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

10th ICG Workshop on GNSS Spectrum Protection and Interference Detection and Mitigation
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US DOT Overall PNT Strategy

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

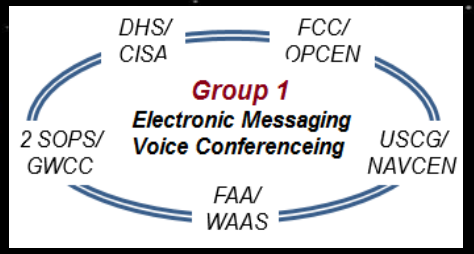
- Space-Based PNT **Requirements** for Civil Applications
- Space-Based PNT **Management and Modernization** for Civil Applications
- Performance Monitoring & **Interference Detection** for Civil Space-Based PNT Services
- PNT **Resiliency**
- Space-Based PNT **Data and Signal Authentication**
- GNSS **International Engagement**.

US DOT High-Level PNT IDM Strategy

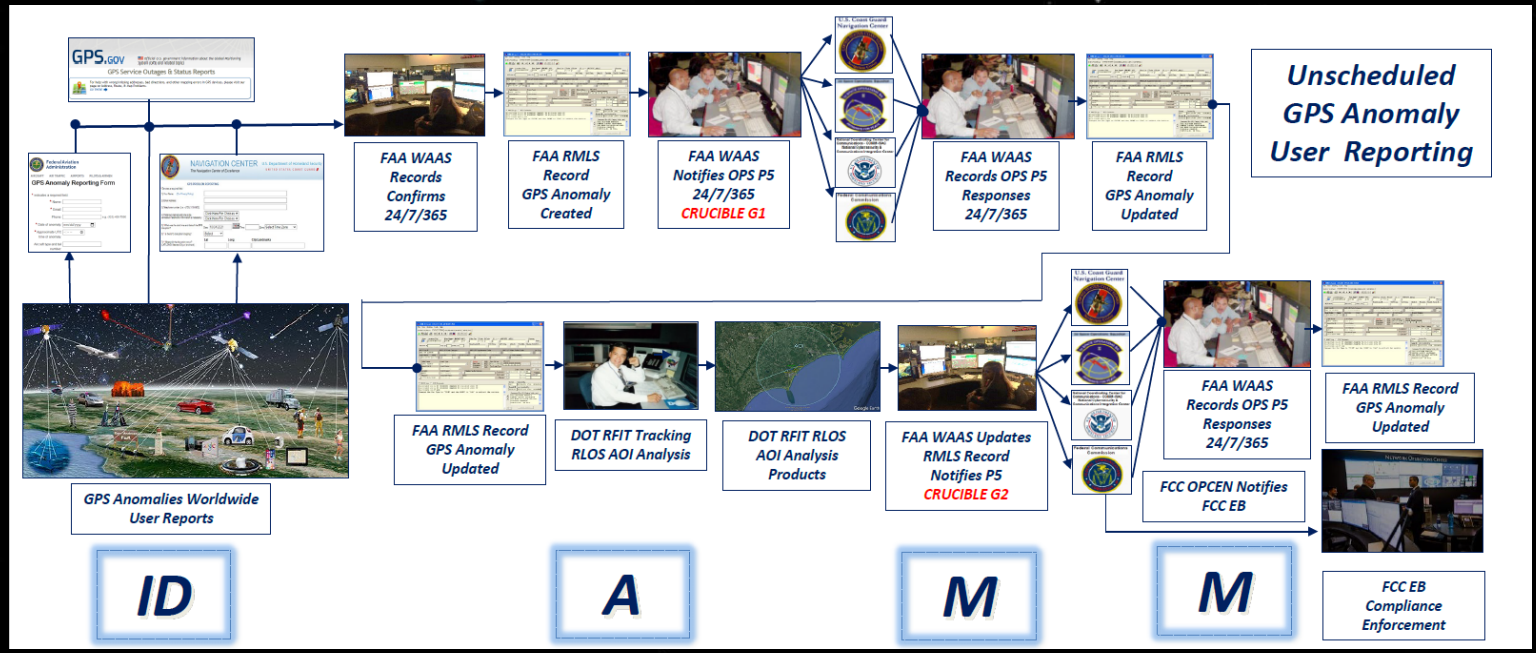
- **Actively Detect and identify L-Band Interference Emissions**
  - In-Band, Adjacent and Out-of-Band Interference
  - In partnership with other Federal Departments/Agencies
- **Leverage Space, Ground, Fixed, Transportable, and Mobile**
  - Sensor Equipment Already in Operation | System-of-Systems
  - 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

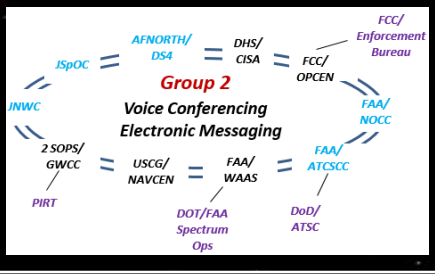
US DOT IDM Present Capability Posture

- **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.



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

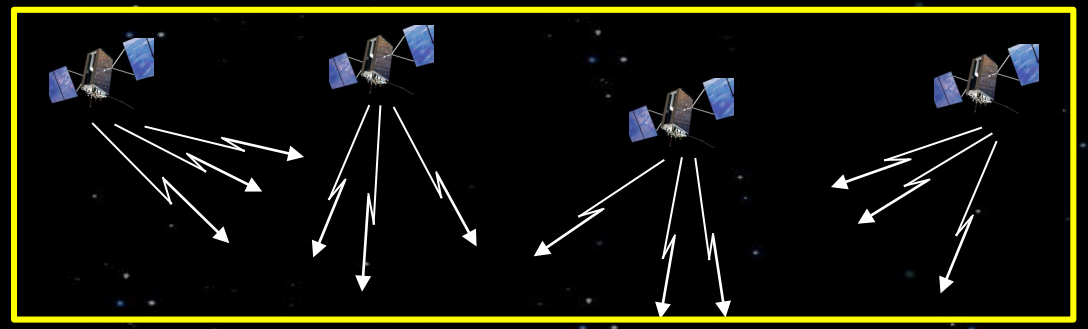




PERSISTENT - ELEVATES TO CRUCIBLE **GROUP 2** CONFERENCING AND INFORMATION SHARING BETWEEN ADDITIONAL OPERATIONS CENTERS AND SUBJECT EXPERTS

- **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

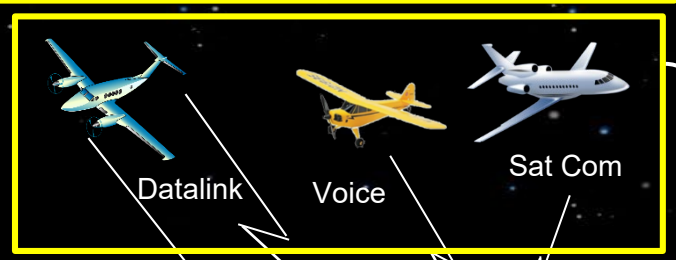


SV OBSERVABLES

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



ADS-B PIREPS

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

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)

OEMs and Suppliers

Government Agencies (GA)

State Operators / Service Centers/ Internal Stakeholders

National International Stakeholder Communications

(NAVCEN) (CENTER) (TWR/TRACON)

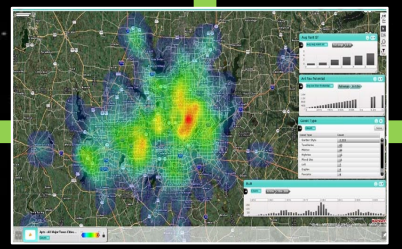
Action/advisories to Field Facilities

GNSS receivers feeds from Vessels, Vehicles, Facilities Affected

GNSS receivers feeds from Space Vehicles & Aircraft Affected

Interagency Processing Center
COP Analysis, Cyber Assessments and Impact Notification

Other Inputs Other Outputs



COP
Affected Area Heat Map

OPS COMMAND CENTERS

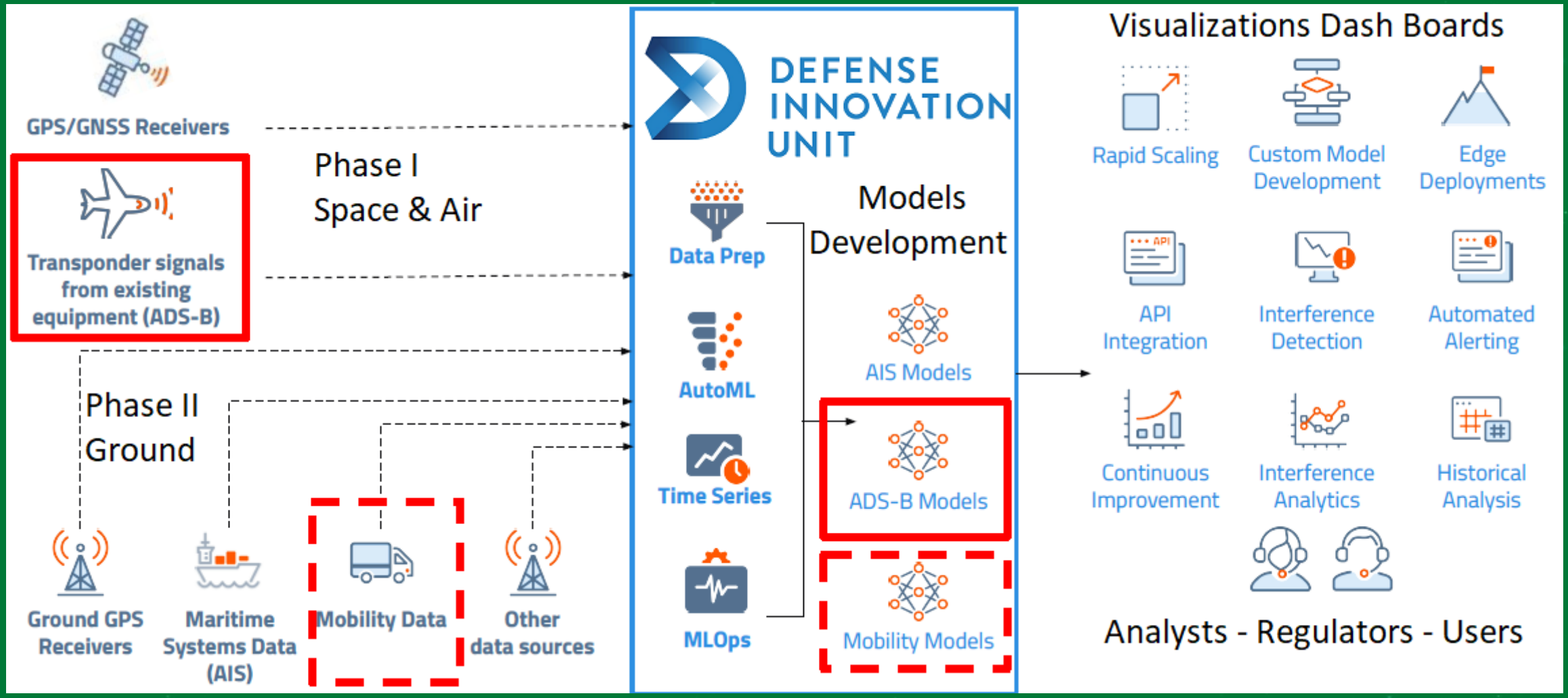
DOMESTIC EVENTS NETWORK (DEN)	JOINT TRAFFIC OPERATIONS COMMAND (JATOC)	NOTICES TO AIR MISSIONS (NOTAMS)

AIS CORS

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

US DOT-DOD Joint Harmonious Rook IDM Initiative

Initiating the Interagency Automated Processing Fusion Center



Harmonious Rook ADS-B Feed Phase I

Automatic

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

Dependent

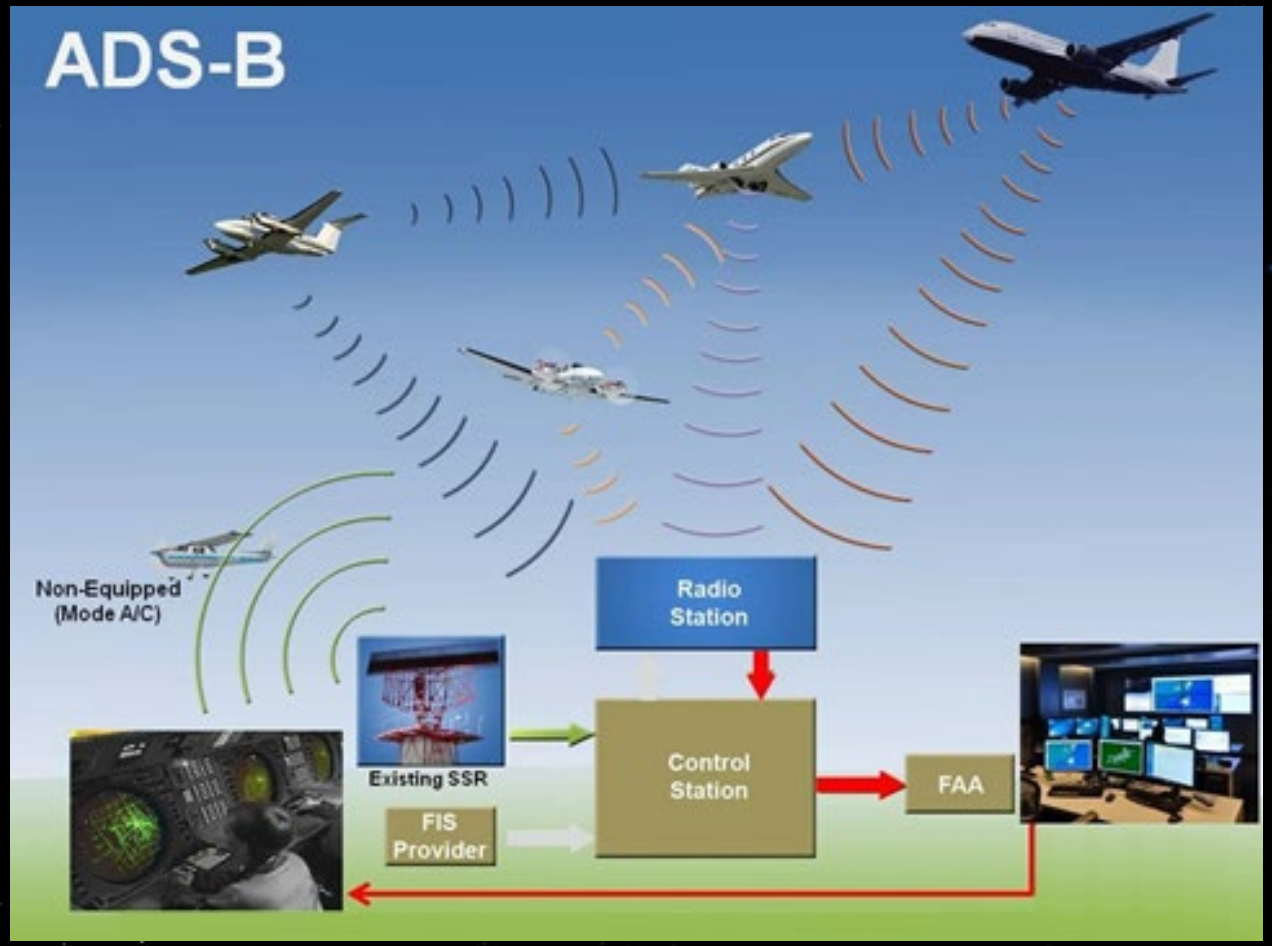
- **Position and velocity derived from the Global Positioning System (GPS)**

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

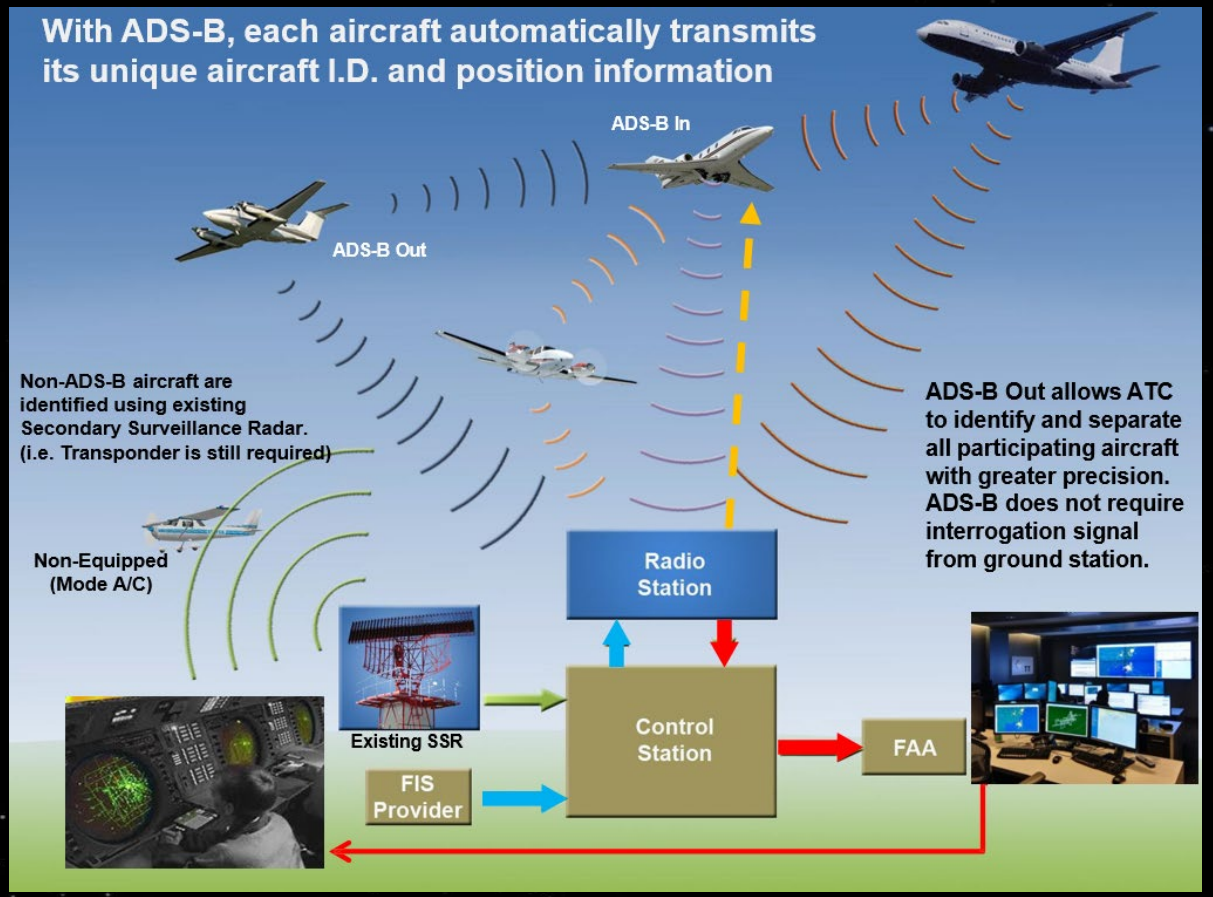
- The ability of the aircraft to receive information from other transmitting aircraft and the ground infrastructure
- (Not Required but most beneficial to pilots)

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

ADS-B Feature	Description
nic	Navigation Integrity Category
rc	Radius of Containment, meters; a measure of position integrity
seen_pos	How long ago since the position was last updated
nic_baro	Navigation Integrity Category for Barometric Altitude
nac_p	Navigation Accuracy for Position
nac_v	Navigation Accuracy for Velocity
sil	Source Integrity Level
gva	Geometric Vertical Accuracy
sda	System Design Assurance
alert	Flight status alert bit
mlat	List of fields derived from MLAT data
tisb	List of fields derived from MLAT data
seen	How long ago since a message was last received from this aircraft
rssi	Recent average RSSI (received signal strength indicator)

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

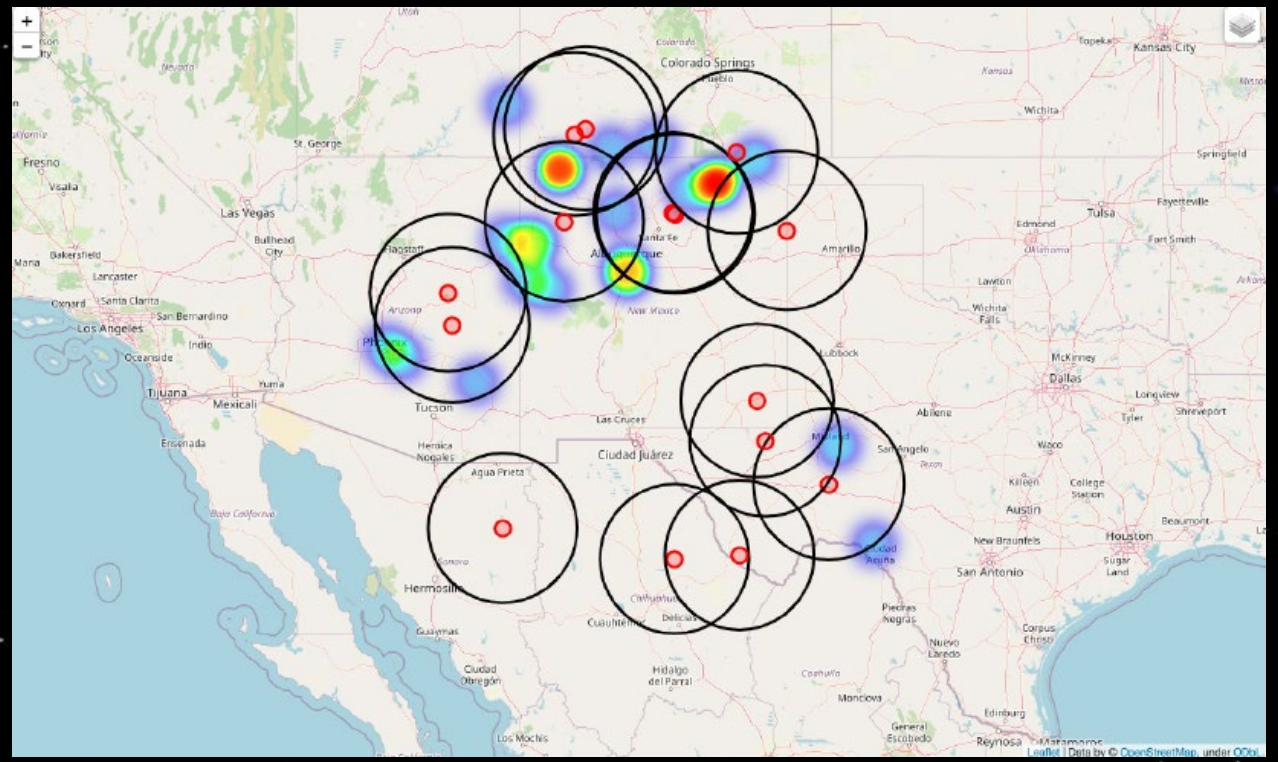
- Shows the Density of ADS-B GNSS Based Anomalies

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

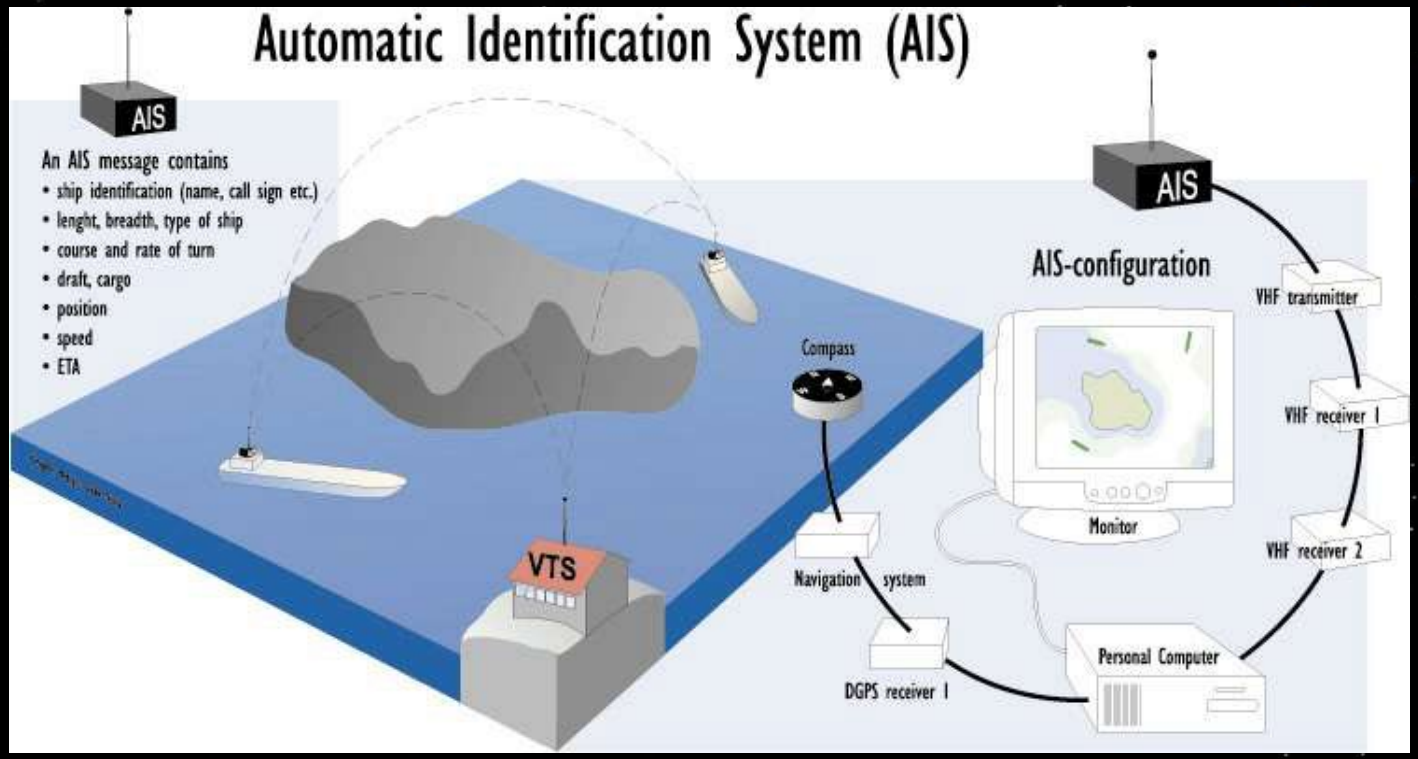
- Messages are transmitted and received periodically Identifying and Monitoring Maritime Traffic

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

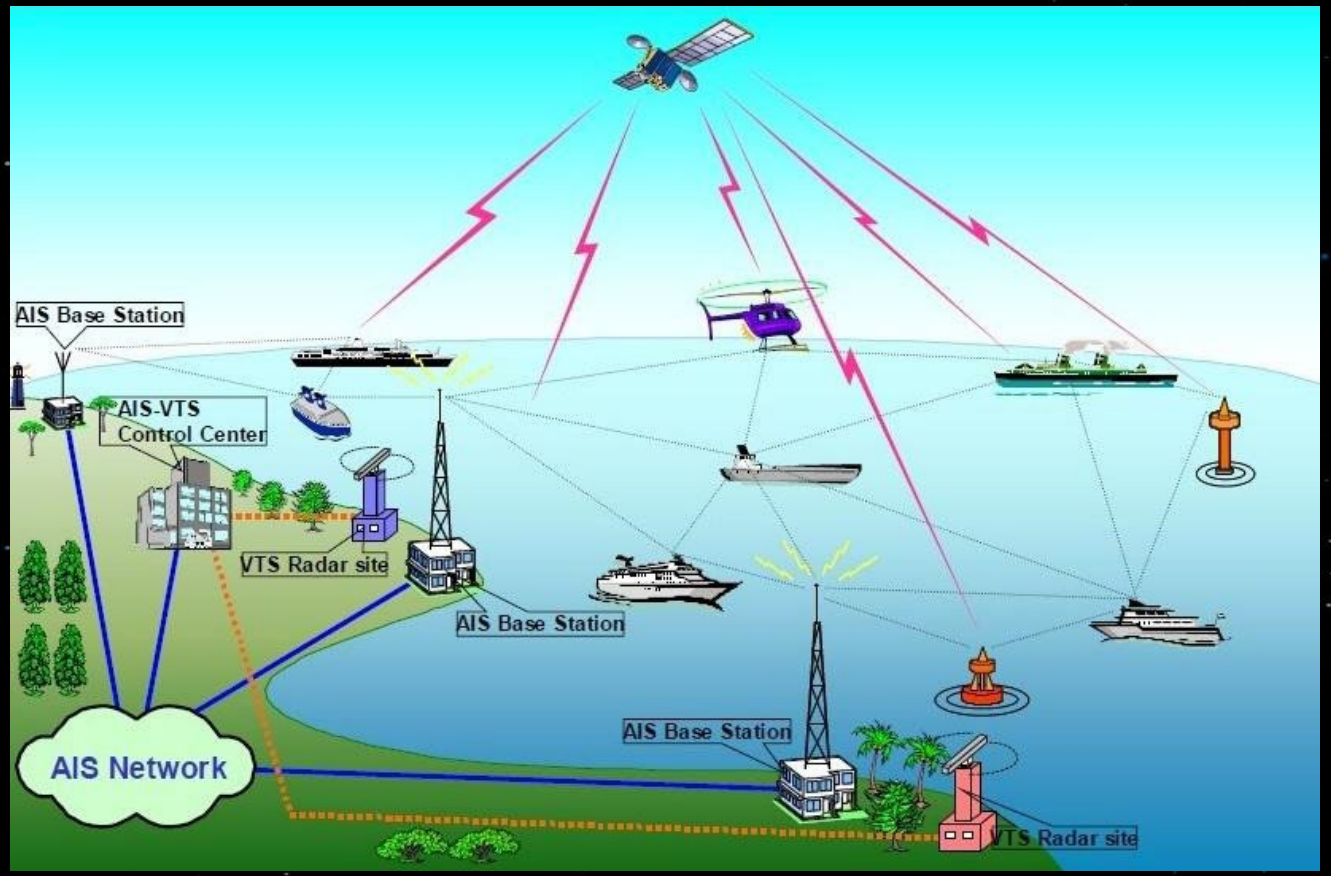
- Safety
- Detailed information for collision avoidance and emergency response

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

Class A AIS			Class B AIS	
Receive	Transmit (Msg ID)	Identifier Information	Transmit (Msg ID)	Receive
✓	1, 2, 3, 5	MMSI #	18, 19, 24A, 24B	✓
✓	1, 2, 3	Navigation Status		✓
✓	1, 2, 3	Rate of Turn		✓
✓	1, 2, 3	Speed Over Ground	18, 19	✓
✓	1, 2, 3	Position Report	18, 19	✓
✓	1, 2, 3	Course Over Ground	18, 19	✓
✓	1, 2, 3	True Heading	18, 19	✓
✓	1, 2, 3	Time Stamp	18, 19	✓
✓	5	IMO Number		✓
✓	5	Radio Call Sign	24B	✓
✓	5	Name of Ship	19, 24A	✓
✓	5	Type of Ship and Cargo Type	19, 24B	✓
✓	5	Overall Dimension/Reference for Position	19, 24B	✓
✓	5	Type of Electronic Position Fixing Device	19	✓
✓	5	Estimated Time of Arrival		✓
✓	5	Maximum Present Static Draught		✓
✓	5	Destination		✓

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

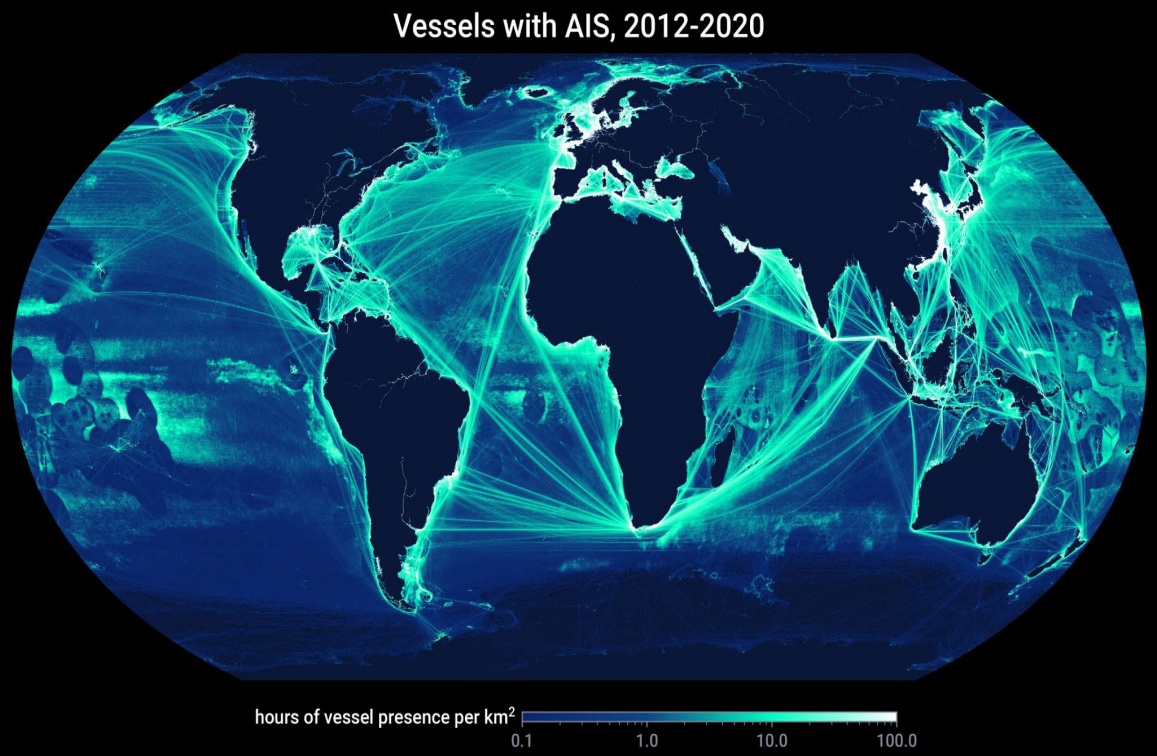
- Billions of Kinematic Points that Cover the Majority of the Globe

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/

Global Fishing Watch

Q&A: Visit Our OST-R PNT Portal

U.S. Department of Transportation

"Advancing PNT and Spectrum Policy and Research"

Positioning, Navigation and Timing (PNT) Program Overview

The Newark Catch in 2011 Hand of Aviles

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 Departments and Agencies.
- Represent the civil Departments and Agencies in the development, acquisition, management, and operations of GPS.
- Provide civil PNT systems analysis and coordination, including requirements development and architectural development.
- Represent the civil Departments and Agencies in Radionavigation Systems Policy, Planning, and Analysis via publishing of the Federal Radionavigation Plan (FRP), the official source of positioning, navigation, and timing policy and planning for the Federal Government.

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 and Global Navigation Satellite System (GNSS) receivers and to advance the Department's understanding of the extent to which such power levels impact devices used for transportation safety and other civil GPS/GNSS applications.

The DOT GPS Adjacent Band Study is the product of an extensive process to gather stakeholder views and input. OST-R and FAA benefited significantly from feedback received via governmental 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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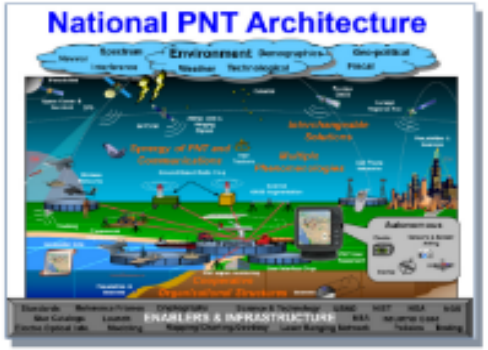
National PNT Architecture & PNT Resiliency

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 Departments of Homeland Security and Defense to increase awareness of vulnerabilities of GPS, evaluate the impact, and to research complementary sources of PNT to increase 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.

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



Civil GPS Service Interface Committee (CGSIC)

The Civil Global Positioning System Service Interface Committee (CGSIC) is the recognized worldwide forum for effective interaction between all civil GPS users and the U.S. GPS authorities. It was established and chartered to identify civil GPS user needs (e.g. navigation, timing, and positioning) and exchange information concerning GPS with the civil user community in support of DOT's civil GPS leadership role. OST-R chairs the CGSIC and the U.S. Coast Guard Navigation Center (NAVCEN) serves as Deputy Chair and Secretariat of the CGSIC.