Workshop on GPS Jamming and Spoofing in the Maritime Environment

December 3, 2020
Introductions and Welcoming Remarks

Diana Furchtgott-Roth
Deputy Assistant Secretary for Research & Technology (OST-R), U.S. DOT
Strengthening National Resilience through Responsible Use of Positioning, Navigation, and Timing Services, EO 13905

Dr. Seth Jonas
National Security Council (NSC) Representative, Executive Office of the President
Perspectives on PNT Resiliency for Transportation

Karen Van Dyke
Director, PNT and Spectrum Management OST-R, U.S. DOT
Transportation Perspectives on PNT Resiliency

Workshop on GPS Jamming and Spoofing in the Maritime Environment

December 3, 2020
Reliable Navigation is Critical to Major DOT Initiatives

Aviation – NextGen
- Reliable and accurate positioning worldwide
- Reduced delays
- More fuel-efficient routes
- Increased system capacity with enhanced safety

Intelligent Transportation Systems
- Enable crash prevention among vehicles and between vehicles and infrastructure

Rail – Positive Train Control
- Reduced probability of collisions
- Increased efficiency and capacity

Maritime
GPS/GNSS Challenged Environments

- Ionospheric Disturbances
- Underground/Indoors
- Urban Canyons
- Inaccurate/Out-of-Date Maps
- High Accuracy with Integrity
- Timely Notification of Misleading Information
Existing GPS/Global Navigation Satellite System Threats

- Jamming is intentionally produced RF waveforms that have the same effect as interference; the only difference is the intent to degrade or deny a target receiver’s operation.

- Spoofing can deny, degrade, disrupt, or deceive a receiver’s operation and can have a range of effects from incorrect outputs of PNT to receiver malfunction. The onset of these effects can be instantaneous or delayed and it is possible for effects to continue even after the spoofing has ended. Ref. DHS Report “Improving the Operation and Development of Global Positioning System (GPS) Equipment Used by Critical Infrastructure”

2018 National Science Foundation grant to University of Virginia published: ROAD TO NOWHERE — $225 GPS Spoofer can send SATNAV-guided vehicles into oncoming traffic.
FY18 NDAA GPS Backup Demonstration Status

- Awarded 11 PNT technology vendor demonstration contracts on rapid acquisition purchase orders through OST-R/Volpe Center
  - Technologies included: Terrestrial RF, Low Earth Orbit, Fiber Optic, and Map Match
- Executed three field campaigns, technology demonstration, and analysis and assessment of data
- Report to Congress currently being drafted
DOT PNT Research for Highly Automated Systems

• PNT for Automated Vehicles (AV): ITS Joint Program Office
  1. AV use cases / scenarios
  2. Determine PNT requirements for AV operations
  3. Assess GNSS and other candidate sensor technologies
  4. Analyze PNT performance of individual sensors
  5. Determine navigation performance enhancements achieved by sensor fusion

• DOT University Transportation Center: Highly Automated Transportation System Research
  - Awarded to consortium led by The Ohio State University (with UC Irvine, UT Austin, and University of Cincinnati): Center for Automated Vehicles Research with Multimodal AssurEd Navigation (CARMEN)
    • Assess PNT threat scenarios and risks to highly automated transportation systems
    • Standards, Guidelines, and Best-practices for cyber-resilient PNT systems

• OST-R Highly Automated System Safety Center of Excellence
Maritime Perspective: How positioning, navigation, and timing supports maritime applications

Kevin Kohlmann
Director, Office of Safety U.S. Maritime Administration, U.S. DOT
Maritime Perspective: How positioning, navigation, and timing supports maritime applications

Cameron Naron
Director, Office of Security, U.S. Maritime Administration, U.S. DOT
Maritime Perspective: How positioning, navigation, and timing supports maritime applications

Michael Emerson
Director, Marine Transportation Systems & Senior Arctic Policy Advisor, U.S. Coast Guard
Break

2:15 – 2:25
What happens when PNT is denied, disrupted, or manipulated in a maritime environment

Captain William Westrem
APL Maritime President Eisenhower
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Captain Richard G. Hoey
Maersk Montana
What happens when PNT is denied, disrupted, or manipulated in a maritime environment

Dana Goward
President & Director, Resilient PNT Foundation
How To Steal A Ship
GPS Vulnerability & Maritime

US DOT Research & Technology
Jamming

Seconds,
Minutes

Newark Intl EWR
Boston

Weeks +
Result 3: Durations of interference events

ALL events (450,363 events)

High Priority events (73,723 events)

Most events are very short durations
12% of ALL events are greater than 60 seconds

34% priority events are greater than 60 seconds

Some findings:
- 7191 events > 5 minutes
- 1112 events > 30 minutes
- 610 events > 60 minutes
- 5 events > 1 day
- Longest event = 5 days
Impacts Entire Supply Chain

“GPS Disruption Halts Ports, Endangers Ships” – US Coast Guard

Jammers aid auto & cargo theft
Illegal Fishing?
Disrupt Oil/Gas Surveys?
Armed Conflict
VIP Protection & Conflict
Unknown
Year-Long ocean cruise finds GPS disruption... everywhere

Figure 5. Vessel route from September 2017 to January 2018 recorded by DLR’s GNSS receiver prototype.
Low-powered GPS jammer

First indications:
- False positions, and velocities
- Autopilot may turn vessel
- But no alarms!

With a little more jammer power:
- Electronic Chart Displays
- Autopilot
- Automatic Identification System
- Differential GPS
- Satellite voice and data comms
- Maritime distress safety system

plus …
Ship’s Radar & Gyrocompass

© David Last
Spoofing – Hazardously Misleading Information
December 2011
Spoofing Demo
June 2012

University of Texas,
Austin

Prof Todd Humphreys
Spoofing Demo
June 2013

https://www.youtube.com/watch?time_continue=17&v=ctw9ECgJ8L0
Tutorial – Build Your Own GPS Spoofer
December 2015

Hackers Convention
Las Vegas
Reposition 2 RCB 90s from Kuwait to Bahrain through International Waters

January 12, 2016
January 12, 2016

Spoofing?

- Right after US/Iran nuclear agreement
- Same day as President’s last major speech to the nation
The Kremlin Eats GPS for Breakfast

Why geolocation in central Moscow has become a real headache
June 2017, M/V Atria

Images
CAPT Gurvan LE MEUR
Motor Vessel Atria
According to AIS: all ships in the area are next to each other. There were actually no radar echo there.
Black Sea Spoofing Activity
January 2016-November 2018

Unless specifically stated, the mention of any company, organization, individual, or other entity in this document or any attachments thereto does not imply the violation of any law, statute, or international agreement, and should not be construed as such.
Port of Shanghai, People’s Republic of China
Spoofing – Cost ↓ Capability ↑ Ease of use ↑

Iran, Dec 2011

UT Austin, 2012-13

Persian Gulf, Jan 2016

Las Vegas, Dec 2015

US Southern Border, Dec 2015

4 sites Russia 1,300+ ships 2016 - Present

Pokemon, July 2016

Portland, Oct 2017

All GNSS at Once June 2018

Signals & Maps, Jul 2018
Change Course 5° to right
Increase speed 2 knots
Victim makes landfall 10 hours early & 220nm away near “lightly governed” area.
What to Do?

- Protect – GPS Signals
- Toughen – Users & Equipment
- Augment – w/other signals & sources
What to Do? - Masters

• Protect –
  • Who and What is Aboard?
  • Interference detection

• Toughen –
  • Secure proximity to GPS/GNSS antennas
  • Standards, requirements, costs

• Augment –
  • Prudent mariner - “Every means available”
What to Do? - Companies

• Protect –
  • Support masters per above

• Toughen –
  • GPS receivers w/ anti-jam & anti-spoof
  • GNSS receivers using multiple constellations
  • Two antennas

• Augment –
  • Loran, eLoran, Chayka
  • Engage w/ Govts, IMO, etc.
Service Areas Approximate. Consult national authorities in UK, Saudi Arabia, Russian Federation, China, & South Korea for more information.
What to Do? - Nations

- **Protect** — GPS Signals
  - Interference detection
  - Enforcement

- **Toughen** — Users & Equipment
  - Anti-jam, anti-spoof
  - Standards, requirements, costs

- **Augment** — w/other signals & sources
  - US Govt Announcements 2008, 2015 “eLoran”
The Resilient Navigation and Timing Foundation is a 501(c)3 scientific and educational charity registered in Virginia
www.RNTFnd.org
What happens when PNT is denied, disrupted, or manipulated in a maritime environment

CAPT Michael Glander
Commanding Officer, U.S. Coast Guard Navigation Center
GPS Problem Report

USCG
FAA
DOD
FCC
DHS

MARAD
Various Intelligence Offices
MOTR (GMCC)
Other PIRT and DOD Stakeholders
International Partners as appropriate

Resolution
Assistance
Warning / awareness
Catalogue, publish, and study
GPS Problem Reports Received by the USCG Navigation Center in 2020

- **Insufficient Information**: 23
- **User Equipment**: 13
- **Unknown Interference**: 21
- **ICD Violation**: 3
- **Mapping Issue**: 2

**62 Total GPS Problem Reports**

**Unknown Interference**

**OCONUS (17)**
- Maritime (16)
  - Egypt (5)
  - Mediterranean Sea (2)
  - Italy (2)
  - Persian Gulf (2)
  - Malta/Libya
  - Brazil
  - Lebanon
  - Cyprus
  - Black Sea
- Land (1)
  - Dubai

**CONUS (4)**
- Maritime (1)
  - Atlantic Beach, FL
  - Land (3)
  - Gibsonton, FL
  - Rehoboth, MA
  - Nashua, NH
GPS Problem Reports Received by the USCG Navigation Center in 2019

91 Total GPS Problem Reports

- Insufficient Information, 2
- ICD Violation, 3
- Mapping Issue, 5

- User Equipment, 39
- Unknown Interference, 42

17 appeared related to Week Number Rollover

Unknown Interference

OCONUS (34)
- Maritime (31)
  - Egypt (10)
  - Malta/Libya (9)
  - China (5)
  - Yemen
  - Lebanon
  - Ukraine
  - Cyprus
  - Greece
  - Italy
  - Brazil
  - Land (3)
  - Germany
  - Spain
  - India

CONUS (8)
- Maritime (5)
  - Mobile, AL (4)
  - Pensacola, FL
  - Land (3)
  - Abilene, TX
  - Carson City, NV
  - Puerto Rico
Options to reduce operational impact and increase PNT resiliency

Cameron Naron
Director, Office of Security, U.S. Maritime Administration, U.S. DOT
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Captain William Westrem
APL Maritime President Eisenhower
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Maersk Montana
Options to reduce operational impact and increase PNT resiliency

Dr. Andrew Hansen
OST-R/ Volpe Center Complementary PNT and GPS Backup Technologies Demonstration Team Representative
Complementary PNT Technology Considerations for Resilient PNT Service

Dr. Andrew Hansen

GPS Jam/Spoof in Maritime Environment
21 Aug 2020

U.S. Department of Transportation
Volpe Center

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Resilient PNT Services for Critical Infrastructure

Support to DOT on Resilient PNT Service

- Recent work on GPS Backup through FY17 & FY18 NDAAAs and the NTRSA (2018)
- Emerging work on Responsible Use of PNT through EO 13905 (2020)

Focused Technical Work

- Sector Specific Agency PNT Profiles, DOT/MARAD pilot program, (EO 13905)
- PNT standards, safety critical requirements, and testing/monitoring development (IMO, ICAO, RTCM/RTCA, EUROCAE, EUROCONTROL, SAE, IEEE, 3GPP)
- GPS Backup and Complementary PNT Technology Demonstration (FY18 NDAA)
Complementary PNT for Increased Resiliency

Gathered Input from Government and Commercial Stakeholders

- DOT Operating Administrations, DHS, DOC, DOI, DoD
- PNT and telecommunications service provider roundtables

Demonstrated Broad Swath of PNT Technologies at High Technical Readiness

- Technical Readiness Level (TRL) of 6 or higher, many already in revenue service
- Mix of 9 use case scenarios on timing (5) and positioning (4)
- Field campaign at two sites (NASA Langley, Joint Base Cape Cod)
- Spectrum diversity, geographic distribution, e.g. terrestrial and orbital transmitters
- Considered both interoperability (efficiency) and independence (resiliency) functions
## DOT Complementary PNT Demonstration

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Technology</th>
<th>Site</th>
<th>Timing Scenarios</th>
<th>Positioning Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo Ridge LLC</td>
<td>LEO commercial S-band (2483.5 - 2500 MHz)</td>
<td>LaRC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hellen Systems, LLC</td>
<td>eLORAN terrestrial RF (90-110 kHz)</td>
<td>JBCC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>NextNav LLC</td>
<td>UHF terrestrial RF (920-928 MHz)</td>
<td>LaRC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>OPNT B.V.</td>
<td>fiber optic time service (white rabbit PTP)</td>
<td>LaRC</td>
<td>X</td>
<td>N/A</td>
</tr>
<tr>
<td>PhasorLab Inc.</td>
<td>802.11 terrestrial RF (2.4 GHz)</td>
<td>JBCC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Satelles, Inc.</td>
<td>LEO commercial L-band (1616 - 1626.5 MHz)</td>
<td>JBCC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Serco Inc.</td>
<td>R-mode terrestrial RF (283.5 - 325 kHz)</td>
<td>JBCC</td>
<td>N/A</td>
<td>X</td>
</tr>
<tr>
<td>Seven Solutions S.L.</td>
<td>fiber optic time transfer (white rabbit PTP)</td>
<td>LaRC</td>
<td>X</td>
<td>N/A</td>
</tr>
<tr>
<td>Skyhook Wireless, Inc.</td>
<td>802.11 terrestrial RF (900 MHz, 2.4 &amp; 5 GHz)</td>
<td>LaRC</td>
<td>N/A</td>
<td>X</td>
</tr>
<tr>
<td>TRX Systems, Inc.</td>
<td>UWB &amp; IMU map matching (3.1 - 5 GHz)</td>
<td>LaRC</td>
<td>N/A</td>
<td>X</td>
</tr>
<tr>
<td>UrsaNav Inc.</td>
<td>eLORAN terrestrial RF (90 - 110 kHz)</td>
<td>JBCC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>GPS (SPS PS)</td>
<td>MEO government L-band (1575, 1227, 1176 MHz)</td>
<td>All</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*static holds only

Key: N/A Technology incompatible with scenario definition
Contact Information

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andrew.hansen@dot.gov
Questions, Discussion, Next Steps
Thank you for attending!