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

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

Department of Transportation
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Transportation Perspectives on PNT Resiliency

Workshop on GPS Jamming and Spoofing in the Maritime Environment

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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

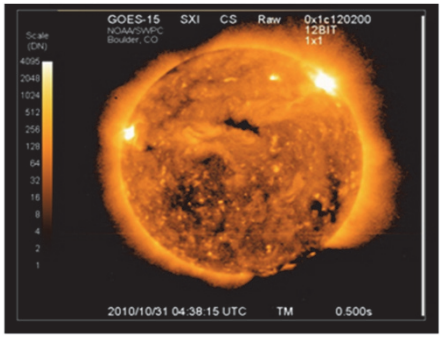
Rail – Positive Train Control

- Reduced probability of collisions
- Increased efficiency and capacity

Maritime

GPS/GNSS Challenged Environments

Ionospheric Disturbances



High Accuracy with Integrity

Timely Notification of Misleading Information

Underground/Indoors

Urban Canyons

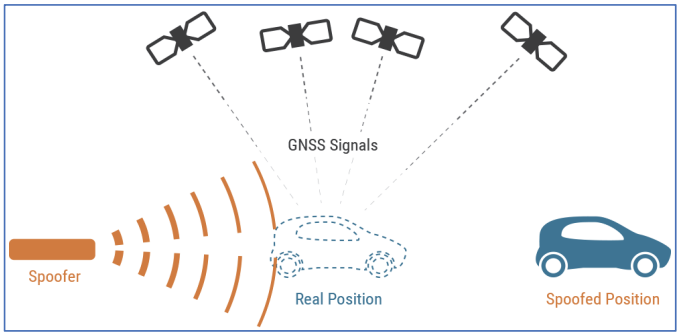
Inaccurate/Out-of-Date Maps

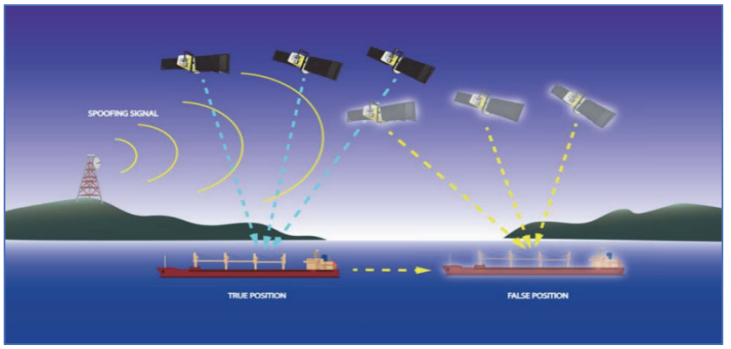
7

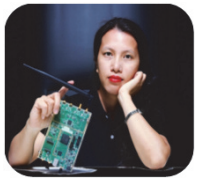
Existing GPS/Global Navigation Satellite System Threats

- 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

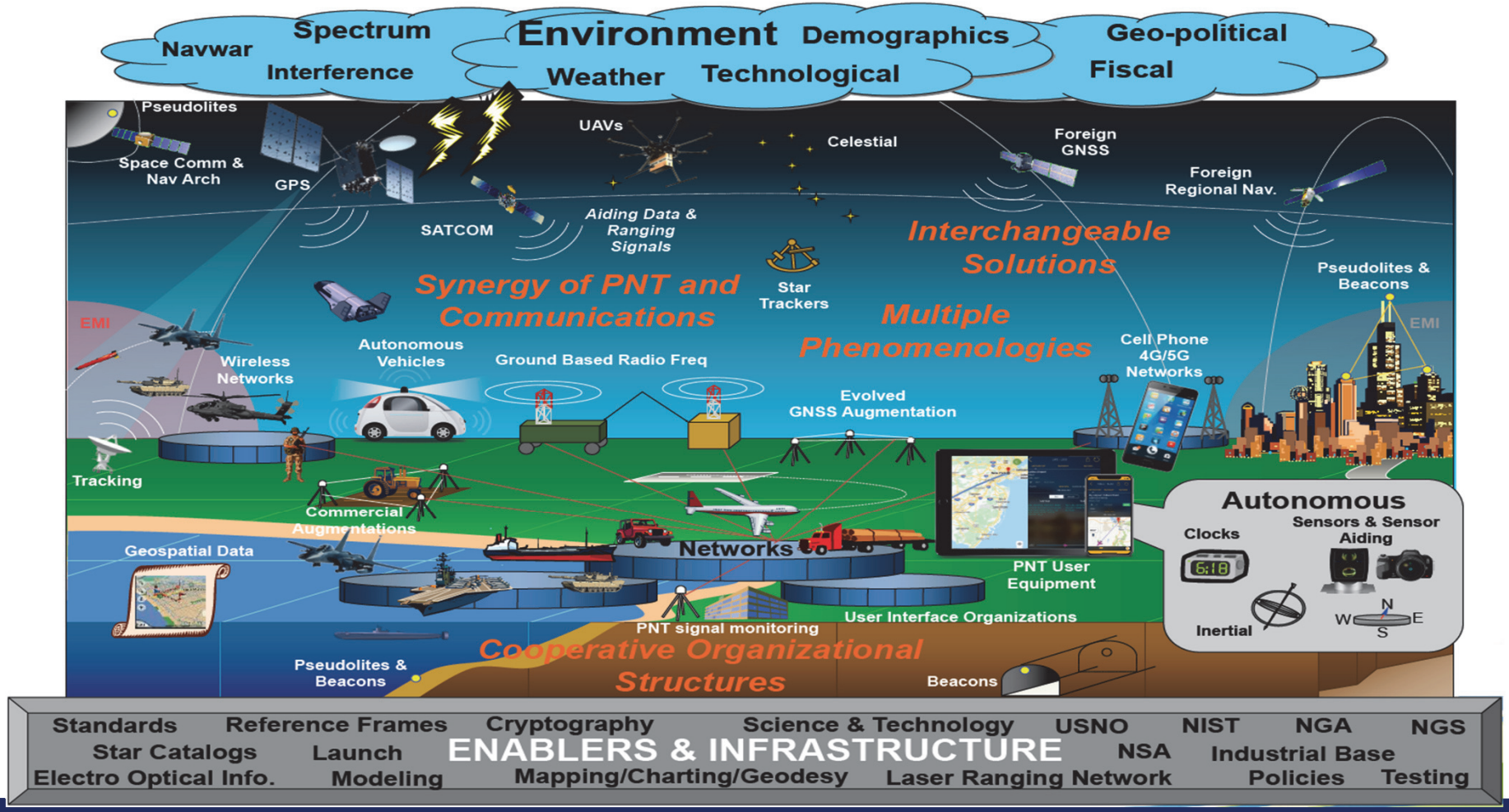
- Awarded 11 PNT technology vendor demonstration contracts on rapid acquisition purchase orders through OST-R/Volpe Center
  - Technologies included: Terrestrial RF, Low Earth Orbit, Fiber Optic, and Map Match
- Executed three field campaigns, technology demonstration, and analysis and assessment of 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**

National PNT Architecture



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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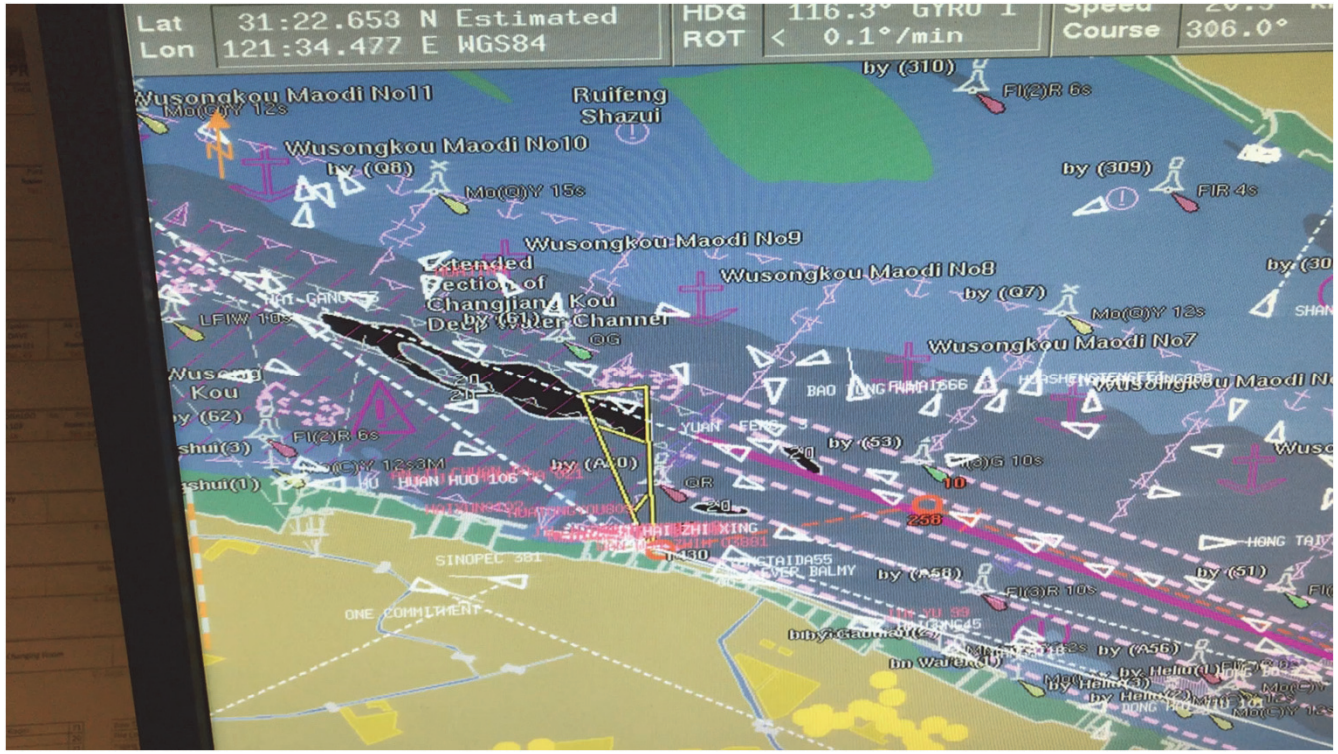

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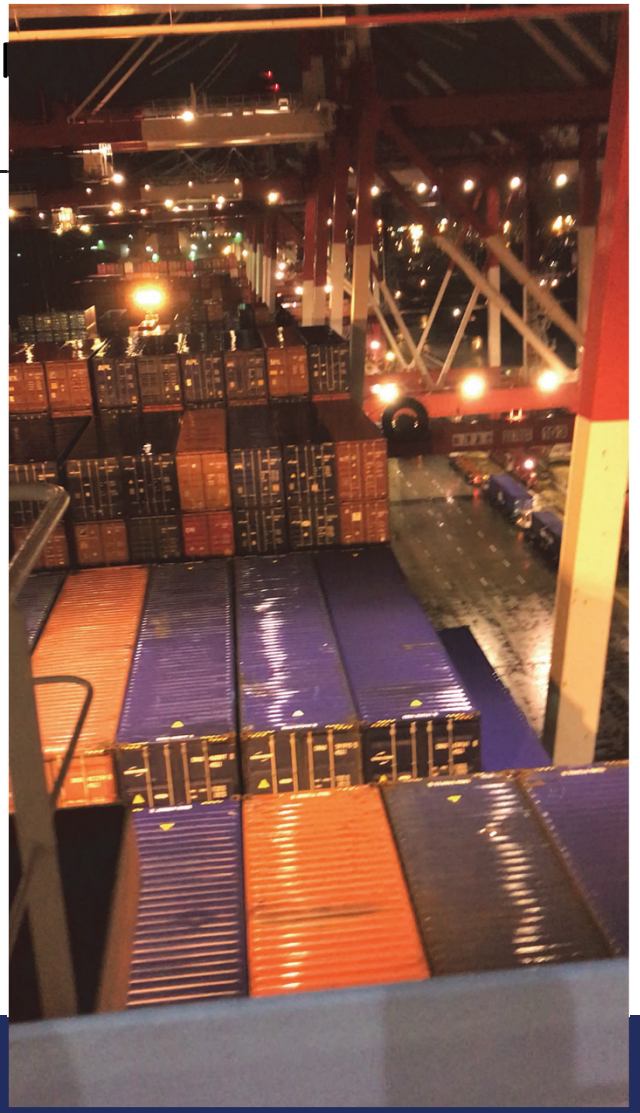

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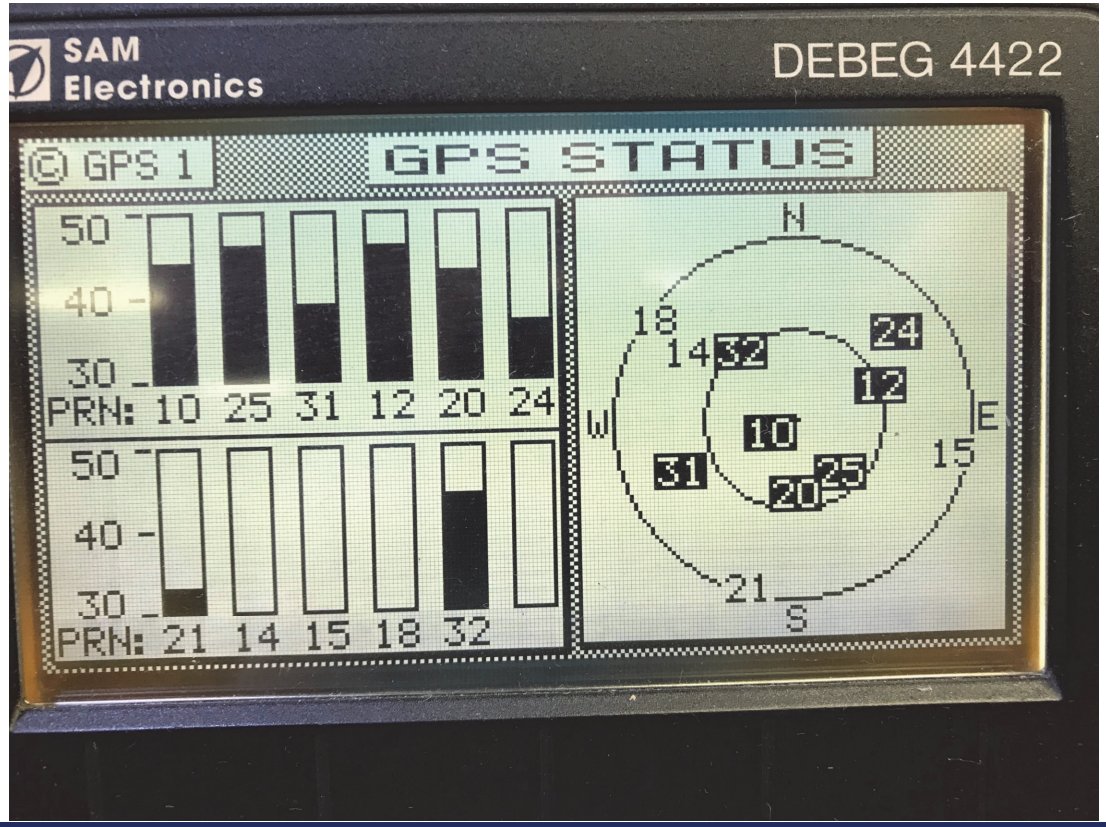

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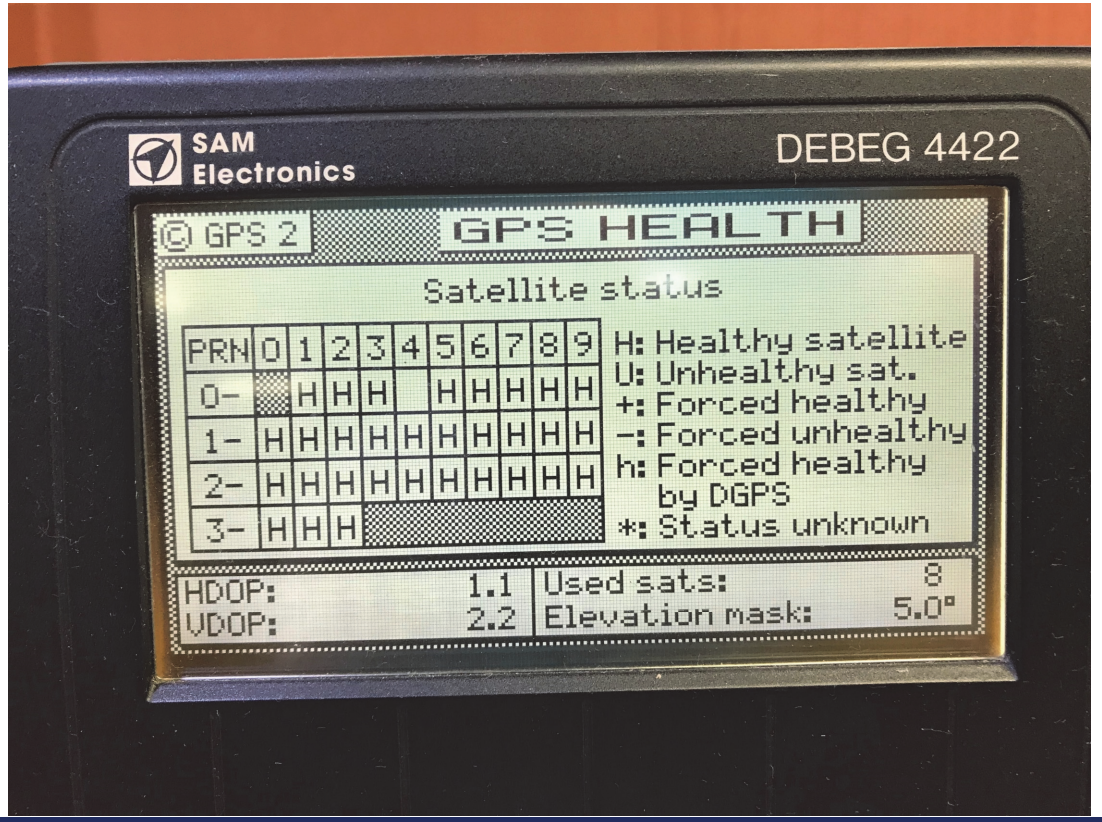

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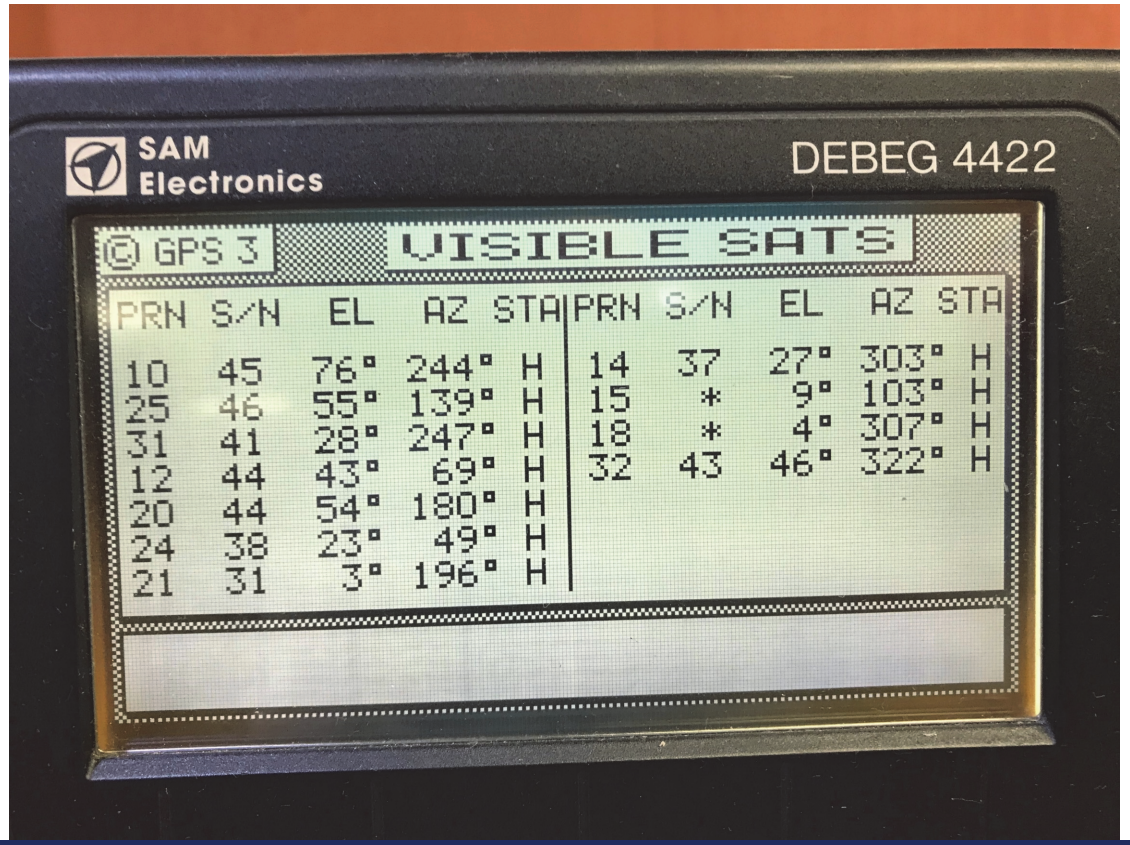


What happens when PNT is denied, disrupted, or manipulated in a maritime environment

Captain William Westrem
APL Maritime *President Eisenhower*

What happens when PNT is denied, disrupted, or manipulated in a maritime environment

Captain Richard G. Hoey

Maersk *Montana*

What happens when PNT is denied, disrupted, or manipulated in a maritime environment

Dana Goward

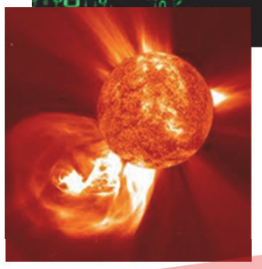
President & Director, Resilient PNT Foundation

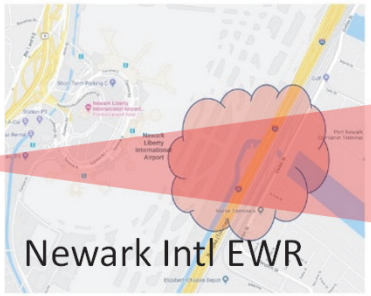
How To Steal A Ship

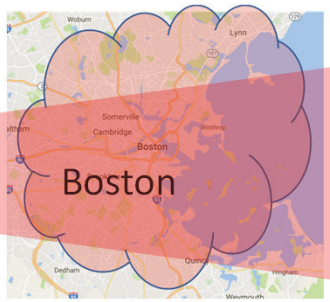
GPS Vulnerability & Maritime

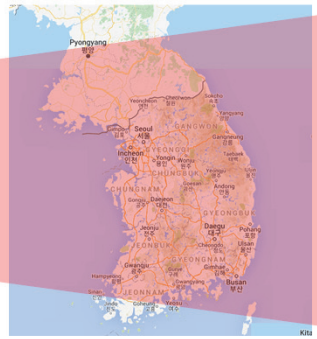
US DOT Research & Technology

Jamming









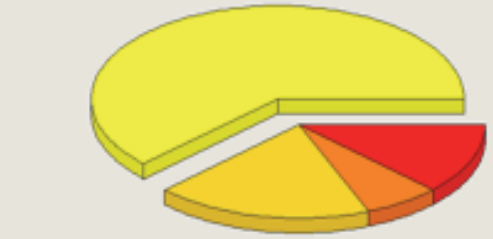
Seconds,
Minutes

Weeks +

STRIKE3

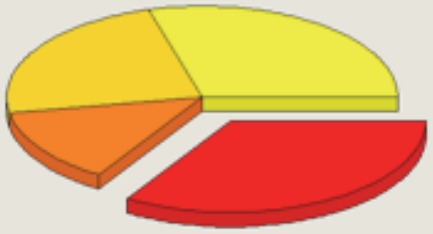
Result 3: Durations of interference events

ALL events (450,363 events)



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

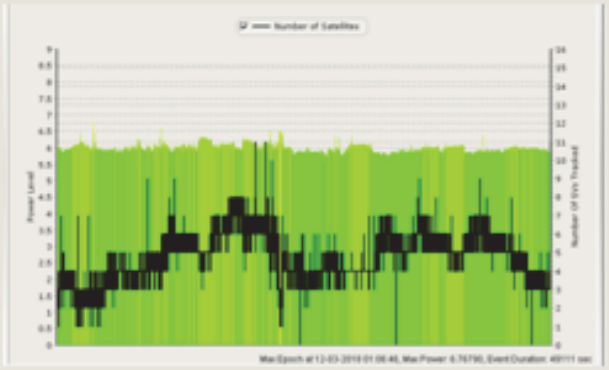
High Priority events (73,723 events)



34% priority events are greater than 60 seconds

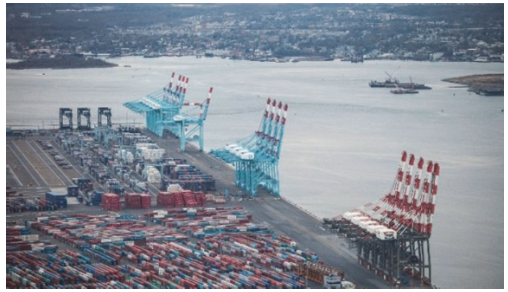
Some findings:

- 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



ammers aid auto & cargo theft

Maritime Jamming Reports

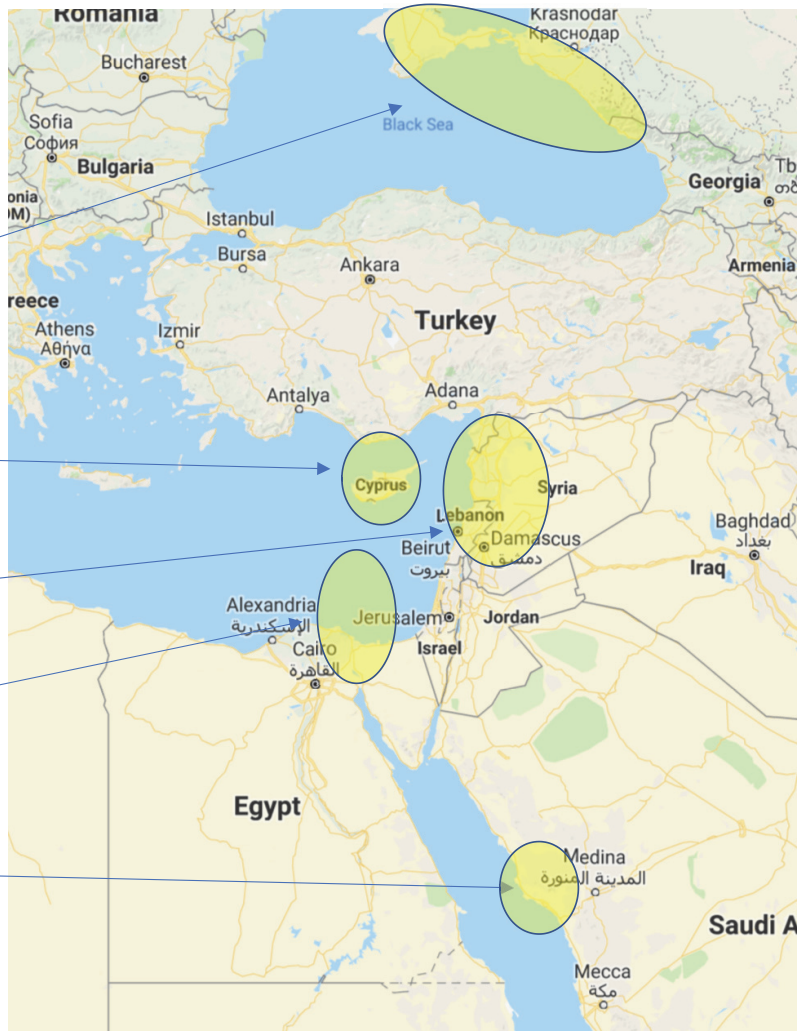
VIP Protection & Conflict

Disrupt Oil/Gas Surveys?

Armed Conflict

Illegal Fishing?

Unknown



GPS WORLD
GNSS POSITION NAVIGATION TIMING

13 March 2019

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

THV *Galatea*

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

Spoofing – Hazardously Misleading Information

December 2011

Spoofing Demo

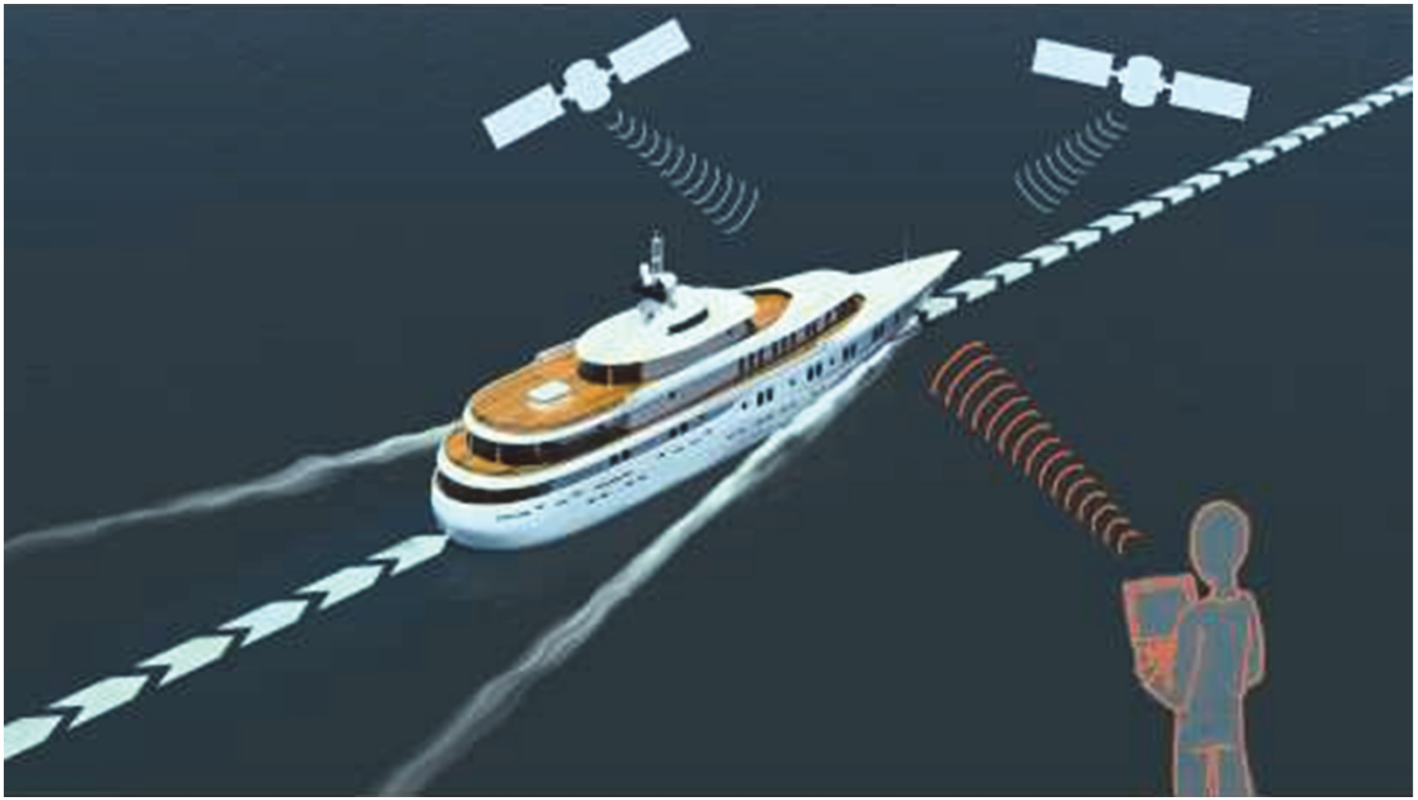
June 2012

University of Texas, Austin

Prof Todd Humphreys

Spoofing Demo

June 2013

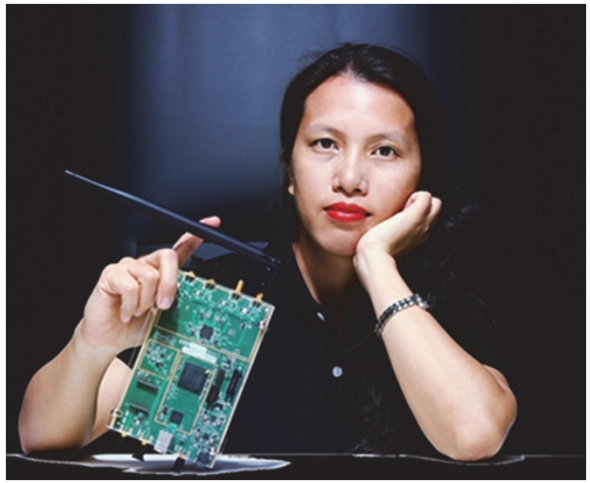


https://www.youtube.com/watch?time_continue=17&v=ctw9ECgJ8L0

Tutorial – Build Your Own GPS Spoofer

December 2015

Hackers Convention
Las Vegas



January 12, 2016

Reposition 2 RCB 90s from Kuwait to Bahrain through International Waters

January 12, 2016

Spoofing?

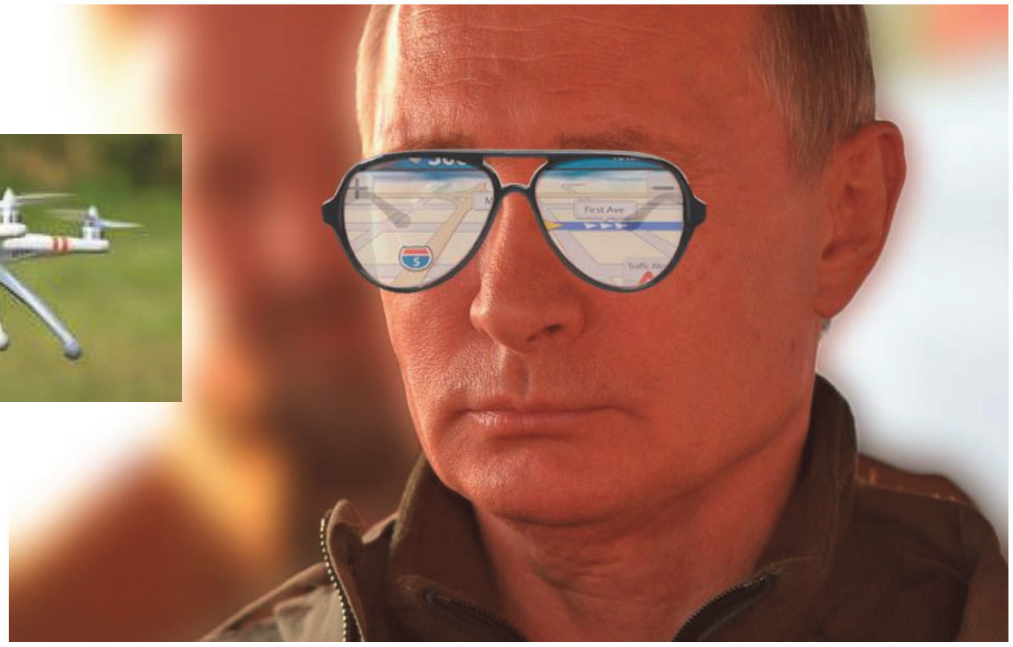
- Right after US/Iran nuclear agreement
- Same day as President's last major speech to the nation

The Moscow Times

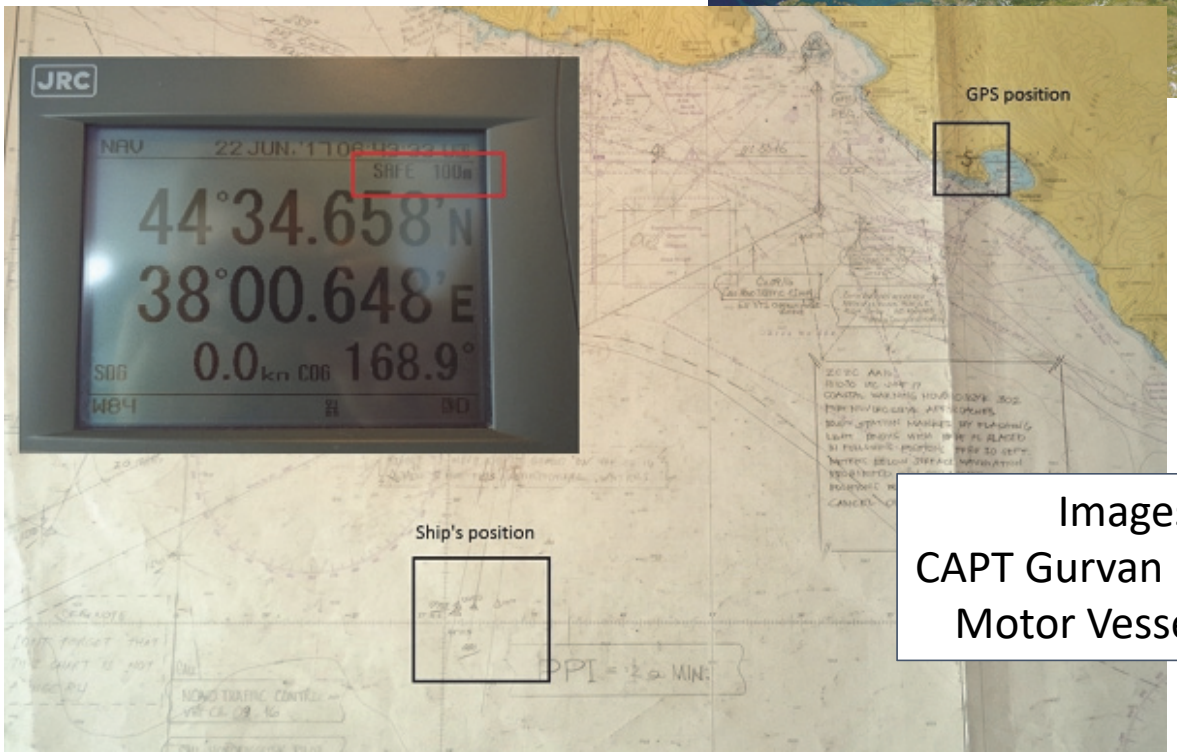
Oct. 21 2016 - 03:10

The Kremlin Eats GPS for Breakfast

Why geolocation in central Moscow has become a real headache



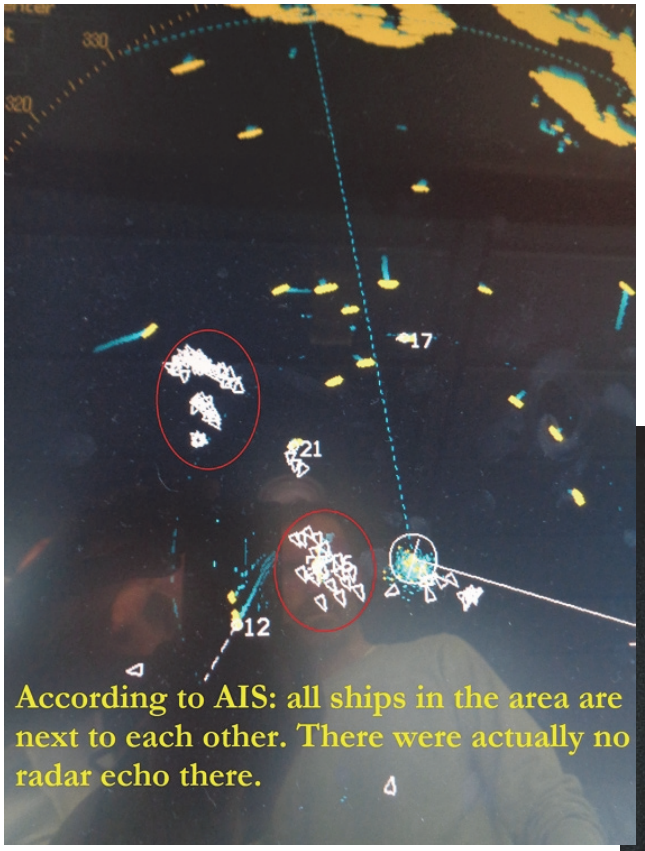
June 2017, M/V Atria

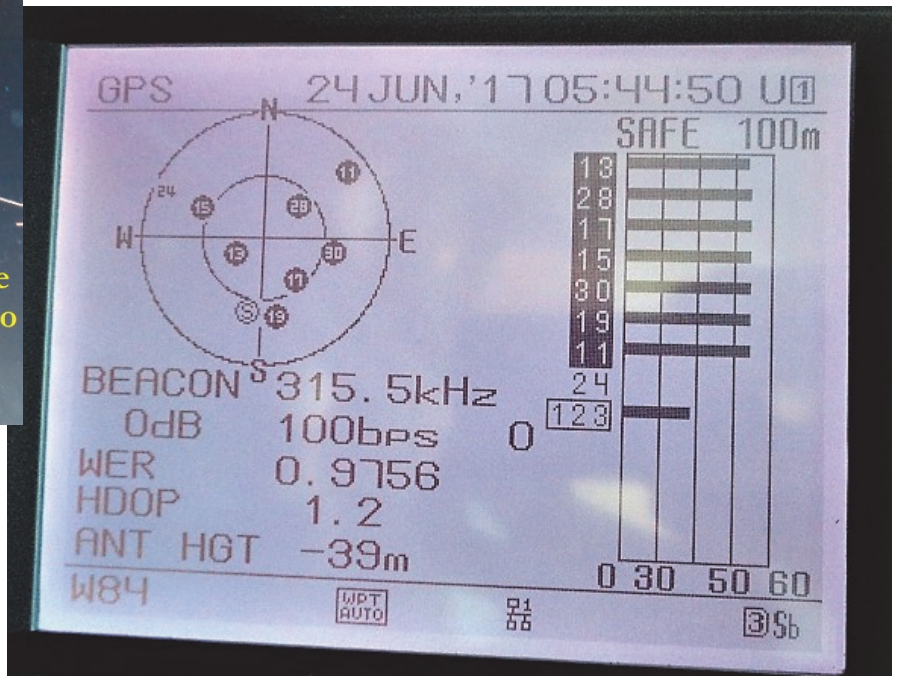


Images
CAPT Gurvan LE MEUR
Motor Vessel Atria

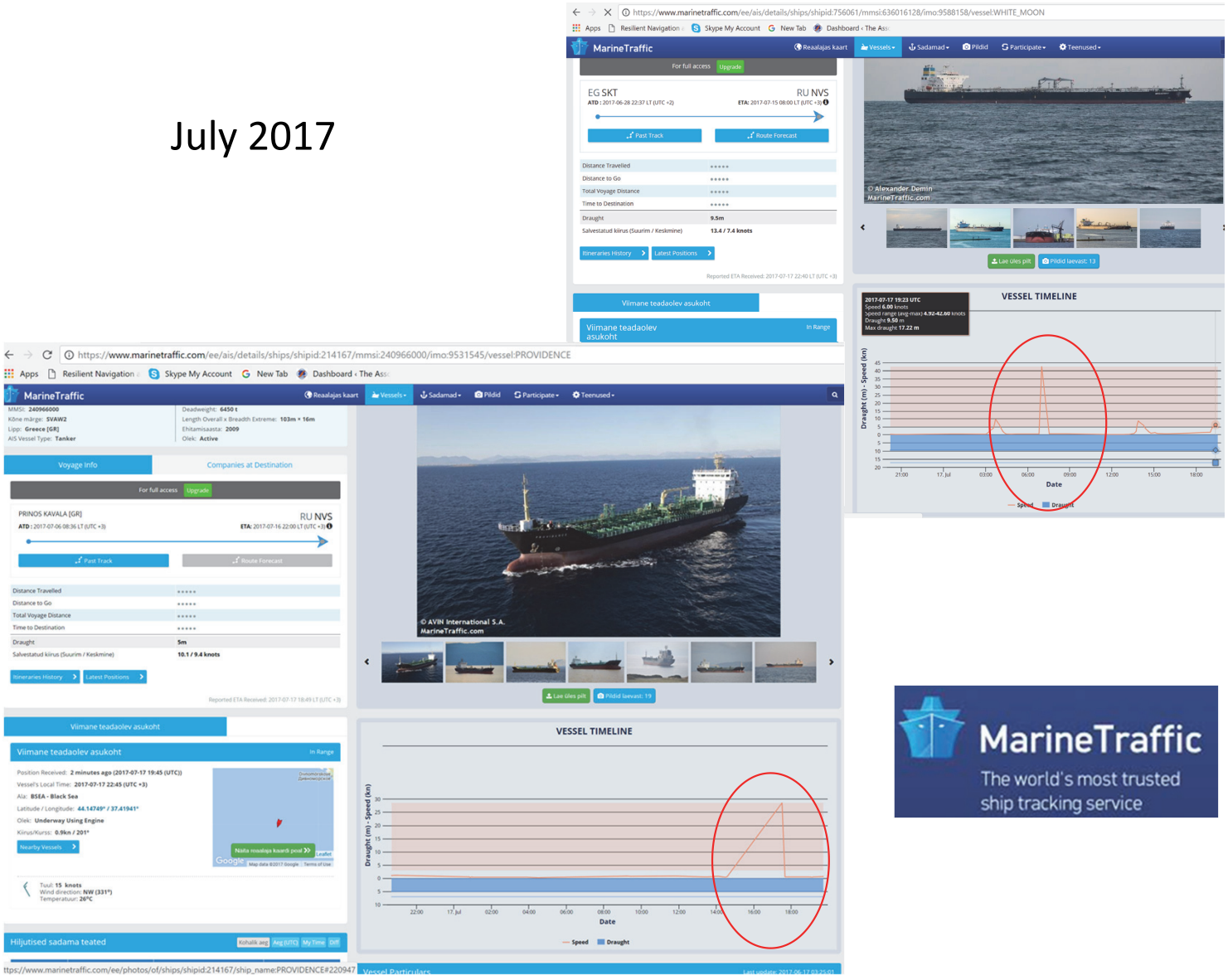
June 2017, M/V Atria

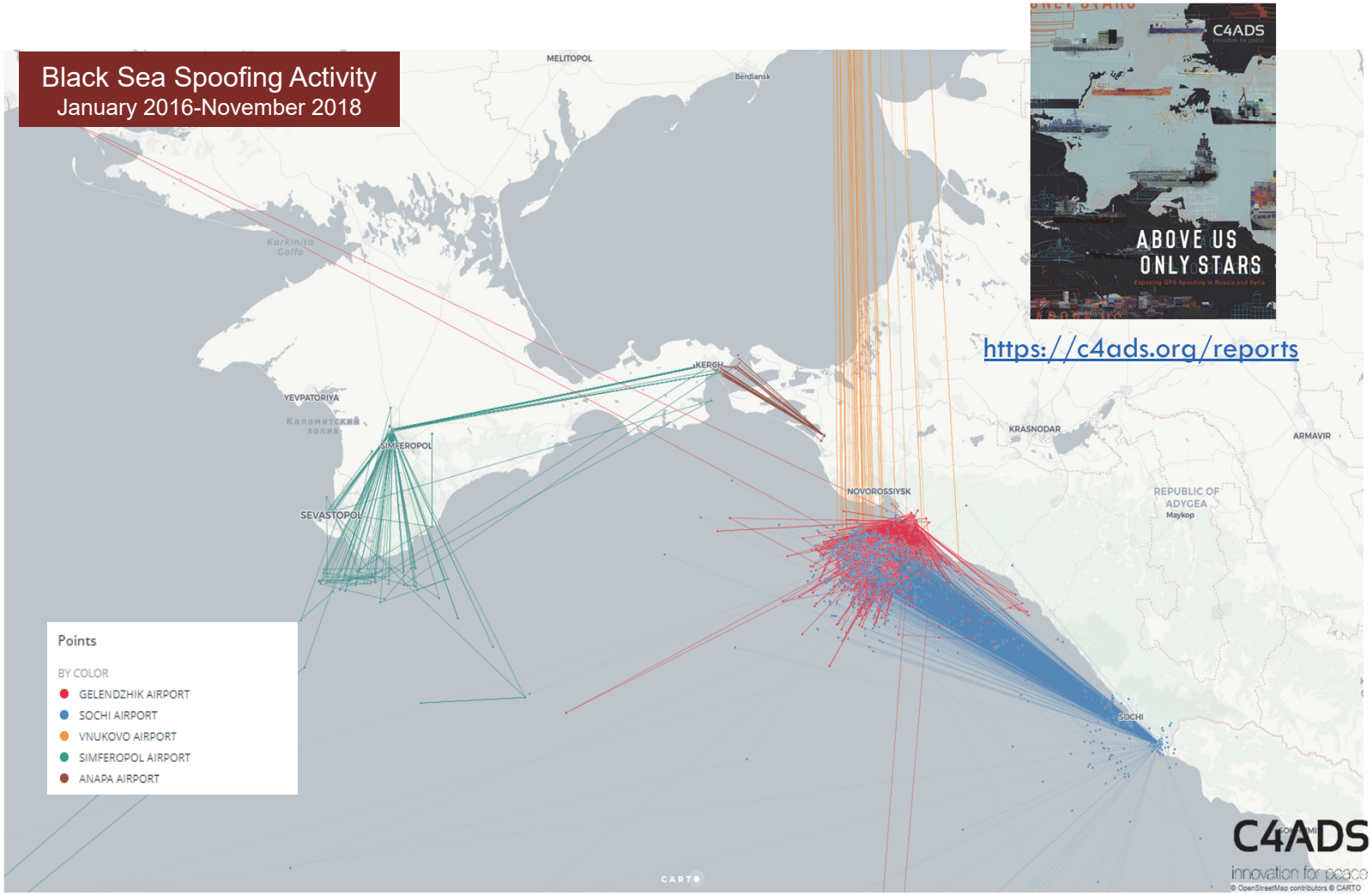
Images
CAPT Gurvan LE MEUR
Motor Vessel Atria



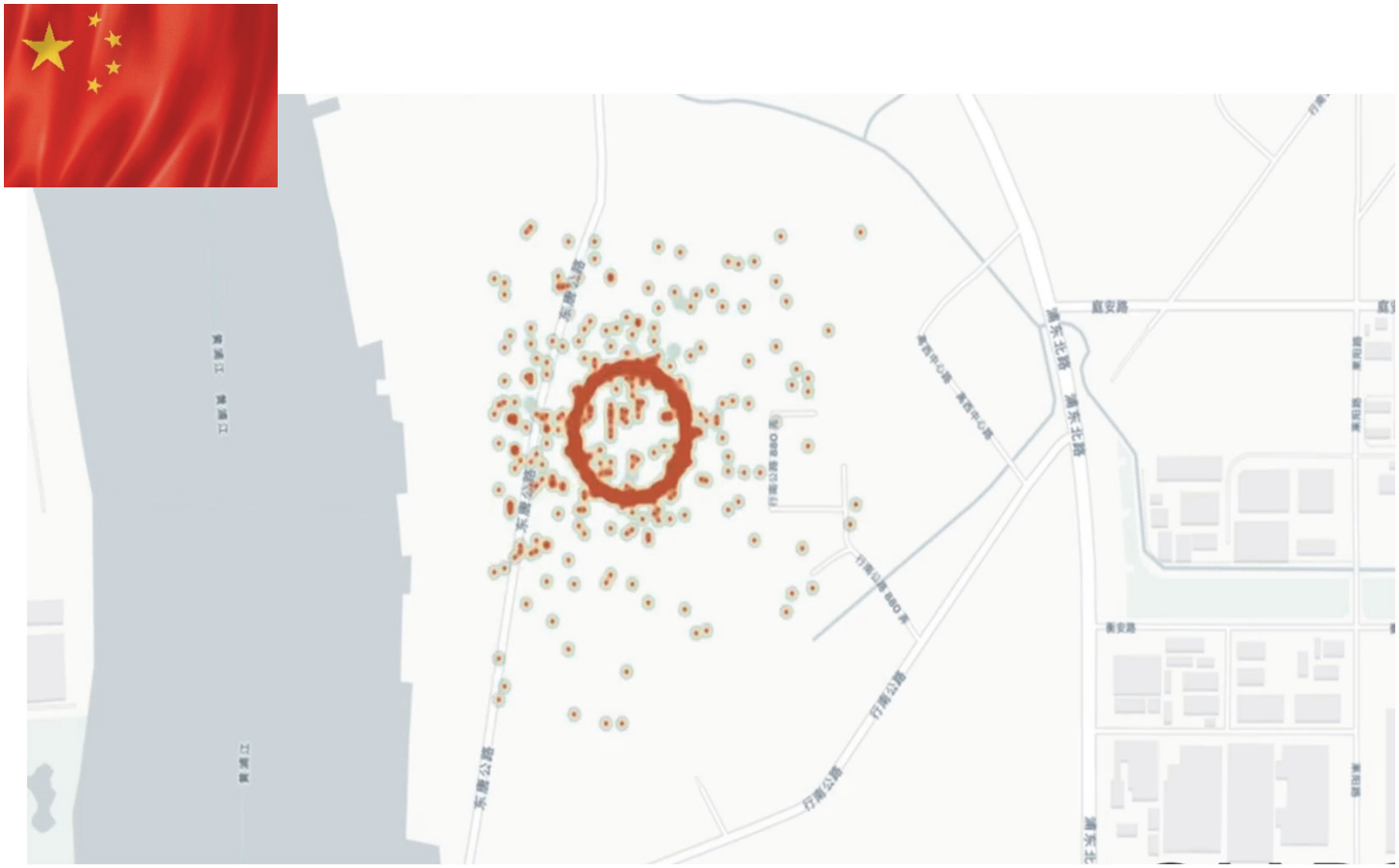


July 2017

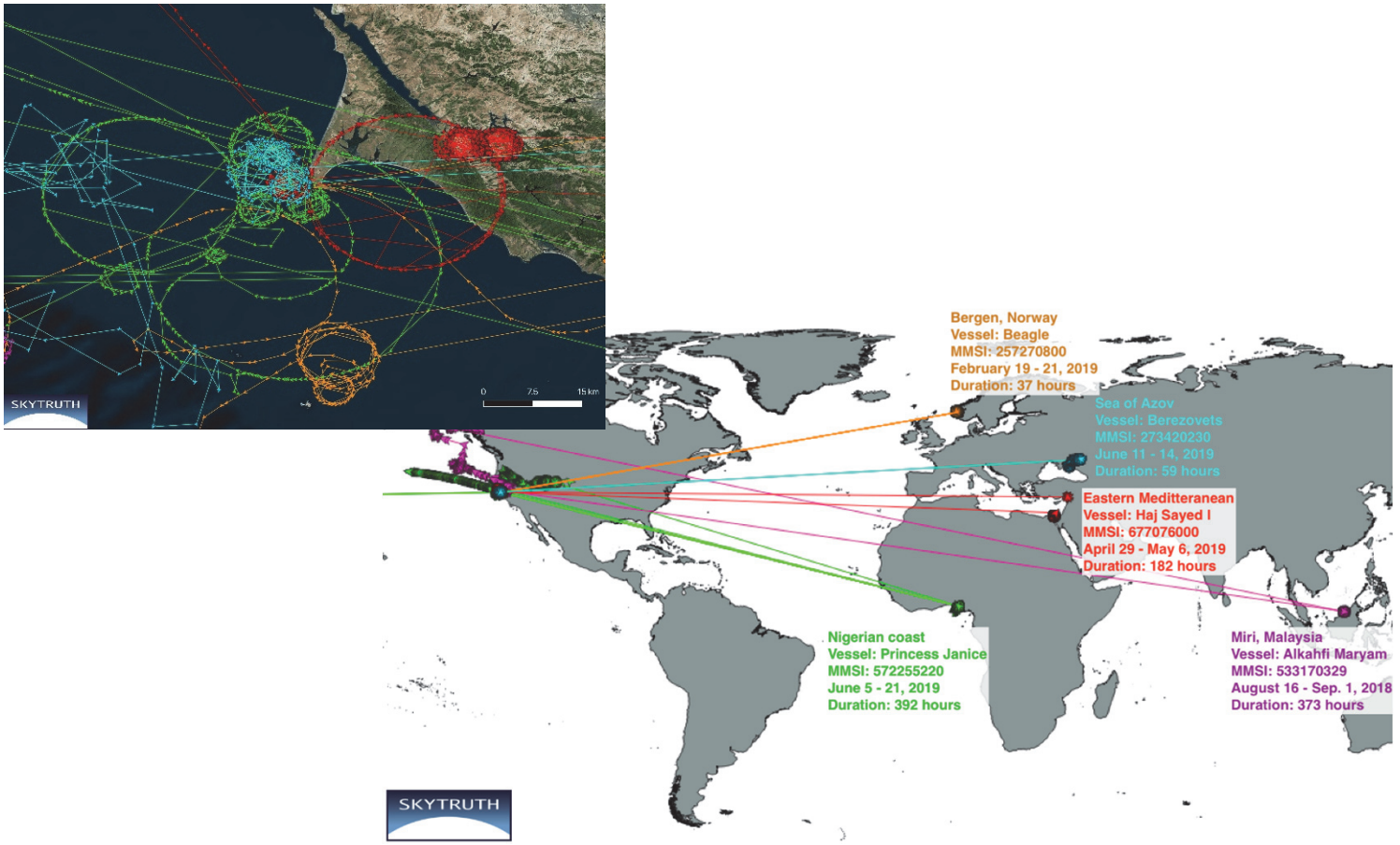

MarineTraffic
VESSEL TIMELINE
MarineTraffic
The world's most trusted
ship tracking service



https://c4ads.org/reports



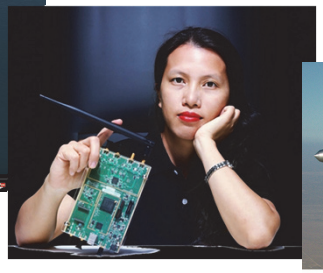
Port of Shanghai, People’s Repubic of China


SKYTRUTH
0
7.5
15 km
Bergen, Norway
Vessel: Beagle
MMSI: 257270800
February 19 - 21, 2019
Duration: 37 hours
Sea of Azov
Vessel: Berezovets
MMSI: 273420230
June 11 - 14, 2019
Duration: 59 hours
Eastern Mediterranean
Vessel: Haj Sayed I
MMSI: 677076000
April 29 - May 6, 2019
Duration: 182 hours
Nigerian coast
Vessel: Princess Janice
MMSI: 572255220
June 5 - 21, 2019
Duration: 392 hours
Miri, Malaysia
Vessel: Alkahfi Maryam
MMSI: 533170329
August 16 - Sep. 1, 2018
Duration: 373 hours
SKYTRUTH

Spoofing – Cost ↓ Capability ↑ Ease of use ↑

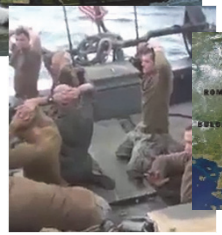
Iran, Dec 2011

UT Austin, 2012-13



Las Vegas, Dec 2015

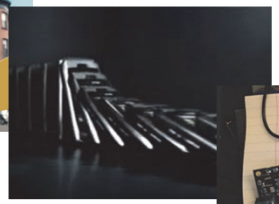
US Southern Border
Dec 2015



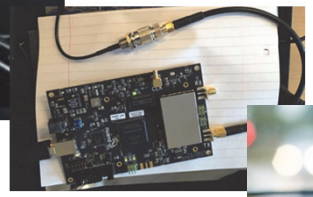
Persian Gulf, Jan 2016

4 sites Russia
1,300+ ships
2016 - Present

Pokemon
July 2016

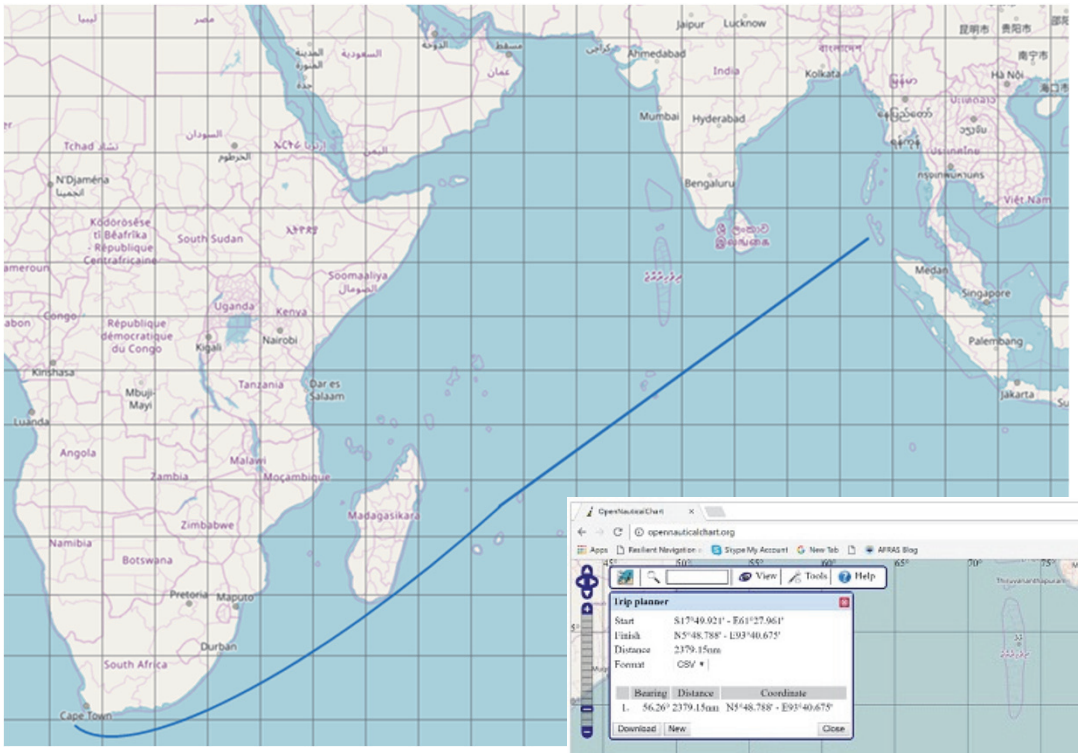


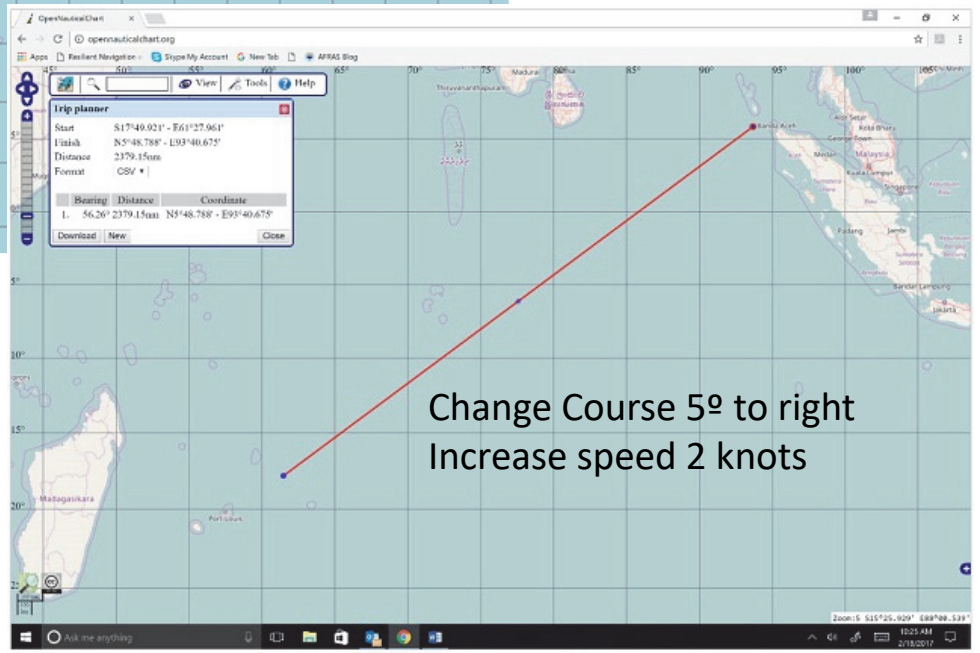
Portland
Oct 2017



All GNSS at Once Jun
2018

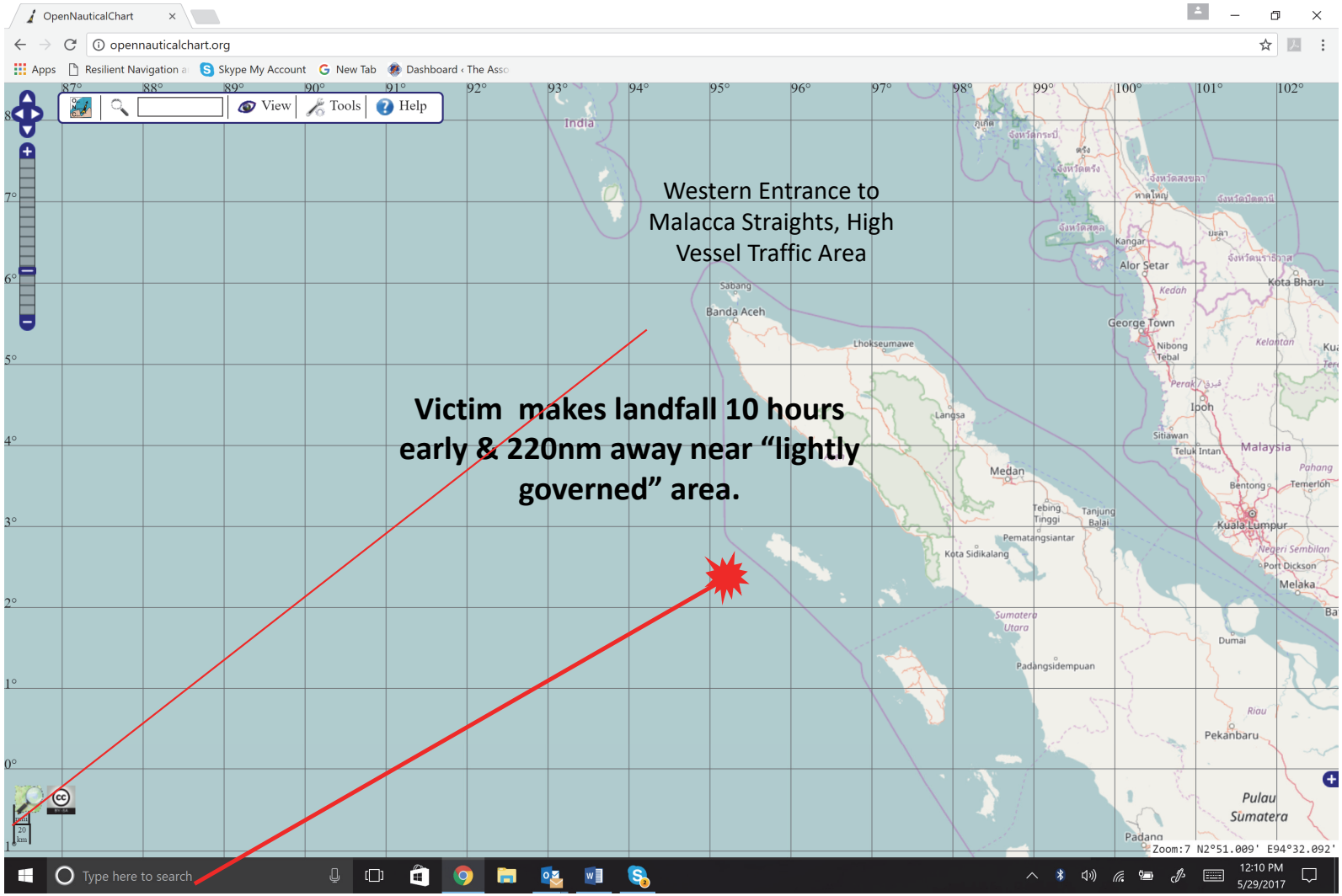
Signals & Maps
Jul 2018





The Maritime Executive
INTELLECTUAL CAPITAL FOR EXECUTIVES

"How To Steal A Ship"
2 June 2017


OpenNauticalChart
opennauticalchart.org
Apps
Resilient Navigation
Skype My Account
New Tab
Dashboard ‹ The Asso
View
Tools
Help
Western Entrance to Malacca Straights, High Vessel Traffic Area
Victim makes landfall 10 hours early & 220nm away near "lightly governed" area.
India
Sabang
Banda Aceh
Lhokseumawe
Langsa
Medan
Tebing Tinggi
Tanjung Balai
Pematangsiantar
Kota Sidikalang
Sumatera Utara
Padangsidempuan
Kangar
Alor Setar
Kedah
George Town
Nibong Tebal
Kota Bharu
Kelantan
Perak
Ipoh
Sitiawan
Teluk Intan
Malaysia
Pahang
Bentong
Temerloh
Kuala Lumpur
Negeri Sembilan
Port Dickson
Melaka
Dumai
Riau
Pekanbaru
Pulau Sumatera
Padang
Zoom:7 N2°51.009' E94°32.092'
Type here to search
12:10 PM
5/29/2017

What to Do?

- Protect – GPS Signals
- Toughen – Users & Equipment
- Augment – w/other signals & sources

What to Do? - Masters

The Maritime Executive

How To Steal a Ship, Part 2
12 June 2017

- 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

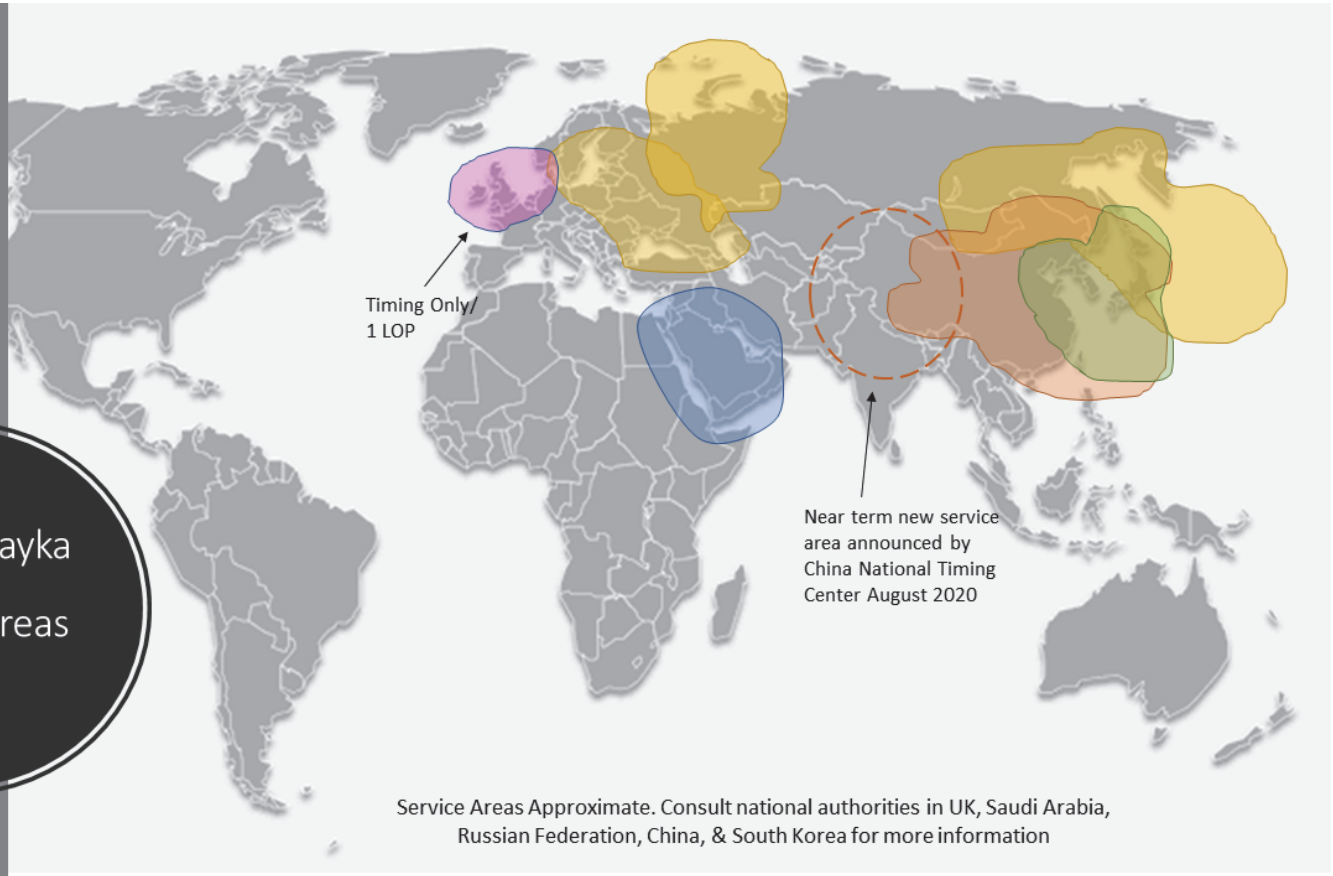
The Maritime Executive

How To Steal a Ship, Part 2
12 June 2017

- 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.

RESILIENT NAVIGATION and TIMING FOUNDATION

Loran/Chayka Service Areas 2020



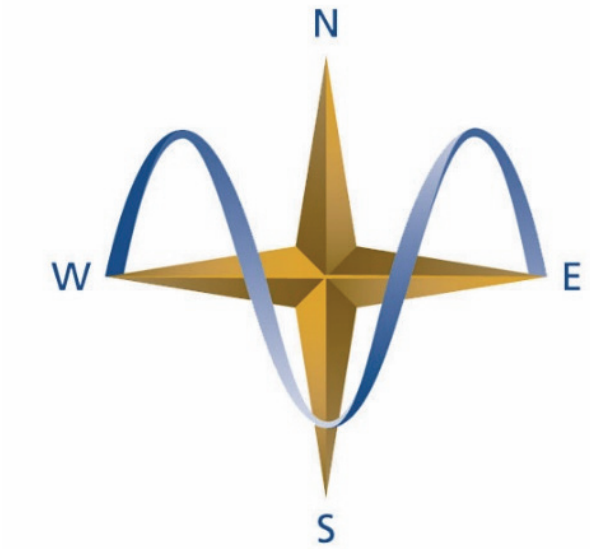
Service Areas Approximate. Consult national authorities in UK, Saudi Arabia, Russian Federation, China, & South Korea for more information

What to Do? - Nations

The Maritime Executive

How To Steal a Ship, Part 2
12 June 2017

- 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”



RESILIENT NAVIGATION *and* TIMING FOUNDATION

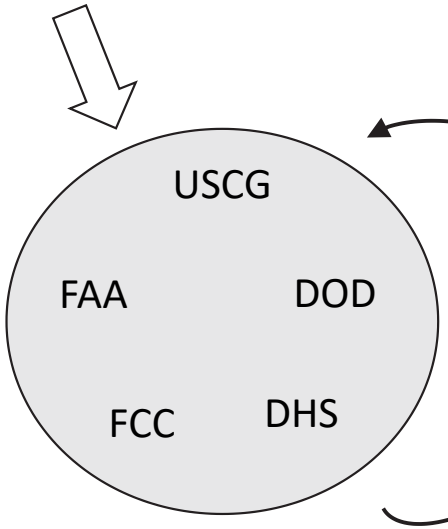
The Resilient Navigation and Timing Foundation is a 501(c)3 scientific and educational charity registered in Virginia
www.RNTFnd.org

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

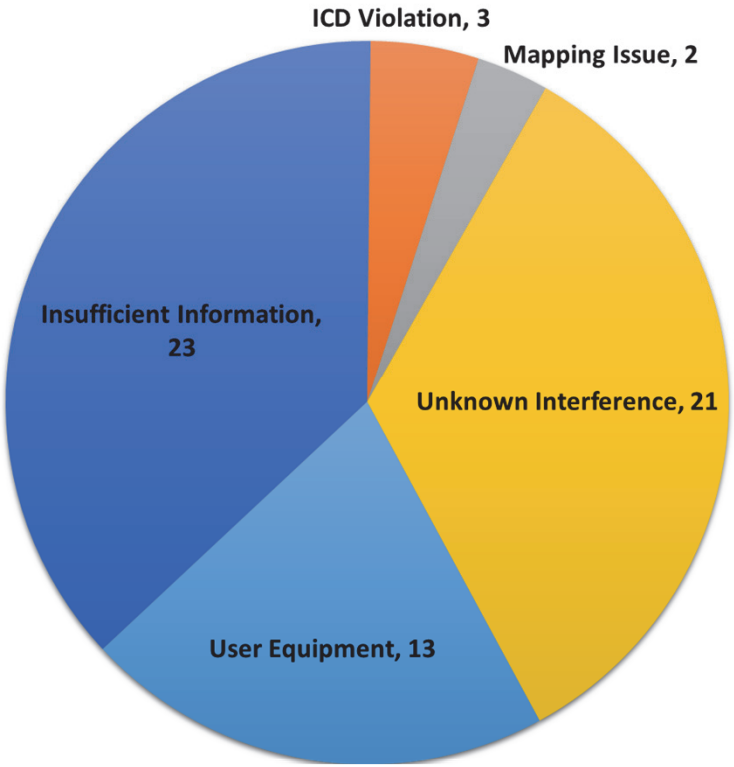


MARAD
Various Intelligence Offices
MOTR (GMCC)
Other PIRT and DOD Stakeholders
International Partners as appropriate

Resolution
Assistance
Warning / awareness
Catalogue, publish, and study

GPS Problem Reports Received by the USCG Navigation Center in 2020

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

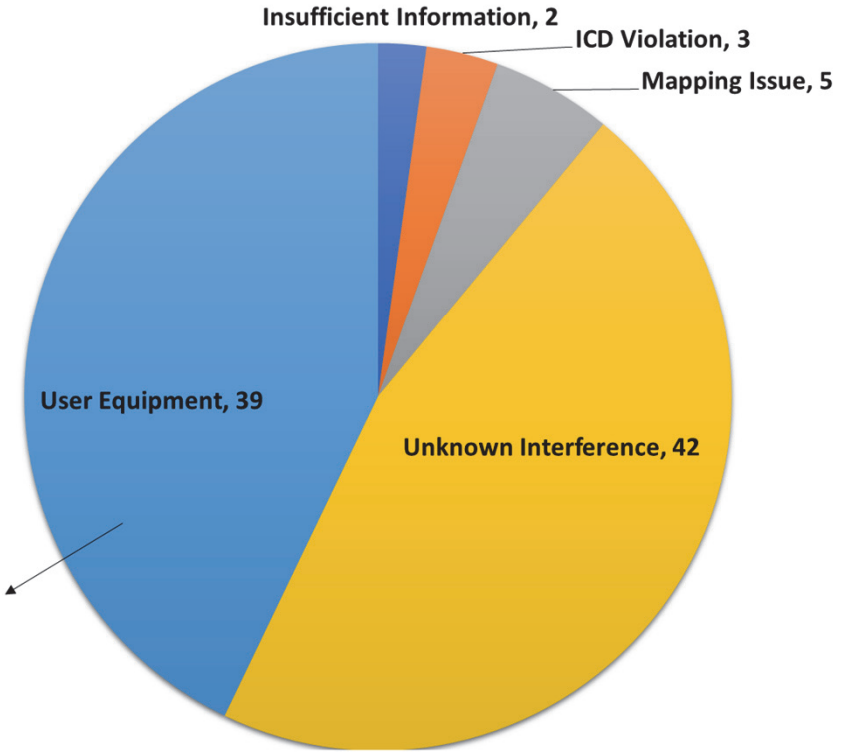
Land (3)
- Gibsonton, FL
- Rehoboth, MA
- Nashua, NH

Homeland Security

U.S. Department of Homeland Security
United States Coast Guard

GPS Problem Reports Received by the USCG Navigation Center in 2019

91 Total GPS Problem Reports



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

Homeland Security

U.S. Department of Homeland Security
United States Coast Guard

Homeland Security

U.S. Department of Homeland Security
United States Coast Guard

Options to reduce operational impact and increase PNT resiliency

Cameron Naron

Director, Office of Security, U.S. Maritime Administration, U.S. DOT

Options to reduce operational impact and increase PNT resiliency

Captain William Westrem

APL Maritime *President Eisenhower*

Options to reduce operational impact and increase PNT resiliency

Captain Richard G. Hoey
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
Advancing transportation innovation for the public good

Resilient PNT Services for Critical Infrastructure

Support to DOT on Resilient PNT Service

- Long-standing DoD-DOT partnership in the GPS Enterprise rooted in NSPD-39 (2004)
- Recent work on GPS Backup through FY17 & FY18 NDAAs 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

Vendor	Technology	Site	Timing Scenarios					Positioning Scenarios			
			Demo Site	72-Hr Bench Static Timing	Static Outdoor Timing	Static Indoor Timing	Static Basement Timing	Reference Station Offset (eLORAN Timing)	Dynamic Outdoor Positioning with Holds	Static Outdoor Positioning	Static Indoor Positioning	Airborne 3D Positioning
Echo Ridge LLC	LEO commercial S-band (2483.5 - 2500 MHz)	LaRC					N/A		X		
Hellen Systems, LLC	eLORAN terrestrial RF (90-110 kHz)	JBCC	X			X	X				
NextNav LLC	UHF terrestrial RF (920 - 928 MHz)	LaRC	X	X	X	X	N/A	X	X	X	X
OPNT B.V.	fiber optic time service (white rabbit PTP)	LaRC	X				N/A				
PhasorLab Inc.	802.11 terrestrial RF (2.4 GHz)	JBCC	X	X	X		N/A	X	X		X
Satelles, Inc.	LEO commercial L-band (1616 - 1626.5 MHz)	JBCC	X	X	X	X	N/A		X		
Serco Inc.	R-mode terrestrial RF (283.5 - 325 KHz)	JBCC					N/A	X	X		
Seven Solutions S.L.	fiber optic time transfer (white rabbit PTP)	LaRC	X				N/A				
Skyhook Wireless, Inc.	802.11 terrestrial RF (900 MHz, 2.4 & 5 GHz)	LaRC					N/A	X	X	X	X
TRX Systems, Inc.	UWB & IMU map matching (3.1 - 5 GHz)	LaRC					N/A	X*	X	X	
UrsaNav Inc.	eLORAN terrestrial RF (90 - 110 kHz)	JBCC	X		X	X	X				
GPS (SPS PS)	MEO government L-band (1575, 1227, 1176 MHz)	All	X	X			X	X	X		X

*static holds only

Key: N/A Technology incompatible with scenario definition

Contact Information

Andrew Hansen

+1.617.494.6525

andrew.hansen@dot.gov

Questions, Discussion, Next Steps

Thank you for attending!