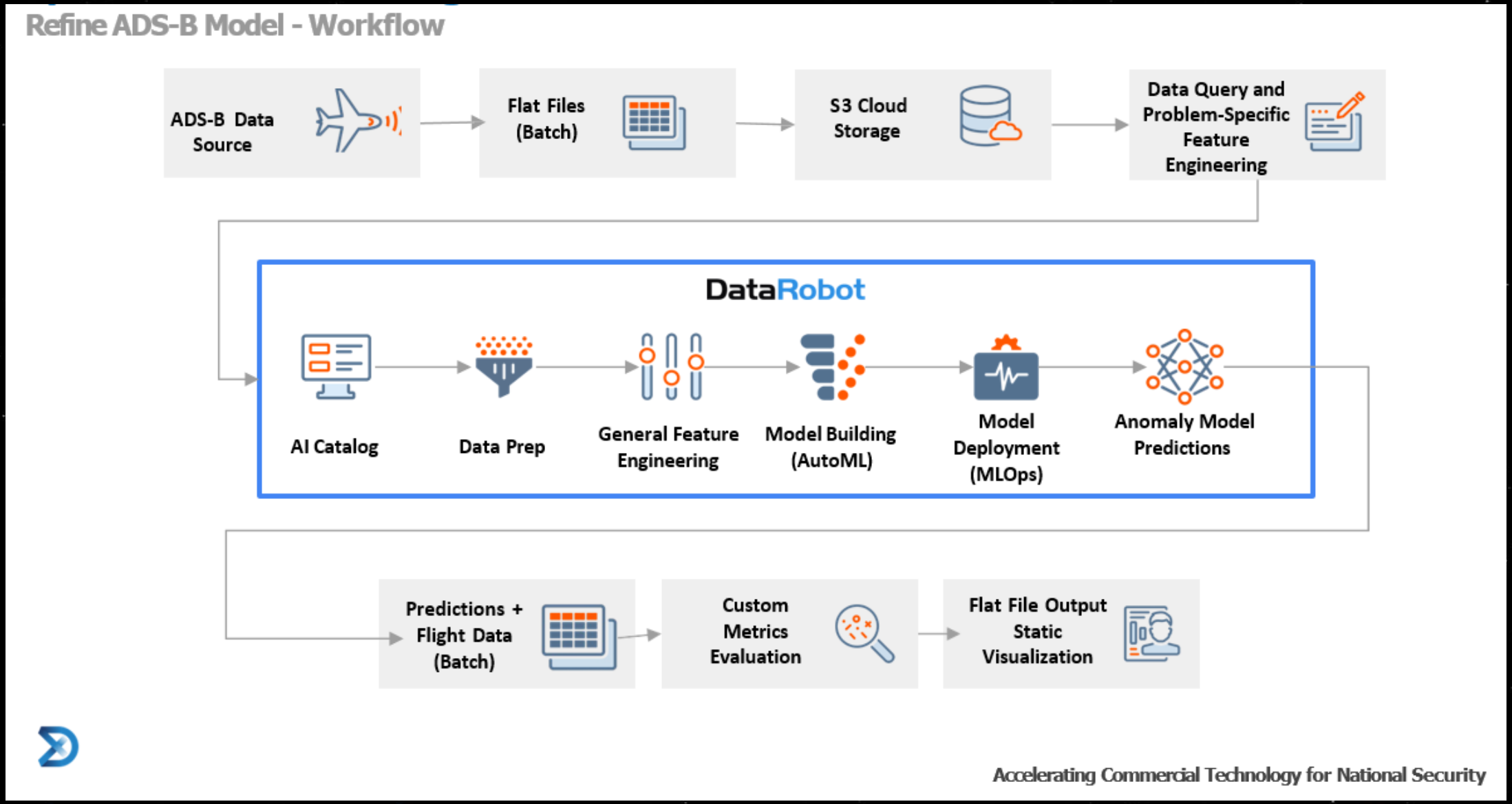
1. **Aerial (ADS-B Exchange)**: ADS-B Exchange is the world's largest unfiltered public source for flight data. The vendor also provides a real-time API that makes it suitable for high-impact events such as potential interference at a major "Core 30" airport.

1. **Terrestrial (Quadrant)**: Quadrant is a mobile device data source purportedly collected from mobile software development kits (SDKs) around the world. In terms of data quality, mobile SDKs are preferred to bidstream data which approximates locations such as by approximating from cached information

Key Takeaway

The primary advantage of the ADS-B Exchange aerial source is the availability of a real-time API for accessing data with a breadth of features relevant to GNSS signal quality, but has coverage concentrated around major airports. Quadrant was selected to supplement terrestrial coverage after edging out other mobility data providers on data quality.

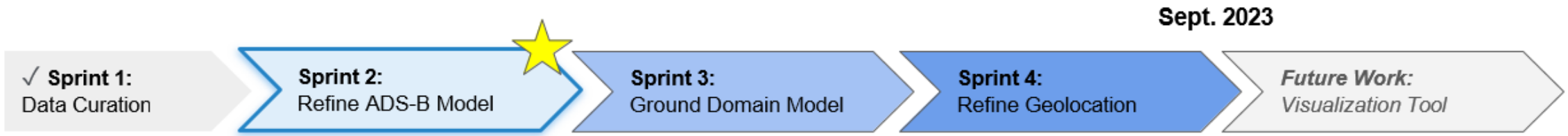
Sprint 2 – Aerial Modeling Workflow



Harmonious Rook – Domestic Prototype Status

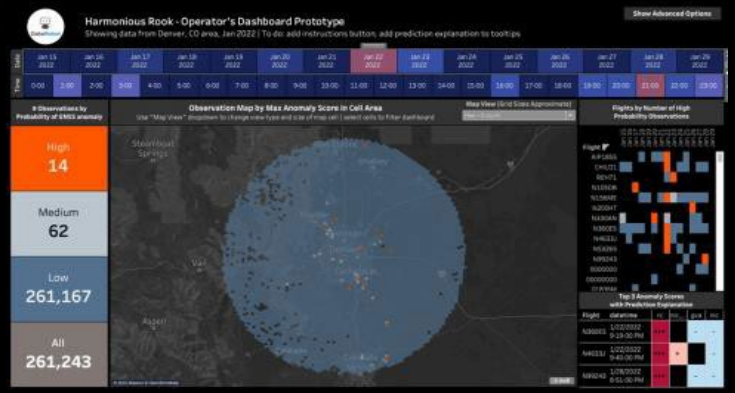
Current Status and What's Next

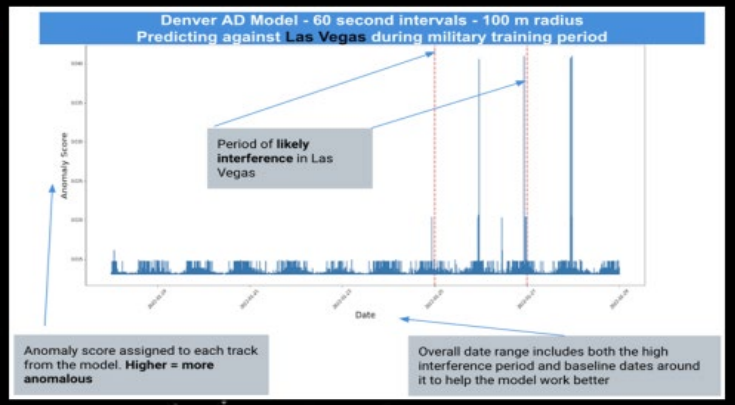
- Sprint 2 is concluding and the team is preparing to focus on continuing to improve performance and incorporating a terrestrial data source into modeling efforts as part of Sprint 3
- Phase II IOC is expected to complete in September 2023
- The next phase of work will focus on completing any additional modeling development, such as incorporating additional data sources, and integrating with a visualization tool
- End-user feedback will be collected to iterate and improve the product's utility and usability

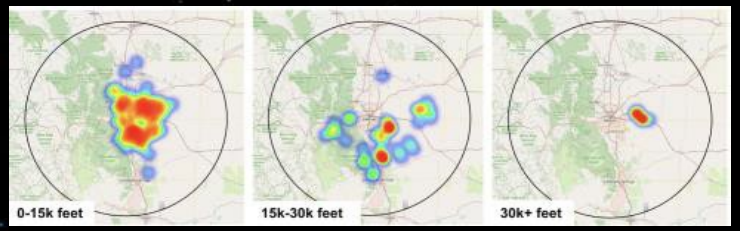


Accelerating Commercial Technology for National Security

DIU Harmonious Rook ML/AI To GOAT Visualizations



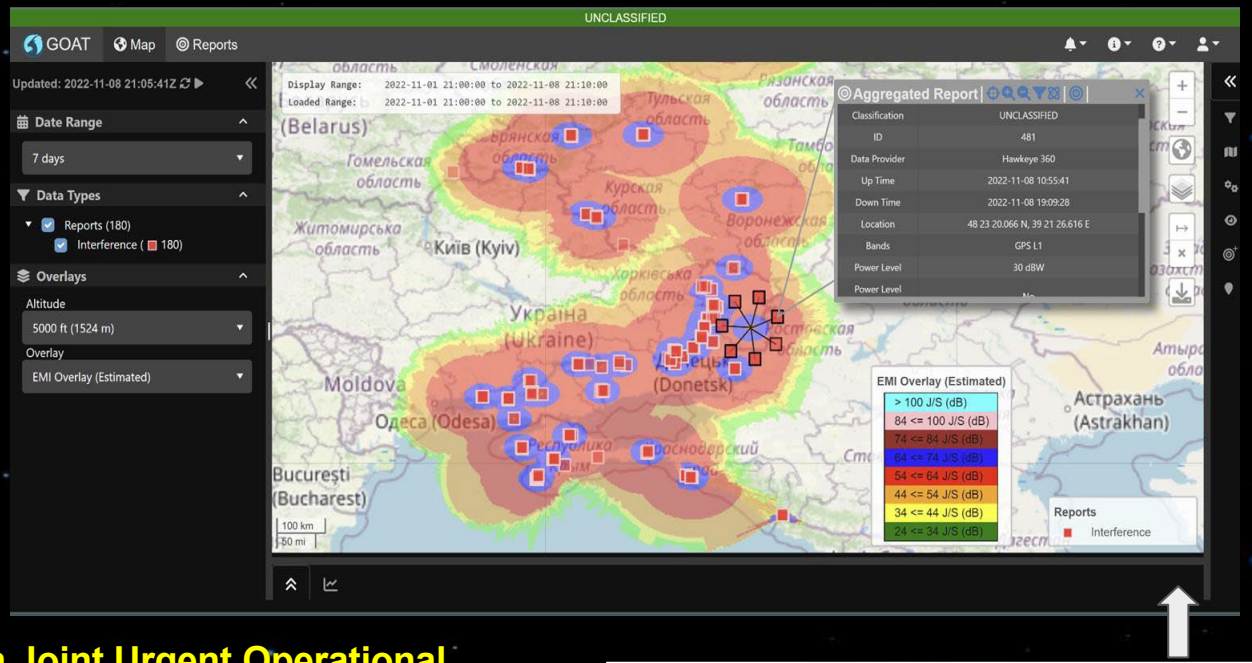




Detection Models

Exports anomaly detection; affected user heat maps, and estimated geolocation to external tool

GPS Operational Awareness Tool (GOAT)



GOAT Emerged From Joint Urgent Operational Need (JUON) CC-0575. Currently Displays:

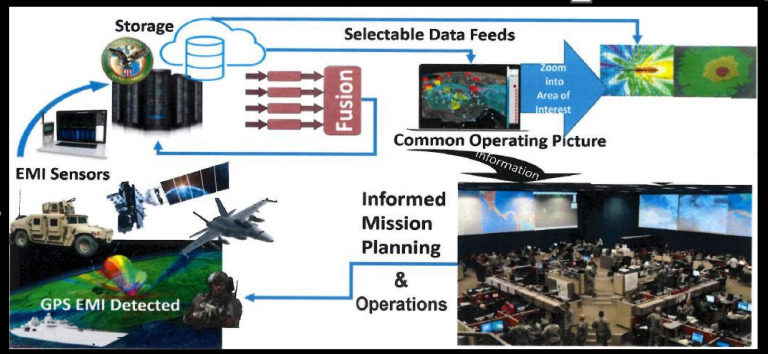
- Commercial RF sensing & geolocation of EMI
- RF propagation models at user defined altitudes

Could Ingest

- Harmonious Rook "Affected Users & Geolocation Data"

Could Enable

- Unclassified detections to COP tools
- LOS Analysis from Affected Users for JX geolocation

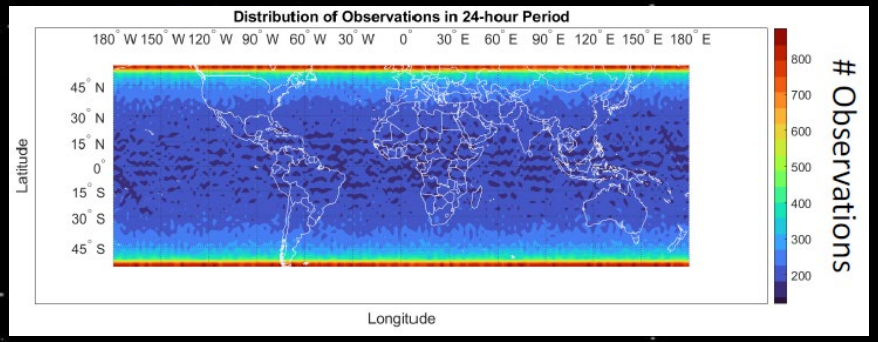


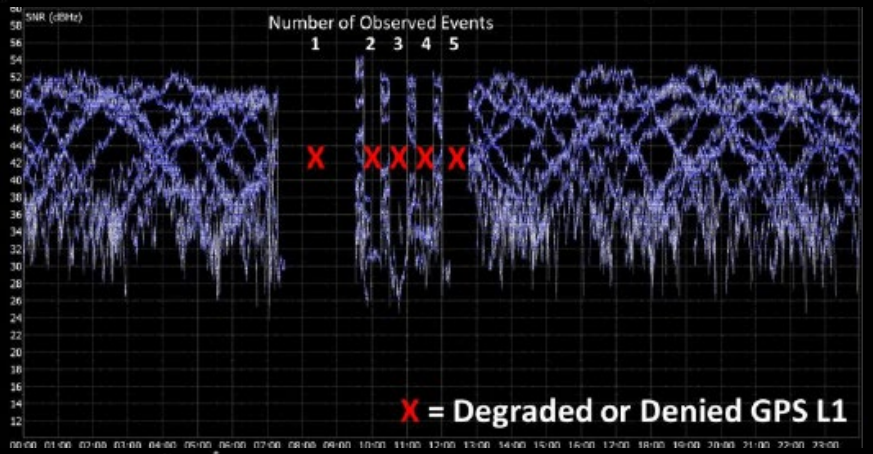
Conceptual Visualizations

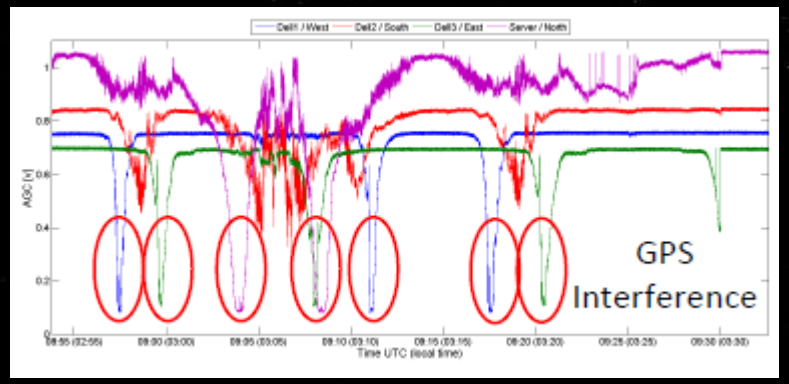
Other PNT-GNSS Interference Data Collection Activities

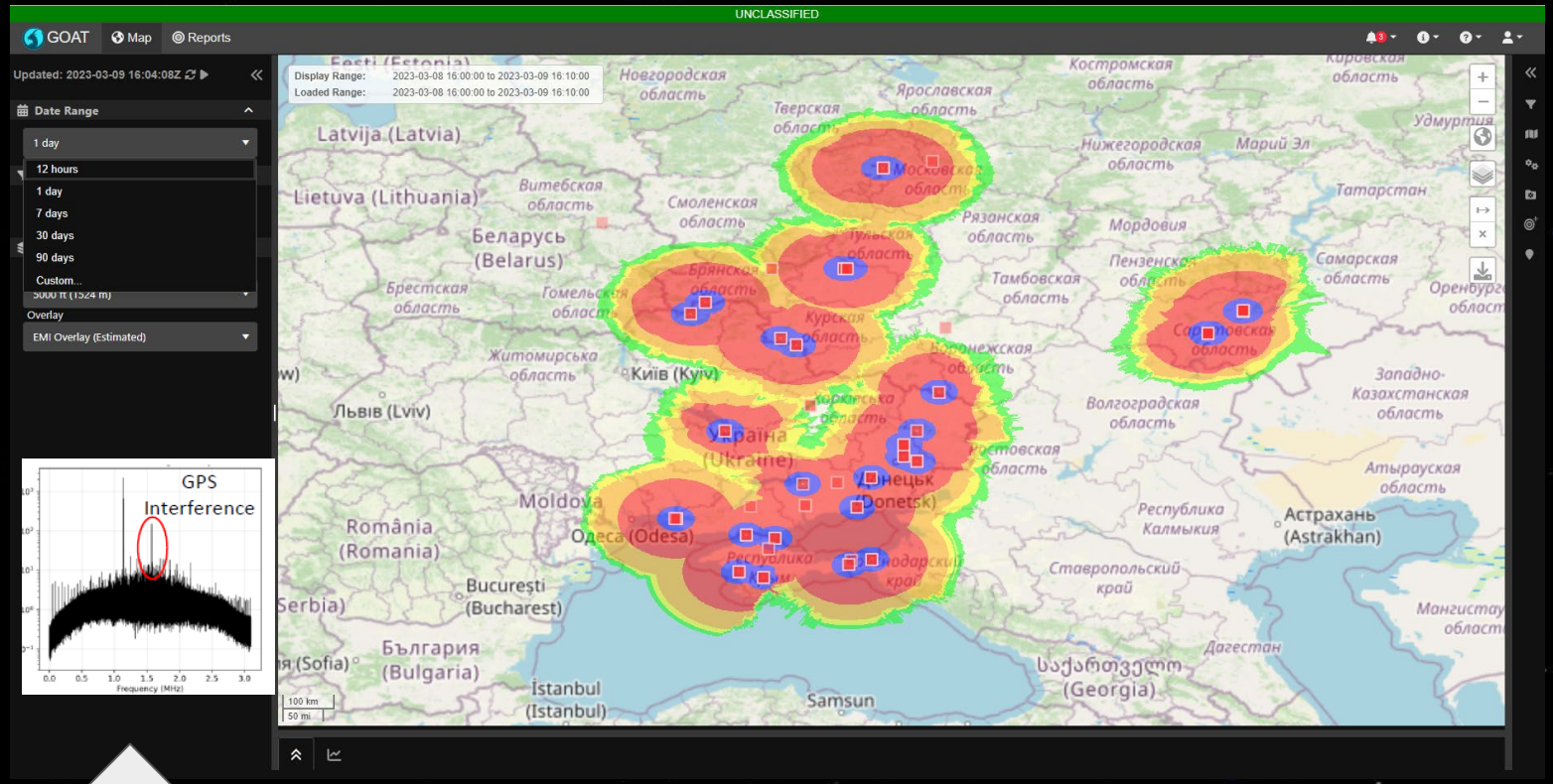
For Near Term Integration with GOAT

DEEP Collections To GOAT Visualizations



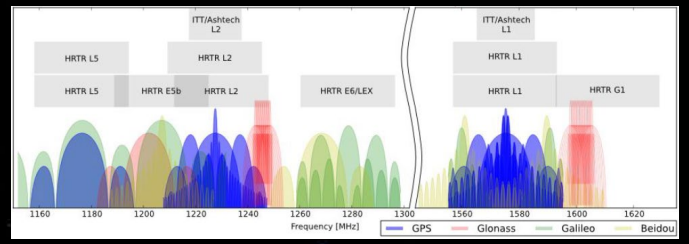


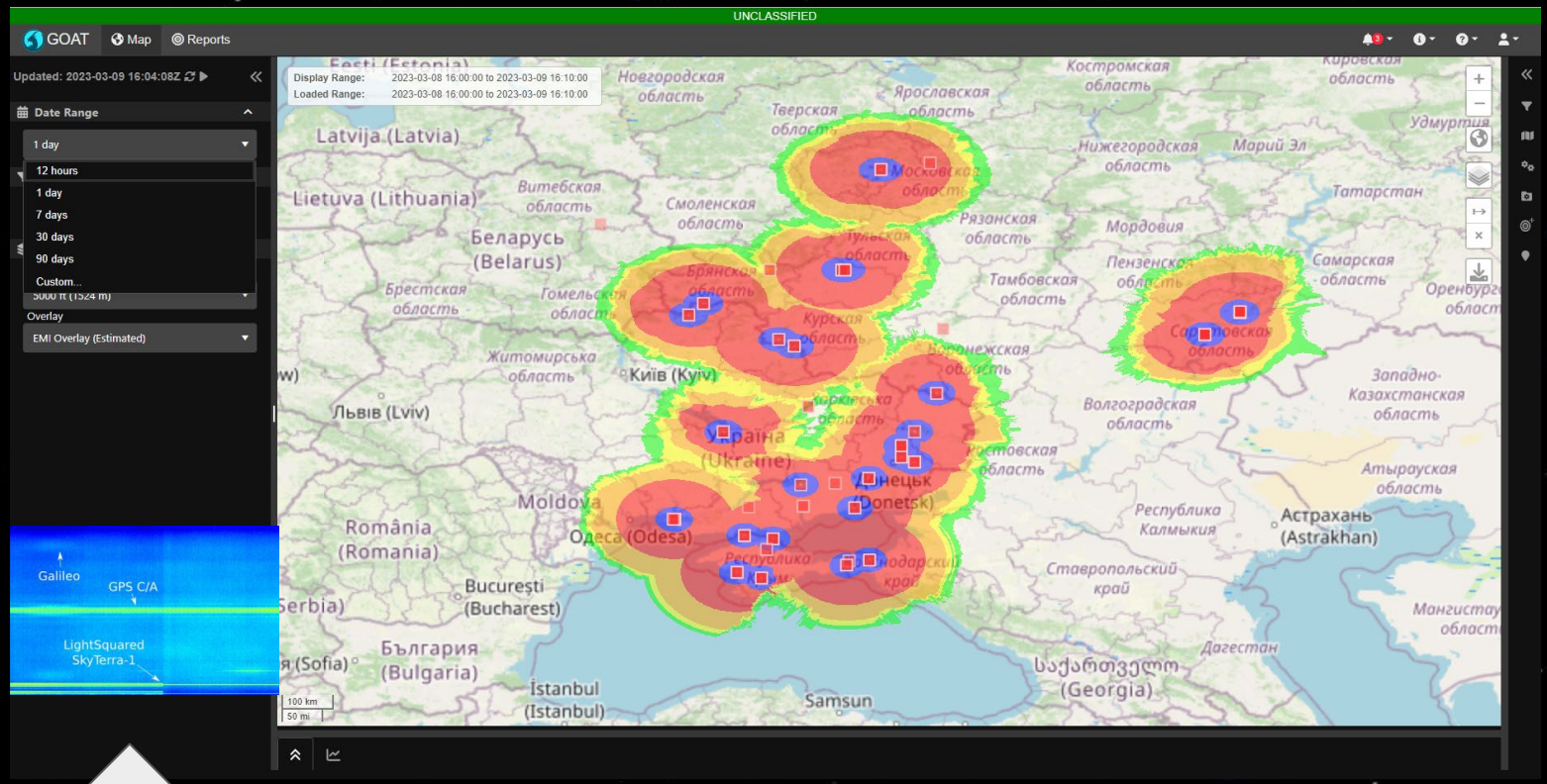




Exports Direct: monitoring physical layer or phenomena of the PNT source (e.g., electromagnetic spectrum such as RF, Doppler shift, etc.) and Indirect: monitoring derived observables or phenomena from another medium using host platform (using data from GPS aided systems to detect GPS EMI like AIS or ADS B) to GOAT Tool

NGA HRTR Collections To GOAT Visualizations





Exports Software-Defined Receiver 2 Gigasamples/s with digital Down Conversions of GNSS signals in real-time using FPGAs Supporting both traditional observations and detailed signal observations to GOAT Tool

Thank You for Your Time
Q&A