Navigation Technology Current State, Future Possibilities, Gaps and Barriers

Transportation Research Board
Marine Board Spring Meeting
June 7-9, 2016

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

Rail – Positive Train Control

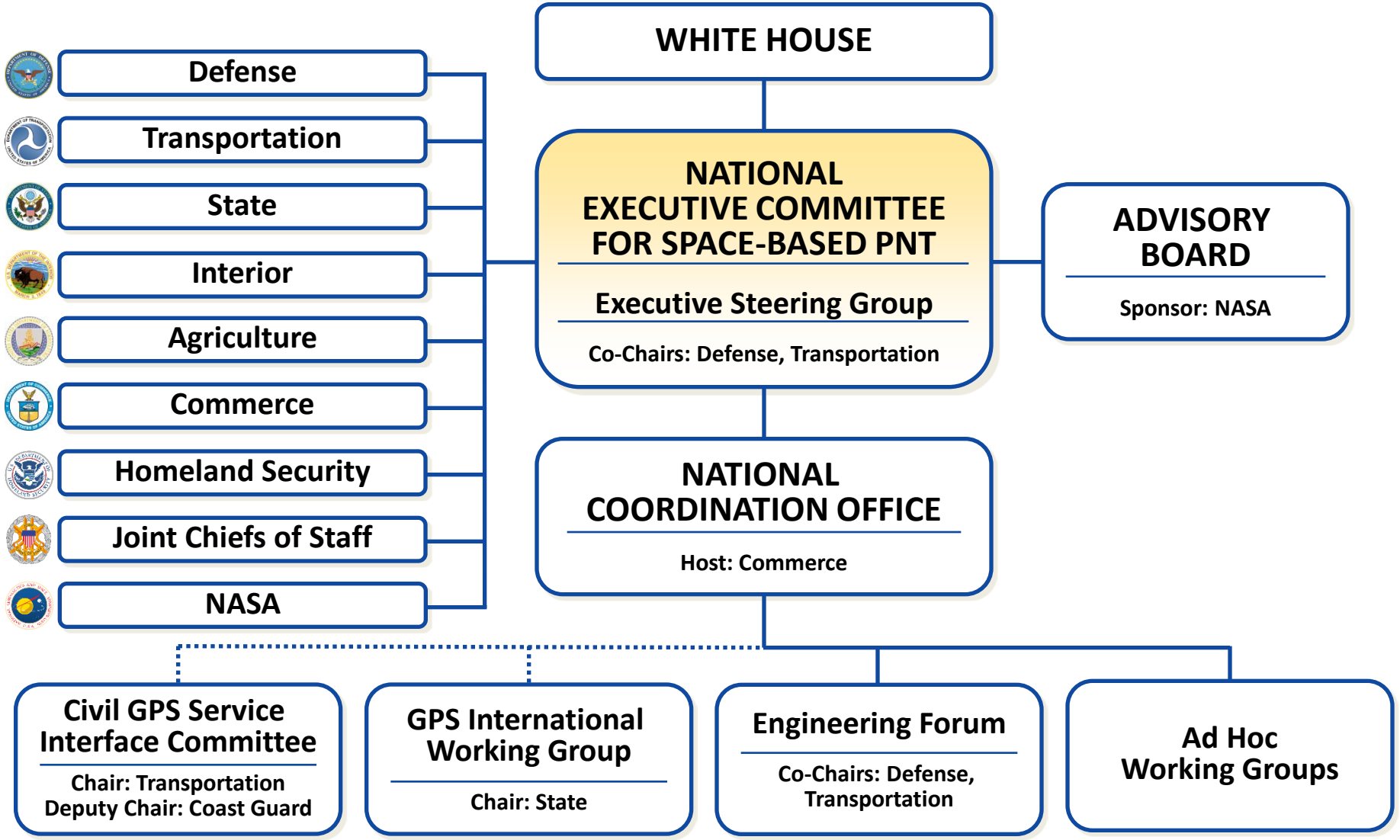
- Reduced probability of collisions
- Increased efficiency and capacity

Crossmodal – ITS

- Enable crash prevention among vehicles and between vehicles and infrastructure
- Increased mobility and reduced environmental impact

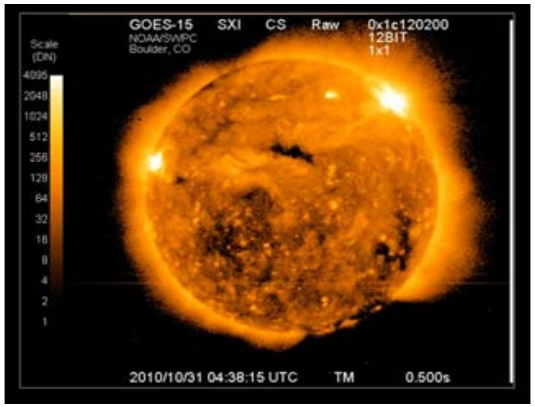
Maritime

National Space-Based PNT Organization



Gaps and Challenges

Ionospheric Disturbances



High Accuracy with Integrity

Timely Notification of Misleading Information

Signal Interference Jamming/Spoofing)

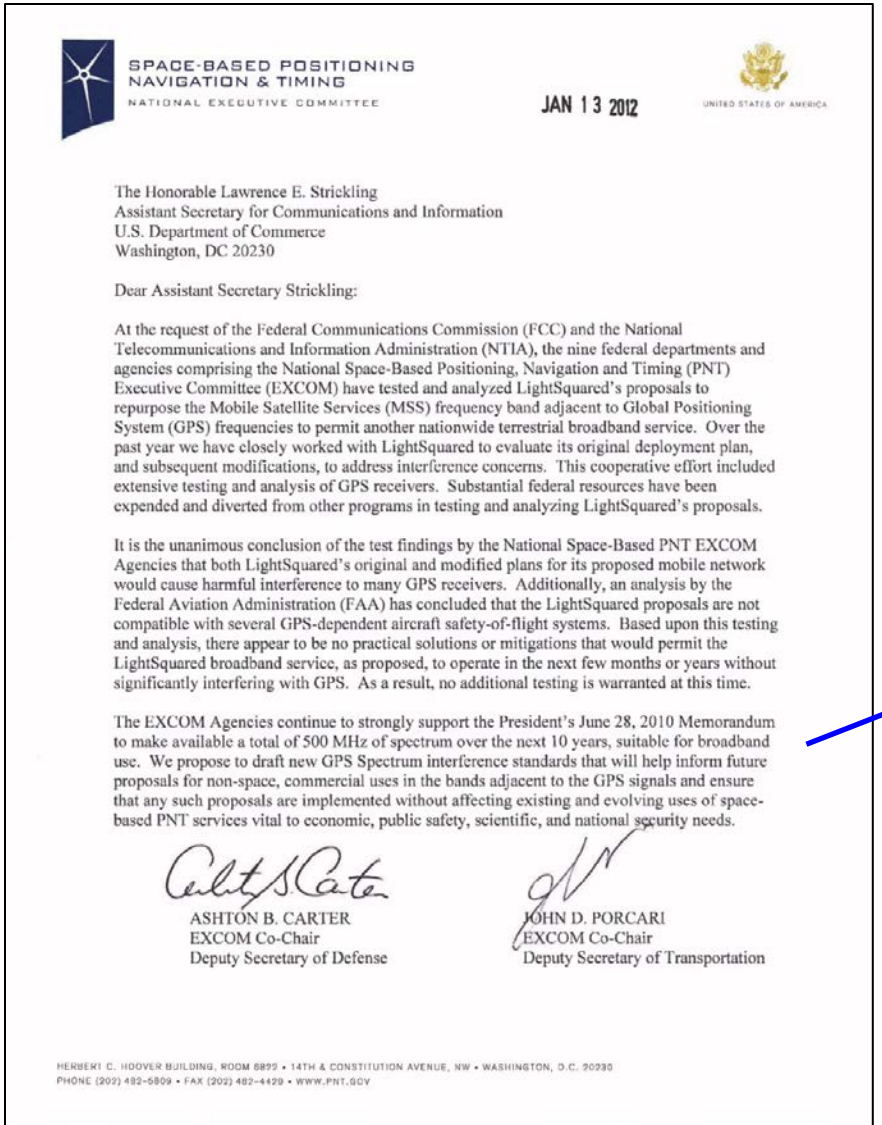
Urban Canyons

Underground/Indoors

Inaccurate/Out-of-Date Maps

National PNT Architecture Recommendations

GPS Adjacent Radiofrequency Band Compatibility Assessment



SPACE-BASED POSITIONING NAVIGATION & TIMING
NATIONAL EXECUTIVE COMMITTEE

JAN 13 2012

UNITED STATES OF AMERICA

The Honorable Lawrence E. Strickling
Assistant Secretary for Communications and Information
U.S. Department of Commerce
Washington, DC 20230

Dear Assistant Secretary Strickling:

At the request of the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), the nine federal departments and agencies comprising the National Space-Based Positioning, Navigation and Timing (PNT) Executive Committee (EXCOM) have tested and analyzed LightSquared's proposals to repurpose the Mobile Satellite Services (MSS) frequency band adjacent to Global Positioning System (GPS) frequencies to permit another nationwide terrestrial broadband service. Over the past year we have closely worked with LightSquared to evaluate its original deployment plan, and subsequent modifications, to address interference concerns. This cooperative effort included extensive testing and analysis of GPS receivers. Substantial federal resources have been expended and diverted from other programs in testing and analyzing LightSquared's proposals.

It is the unanimous conclusion of the test findings by the National Space-Based PNT EXCOM Agencies that both LightSquared's original and modified plans for its proposed mobile network would cause harmful interference to many GPS receivers. Additionally, an analysis by the Federal Aviation Administration (FAA) has concluded that the LightSquared proposals are not compatible with several GPS-dependent aircraft safety-of-flight systems. Based upon this testing and analysis, there appear to be no practical solutions or mitigations that would permit the LightSquared broadband service, as proposed, to operate in the next few months or years without significantly interfering with GPS. As a result, no additional testing is warranted at this time.

The EXCOM Agencies continue to strongly support the President's June 28, 2010 Memorandum to make available a total of 500 MHz of spectrum over the next 10 years, suitable for broadband use. We propose to draft new GPS Spectrum interference standards that will help inform future proposals for non-space, commercial uses in the bands adjacent to the GPS signals and ensure that any such proposals are implemented without affecting existing and evolving uses of space-based PNT services vital to economic, public safety, scientific, and national security needs.

ASHTON B. CARTER
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Deputy Secretary of Defense

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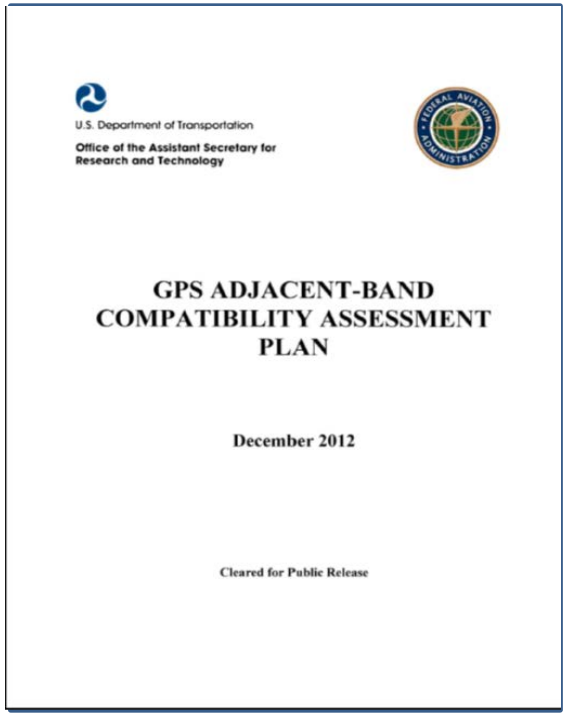
". . . without affecting existing and evolving uses of space-based PNT services vital to economic, public safety, scientific, and national security needs."

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

DOT GPS Adjacent Band Compatibility Assessment Plan

- DOT Study to Evaluate:
  - Adjacent-band power levels, as a function of offset frequency, necessary to ensure continued operation of all applications of GPS services
  - Adjacent-band power levels to ensure continued operation of all applications of GPS services by future GPS receivers utilizing modernized GPS and interoperable Global Navigation Satellite System (GNSS) signals



Approach to DOT GPS Adjacent Band Compatibility Assessment

- Certified Aviation Portion of Effort Led by FAA
- Non Aviation Certified effort (all other applications) led by DOT/OST-R Volpe Center
- DOT Extended Pos/Nav Working Group (Civil Departments and Agencies)
  - GPS Directorate, Aerospace, Mitre, Zeta Associates, and Stansell Consulting
- Conduct public outreach to ensure the plan, on going work, and assumptions are vetted and an opportunity to gain feedback
  - Held Many Public Workshops
  - Federal Register Notice for Comments/Input on Draft Test Plan
  - One-on-One Discussions with Industry
  - Open and Transparent Approach

Testing Overview

- GPS Receiver Testing Conducted April 25-29, 2016 at the Army Research Laboratory's (ARL) Electromagnetic Vulnerability Assessment Facility (EMVAF), White Sands Missile Range (WSMR), NM
  - EMVAF – 100’ x 70’ x 40’ Anechoic Chamber
- Participation included DOT’s federal partners/agencies and GPS manufacturers
- 80 receivers were tested representing six categories of GPS/GNSS receivers: General Aviation (non certified), General Location/Navigation, High Precision & Networks, Timing, Space Based, and Cellular
- Tests Conducted:
  - Linearity (receivers CNR’s estimators are operating in the linear region)
  - 1 MHz Bandpass Noise (Type 1)
  - 10 MHz LTE (Type 2)
  - Intermodulation (effects of 3rd order intermodulation)

Next Steps

- Analyze test data and develop interference tolerance masks for all receivers tested based on 1 dB CNR degradation
- Conduct lab testing on a limited number of receivers to determine how well test results can be reproduced
- Conduct receiver acquisition testing on a limited number of receivers
- Evaluate correlation of 1-dB CNR degradation to other receiver data collected
- Develop use-case scenarios
- Evaluate appropriate propagation models for each use-case scenario
- Develop maximum tolerable transmitter power level as a function of frequency offset

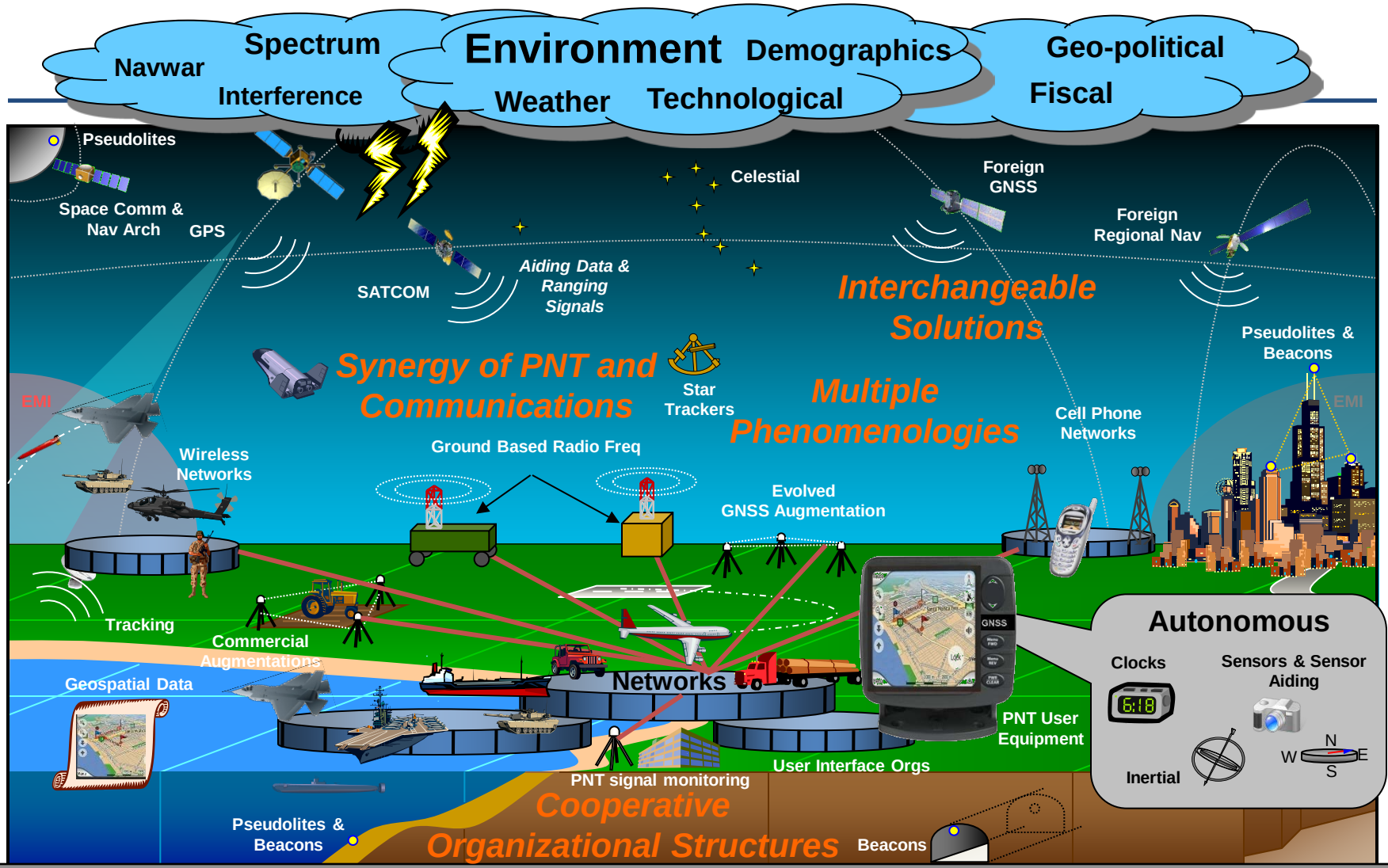
Complementary PNT

- EXCOM looked at need for complement to GPS
- Assessment driven by many factors: from policy to technology
- U.S. coverage for GPS outage from natural or man-made events
- Assessed a broad mix of terrestrial, RF, and autonomous PNT technologies
- Public stakeholder comments obtained by *Federal Register* Notice

Stakeholder Outreach

- Federal Register Notice published March 23, 2015 seeking:
  - PNT performance required for a CPNT capability
  - Availability and coverage area required for CPNT
  - Willingness to equip with an eLoran receiver
  - Current/planned availability of eLoran user equipment
- Summary of Comments (period closed May 22nd)
  - Approximately 200 responses received
  - Majority of responses were supportive of eLoran as a U.S. CPNT technology, but were not application-specific
  - Maritime community indicated it would equip with eLoran
  - Aviation community prefers existing ground-based navaids
  - Recognition that there is a dependence on GPS augmentations that deliver better/higher accuracy
- Current Focus on Requirements Development

Future of Positioning, Navigation, and Timing



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