US DOT Overall PNT Strategy

Execute US Space Policy Directive - 7 Implementation Responsibilities Grouped in The Following Categories:

- Space-Based PNT Requirements for Civil Applications
- Space-Based PNT Management and Modernization for Civil Applications
- Performance Monitoring & Interference Detection for Civil Space-Based PNT Services
- PNT Resiliency
- Space-Based PNT Data and Signal Authentication
- GNSS International Engagement.
US DOT High-Level PNT IDM Strategy

- **Actively Detect and identify L-Band Interference Emissions**
  - In-Band, Adjacent and Out-of-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 IDM Present Capability Posture

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

**Technology Implementation Is Needed** = Independent Dedicated Technology for Automated Monitoring of GPS Interference Signals by Chartered Federal Interagency Partners is Required to Improve Faster Resolution Posture.
US DOT IDM Joint Concept of Operations

Known event information is reported to transportation stakeholders after being ‘operationalized’ by DOT; assessment results in notifications of appropriate activities (e.g., Surface, Aviation, Maritime, Telecom, Finance)

Space-Airborne detection to notify space-aeronautical operators of potential jamming or spoofing including Space vehicle and aircraft report generation

DOMESTIC EVENTS NETWORK (DEN)
JOINT TRAFFIC OPERATIONS COMMAND (JATOC)
NOTICES TO AIR MISSIONS (NOTAMS)

SV OBSERVABLES
Space & Aviation Segments
Automated Reports of GNSS Anomalies = SV Observables, ADS-B, Datalink, Voice for light GA non-datalink capable

Data Sets collected from multiple vehicles.
Timely processing of automated data from transport vehicle, AIS, Fixed Sites and other sources by 3rd party provides for timely notification of event-effected area

OEMs and Suppliers

Government Agencies (GA)

State Operators / Service Centers/ Internal Stakeholders

National International Stakeholder Communications

Interagency Processing Center
COP Analysis, Cyber Assessments and Impact Notification

Vessel, Vehicle & Fixed Building detection (low-cost or installed electronics) to notify users of potential jamming or spoofing including auto-alert report generation

Affected Area Heat Map

Action/advisories to Field Facilities

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Other Inputs
Other Outputs

AIS
CORS

GNSS receivers feeds from Vessels, Vehicles, Facilities Affected

GNSS receivers feeds from Space Vehicles & Aircraft Affected

(NAV/CEN) (CENTER) (TWR/TRACON)

Datalink
Voice
Sat Com

ADS-B
PIREPS

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Action/advisories to Field Facilities
US DOT-DOD Joint Harmonious Rook IDM Initiative

Initiating the Interagency Automated Processing Fusion Center

Phase I
Space & Air

GPS/GNSS Receivers
Transponder signals from existing equipment (ADS-B)

Phase II
Ground

Ground GPS Receivers
Maritime Systems Data (AIS)
Mobility Data
Other data sources

DEFENSE INNOVATION UNIT

Models Development

Data Prep
AutoML
Time Series

AIS Models
ADS-B Models

Visualizations Dash Boards

Rapid Scaling
Custom Model Development
Edge Deployments

API Integration
Interference Detection
Automated Alerting

Continuous Improvement
Interference Analytics
Historical Analysis

Analysts - Regulators - Users
**Harmonious Rook ADS-B Feed Phase I**

**Automatic**
- Messages are sent out periodically without interrogation (unlike transponder)

**Dependent**
- Position and velocity derived from the Global Positioning System (GPS)

**Surveillance**
- Primary purpose is for ATC to know where aircraft are

**Broadcast**
- Messages are broadcast to everyone not just sent to specific receiver. Many available commercially.
- 978 & 1090 MHz
ADS-B Mandate Will be Leveraged in Phase I

**ADS-B OUT**
- The ability to transmit information from the aircraft to ground stations and to other equipped aircraft
- (Required to meet mandate)

**ADS-B IN**
- The ability of the aircraft to receive information from other transmitting aircraft and the ground infrastructure
- (Not Required but most beneficial to pilots)

**Increased Safety**
- Faster update rates and position updates
- Improved last-position data for Search & Rescue

**Enhanced ATC services**
- Free Weather
Harmonious Rook ADS-B for GNSS RFI Analysis

Build the Model
- Anomaly Scores Assigned to the ADS-B Features to Each Track

Test the Model
- Known GNSS Test Events with published NOTAMs

Validation with Negative Samples
- Model Produces Significantly more Anomalies than Expected in an Area of Interest

Validate Model With Satellite RF Collection
- RF Collections Over Test Exercises to use as Ground Truth of Known Interference

<table>
<thead>
<tr>
<th>ADS-B Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nic</td>
<td>Navigation Integrity Category</td>
</tr>
<tr>
<td>rc</td>
<td>Radius of Containment, meters; a measure of position integrity</td>
</tr>
<tr>
<td>seen_pos</td>
<td>How long ago since the position was last updated</td>
</tr>
<tr>
<td>nac_baro</td>
<td>Navigation Integrity Category for Barometric Altitude</td>
</tr>
<tr>
<td>nac_p</td>
<td>Navigation Accuracy for Position</td>
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<tr>
<td>nac_v</td>
<td>Navigation Accuracy for Velocity</td>
</tr>
<tr>
<td>sil</td>
<td>Source Integrity Level</td>
</tr>
<tr>
<td>gva</td>
<td>Geometric Vertical Accuracy</td>
</tr>
<tr>
<td>ada</td>
<td>System Design Assurance</td>
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<tr>
<td>alert</td>
<td>Flight status alert bit</td>
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<tr>
<td>mlat</td>
<td>List of fields derived from MLAT data</td>
</tr>
<tr>
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</tr>
<tr>
<td>seen</td>
<td>How long ago since a message was last received from this aircraft</td>
</tr>
<tr>
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<td>Recent average RSSI (received signal strength indicator)</td>
</tr>
</tbody>
</table>
Harmonious Rook ADS-B Model Predictions

100-mile Radius Test
- Red Dots are the Center Locations of Emitter
- Black Circle 100-mile Radius Around the Emitters

Model Heatmap
- Shows the Density of ADS-B GNSS Based Anomalies

Other Data Feeds
- Additional Data Feeds to Refine Area of Interest to the Initial Model

Validation of M/L With Multiple Feeds
- Fixed Site GNSS & Timing Data Feeds
- Mobility GNSS Data Feeds
- Surface Vehicle Data Feeds
- Maritime AIS Data Feeds
Harmonious Rook AIS Feed Phase II

Automatic
• Messages are transmitted and received periodically Identifying and Monitoring Maritime Traffic

Identification
• Sending and Receiving vessel information on dedicated VHF Radio Frequencies 161.975 & 162.025 MHz. Many available commercially.
• Position and velocity from the Global Positioning System (GPS)

System
• Displaying information on a laptop computer, chart plotter, or other MFD (Multi-Function Display)
AIS IMO Mandate Will be Leveraged in Phase II

**AIS Broadcast**
- Stewardship
- Monitoring marine sanctuaries for environmental protection

**AIS Location**
- Safety
- Detailed information for collision avoidance and emergency response

**AIS Radio Call Sign**
- Security
- Accident and crime prevention through Maritime Domain Awareness

**AIS MMSI Number**
- Unique Identifier assigned to a boat, buoy, or other water-borne vessel
Harmonious Rook AIS for GNSS RFI Analysis

Build the Model
• Anomaly Scores Assigned to the AIS Features to Messages

Test the Model
• Known GNSS Test Events with published Notices to Mariners (NtM)

Validation with Negative Samples
• Model Produces Significantly more Anomalies than Expected in an Area of Interest

Validate Model With Satellite RF Collection
• RF Collections Over Test Exercises to use as Ground Truth of Known Interference
GNSS Interference in AIS Ship Tracking Data

AIS, like ADS-B, is Publicly Available
- Distributed user Protocol that is Ideal for Discovery and Analysis of GNSS Disruptions
- Workflow Infers Events Based on the Anomalies Observed in GNSS Derived Devices

Rich Dataset
- Billions of Kinematic Points that Cover the Majority of the Globe

Anomalies Detected With Analytics
- Rules Based or Machine Learning

GFW is an NGO Applying Analytics
- For Maritime Domain Operations
- Working with the USG in GNSS Disruption Situational Awareness

100+ billion GPS positions processed with GFW data pipeline
https://globalfishingwatch.org/map-and-data/
Q&A: Visit Our OST-R PNT Portal

U.S. Department of Transportation

National PNT Architecture & PNT Resiliency

The National PNT Architecture identifies recommendations to be implemented to overcome PNT capability gaps, predominantly resulting from the limitations of GPS. There are increasing occurrences of unintentional and intentional interference to GPS, including the potential for spoofing of the signal. DOT works closely with the Department of Homeland Security and Defense to increase awareness of vulnerabilities of GPS, evaluate the impact, and to research complementary avenues of PNT to enhance resiliency for safety, critical transportation applications. DOT also coordinates research on new technologies to address emerging PNT needs for applications such as autonomous vehicles, across all modes of transportation.

Increasing occurrences of unintentional and intentional interference to GPS, including spoofing of the signal, have been observed. It is important to increase awareness of vulnerabilities of GPS, evaluate the impact, and to research complementary avenues of PNT to increase resiliency and make intentional interference less desirable. Best practices should be adhered to for implementation and installation of GPS receivers in critical infrastructure applications.

Civil Global Positioning System (GPS)/PNT Leadership

- Coordinate the development of departmental positions on PNT and spectrum policy and protection from harmful radio frequency interference and operational degradation of capabilities.
- Responsible for the development of requirements for civil applications from all United States Government civil agencies and departments.
- Represent the civil agencies and departments in the development, acquisition, management, and operations of GPS.
- Provide civil PNT systems analysis and coordination, including development, development, and architectural development.
- Represent the civil agencies and departments in National Telecommunications Policy, Planning, and Analysis, via the publishing of the Federal Radio Navigation Plan.

GPS Adjacent Band Compatibility Study

The goal of the GPS Adjacent Band Compatibility Assessment Study and resultant Final Report was to evaluate the adjacent radio frequency band power levels that can be tolerated by GPS Global Navigation Satellite System (GNSS) receivers and advance the Department’s understanding of the extent to which such power levels impact devices used for transportation safety and other civil GNSS/GNSS applications. The DOT GPS Adjacent Band Study is a product of an extensive process to gather stakeholder views and input. OST-R and FAA benefited significantly from feedback received via government and public outreach on equipment use cases, interaction scenarios, propagation models, and transmitter characteristics.

For more information, please visit us at https://www.transportation.gov/pnt

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