



SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

National Space-Based PNT Advisory Board 15th Meeting Update June 11, 2015

**Dr. Bradford Parkinson
Vice Chair PNTAB**

Original Program Director and Chief Architect of GPS
Co-Founder of GPS Research Center at Stanford University



PNT Advisory Board's Role Within National PNT Policy

- **2004 U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy**
 - U.S. must continue to improve and maintain GPS, augmentations, and backup capabilities
 - Establish a permanent National Space-Based PNT EXCOM
 - Establish a National Space-Based PNT Coordination Office
 - Establish a Space-Based PNT Advisory Board (PNTAB). The Board shall be comprised of experts from outside the U.S. Government.
- **PNTAB Charter renewed by NASA Administrator C. Bolden on May 8, 2015**
 - PNTAB operates under FACA rules with members nominated by PNT EXCOM agencies and appointed by NASA Administrator
 - PNT EXCOM departments determine merit and prioritize subject matter expertise desired
 - Sponsor agency strives for diversity and balance in terms of sector expertise, agencies represented, and points of view reflected
 - 20 experts reappointed; 5 new experts added
- **NASA has sponsored 14 PNTAB meetings since 2007 on behalf of PNT EXCOM**
 - Minutes, Recommendations, and Reports from taskings available at www.gps.gov
 - Last meeting held Dec. 10-11, 2014, in Washington DC
 - Next meeting scheduled for Oct. 30-31 in Boulder, CO



2015-2017 PNTAB Membership

- [John Stenbit](#) (Chair), former DoD Assistant Secretary
 - [Bradford Parkinson](#) (Vice Chair), Stanford University original GPS Program Director
 - [James E. Geringer](#) (2nd Vice Chair), ESRI Former Governor of Wyoming
 - [Thad Allen](#), Booz Allen Hamilton retired Commandant of the Coast Guard
 - [Penina Axelrad](#), University of Colorado, Chair of Department of Aerospace Engineering
 - [John Betz](#), MITRE, Former Chair Air Force Scientific Advisory Board
 - [Dean Brenner](#), Vice President, Government Affairs Qualcomm
 - [Scott Burgett](#), [Garmin International](#)
 - [Joseph D. Burns](#), United Airlines, Former Chief Technical Pilot, United Airlines
 - [Per K. Enge](#), Stanford University, Head of Stanford Center for PNT
 - [Martin C. Faga](#), MITRE Retired CEO of Mitre
 - [Dana A. Goward](#), [Resilient Navigation & Timing Foundation](#), [Founde](#),
 - [Ronald R. Hatch](#), consultant to John Deere, inventor of the GPS “Hatch” filter
 - [Larry James](#), Deputy Director, Jet Propulsion Laboratory
 - [Peter Marquez](#), Planetary Resources, Former White House National Security Space Policy
 - [Terence J. McGurn](#), private consultant, retired CIA analyst of Position, Navigation and Control
 - [Timothy A. Murphy](#), The Boeing Company, Technical Fellow with Boeing Commercial Airplane
 - [Ruth Neilan](#), Jet Propulsion Laboratory, vice chair, Global Geodetic Observing System
 - [T. Russell Shields](#), Ygomi, a founder of NavTeq
 - [Ann Ciganer](#), VP Trimble Navigation, Director of GPS Innovation Alliance
- International Members:**
- [Gerhard Beutler](#), Professor of Astronomy and Director of the Astronomical Institute, U. of Bern.
 - [Sergio Camacho-Lara](#), [Regional Centre for Space Science and Technology Education for Latin America and the Caribbean, Mexico](#)
 - [Arve Dimmen](#), Division Director Maritime Safety Norwegian Coastal Administration (Norway)
 - [Matt Higgins](#), President International GNSS Society (Australia)
 - [Rafaaf M. Rashad](#), Chairman Arab Institute of Navigation (Egypt)



PNTAB Focus Areas

- **Primary PNTAB Objective:**
 - Assured PNT for all users
- **Current Assessment**
 - No current or foreseeable alternative to GNSS (primarily GPS) can deliver equivalent accuracy (to millimeters, 3D) and world wide 24/7 availability
 - But the L-Band signals are very weak
- **Therefore our Focus is PTA Program**
 - **P**rotect the radio spectrum + identify + prosecute interferers
 - **T**oughen GPS receivers against natural and human interference
 - **A**ugment with additional PNT sources and techniques



Previous PNTAB Recommendations & Outcomes

- **Eliminate S/A capabilities from GPS III**
 - Officially announced by DoD DepSec England on Sep. 18, 2007
- **Implement Laser Retro-reflector Arrays on GPS III**
 - MOU signed by Gen Shelton (AFSPC), Gen Kehler (USSTRARCOM), and C. Bolden (NASA) on Aug. 22, 2013
- **Ensure balanced participation by agencies, manufacturers, and users in NTIA/DoD/DOT spectrum studies**
 - Full understanding of impacts and alternatives
 - On-going Adjacent Band Compatibility Assessment
- **Incorporate NASA worldwide civil-signal monitoring into OCX verification of GPS signal**
 - Cost effective, early satisfaction of up to 96% of requirements
 - On-going discussions with DOT





Latest PNTAB Recommendations

(29 Aug. 2014 letter to DepSecs Work and Mendez)

- 1. Formally Designate GPS as a Critical Infrastructure Sector for the United States**
 - 14 of 16 current CIs deeply dependent (restatement of recommendation)**
- 2. Develop a Formal National Threat Model for PNT Applications in Critical Infrastructure**
 - Build on earlier Ms. K. Van Dyke effort at DOT**
- 3. Prevent the Proliferation of Commercial Emitters/Pseudolites in GPS Frequency Bands**
 - Threat continues**
- 4. Establish a Nationwide CONUS Back-Up to GPS with Existing Infrastructure (eLoran)**
 - Previously accepted by PNT EXCOM (2009), requires refocus**



Way Forward

- **Continue current and related study efforts**
 - PNT EXCOM-directed tasks, including the GPS Economic Assessment
 - Stand ready to assist in development of National Threat Model if PNT EXCOM directs
 - Measures to insure PNT for all users – The **PTA** Program – examples:
 - Anti-spoofing authentication codes
 - Tracking progress for eLoran deployment
 - Status of FCC Licensing use of non-US GNSS receivers
 - Explore state-of-the-art in commercially available receiver toughening
- **Participation in International Fora related to GPS and GNSS**
 - ICG-10 sponsored by UN in Boulder, Colorado, November 2015
 - Renewed interest in reciprocal participation of Foreign Advisory Boards
- **Develop new Recommendations and Tasks based on PNT Board member deliberations and consensus**



Backup Slides



eLoran Previously Recommended by PNT EXCOM

Conclusions – (DOT IRB Dec. 2006):

- Reasonable assurance of national PNT availability is prudent & responsible policy
 - For critical safety-of-life & economic security applications
 - For all other "quality-of-life" applications
- eLoran is a cost-effective backup –to protect and extend GPS- for identified national critical GPS-based applications
 - Interoperable & independent
 - Different physical limitations & failure modes
 - Seamless operations & **GPS threat deterrent**
- Given US Government support, it is anticipated users will equip with eLoran as backup of choice
 - International community is looking for US leadership

Recommendation:

Summary of Results from Independent Review Board

Re: Loran – Convened by US/DOS (2006)

- Unanimous Recommendation – deploy eLoran
- DOT, DHS, **and PNT EXCOM** supported this recommendation
- But eLoran was a victim of budget tightening, and dismantling or existing Loran stations began



GPS Economic Assessment

- **NASA and DOC partnered to hire economist, strategic planner and public policy advisor Irving Leveson, PhD. Dr. Leveson will execute an economic assessment quantifying the civilian benefits of GPS technology and services in a two part study:**
 - **Validate & update existing studies of economic benefits derived from satellite navigation applications and identify gaps where further analyses are needed**
 - **Classify and rank representative sectors making the most significant contributions to the U.S. and global economies, such as mobile devices, precision agriculture, geospatial applications, etc.,**
- **Statement of Work:**
 - **Describe approaches for assigning quantitative values to public safety, environmental protection, and other intangible benefits & selectively estimate non-economic benefits**
 - **Assess potential future applications and project market penetration and GPS economic benefit values to U.S. sectors under alternative scenarios**
 - **Approximate economic benefits of GPS to other regions of the world**
 - **Estimate economic costs of partial or complete loss of GPS service availability under alternative scenarios for select sectors**
 - **Prepare a comprehensive technical report integrating the two phases that provides a compelling narrative that informs all stakeholders and the general public**



PNTAB Recommendations

(29 Aug. 2014 letter to DepSecs Work and Mendez) 1/2

1) Formally Designate GPS as a Critical Infrastructure Sector for the United States

Virtually every Department of Homeland Security (DHS)-designated critical infrastructure sector is dependent on access to GPS for positioning, timing, or both. Specifically, these PNT services are pervasive elements in 14 of 16 critical U.S. sectors. Preliminary economic studies show a *direct* value of GPS equipment manufacturing of over \$30B a year, which may triple to over \$90B when also including the *indirect* benefits facilitated by the use of GPS. These impacts, however, are not yet fully understood nor appreciated by the critical infrastructure sectors, thus relegating GPS to a “stealth utility” status, lacking appropriate protections. Serious potential threats to GPS users range from changes in spectrum regulations, to intentional interference, cyber-attacks, spoofing, and even natural atmospheric disturbances. Such threats are credible and rapidly growing. It is therefore essential that resources and attention be focused on addressing such vulnerabilities. In order to achieve this goal, the PNTAB recommends that the DHS advocate and the President designate GPS as a separate sector of critical infrastructure and provide national leadership to counter these threats to our economy and security.

2) **Develop a Formal National Threat Model for PNT Applications in Critical Infrastructure**

The Department of Defense (DoD) routinely develops and updates threat models to GPS defense capabilities, and also prioritizes countermeasures to these threats. However, public safety GPS stakeholders, and other critical infrastructure sectors, do not have a validated threat model. We have studied this in some detail and strongly believe that there is a potential for serious national economic and public safety disruption. The PNTAB therefore proposes that the PNT National Coordination Office (NCO) be tasked and funded to lead the development of a detailed, PNT National Threat Model (PNT NTM) for GPS. This study should include all classes of threats, the probabilities and economic impacts, and outline potential countermeasures. The PNT NTM study should be developed in cooperation with all appropriately cleared civil GPS stakeholders, in particular GPS equipment manufacturers and PNT service providers. We believe the PNT NTM will enable federal departments and agencies, state and local governments, and commercial service providers to better understand and prioritize resource allocation for mitigation strategies.



PNTAB Recommendations

(29 Aug. 2014 letter to DepSecs Work and Mendez) 2/2

3) Prevent the Proliferation of Licensed Emitters in GPS Frequency Bands

Recent regulatory proposals by the European Conference of Postal and Telecommunications Administrations (CEPT) would license certain terrestrial transmitters, or “pseudolites,” to operate in the primary GPS band (also known as GPS L1). This frequency band is designated as a Radionavigation Satellite Service (RNSS) and should be very carefully regulated. These transmitters pose a significant interference threat to GPS and other Global Navigation Satellite Systems (GNSS), including Europe’s emerging Galileo system. Therefore, the PNT AB recommends that the PNT EXCOM strongly oppose such licenses and that the U.S. Department of State urgently engage the European Signatories under a demarche pursuant to the terms of the 2004 U.S.-E.U. GPS-Galileo Agreement. The U.S. and the European Union should work cooperatively with the European Commission and CEPT, to prevent the authorization and proliferation of harmful devices in GNSS frequency bands.

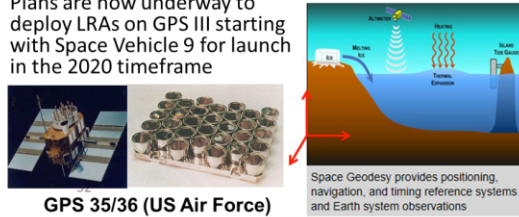
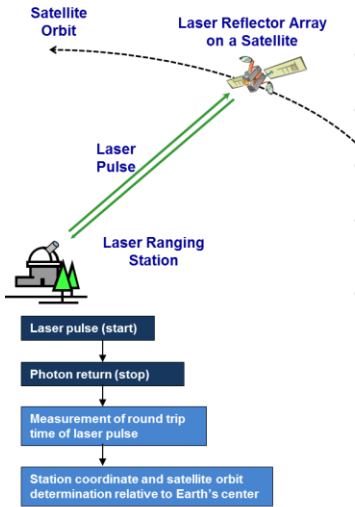
4) Establish a Nationwide CONUS Back-Up to GPS with Existing Infrastructure (eLoran)

In 2006, an Independent Assessment Team (IAT), commissioned by DOT, unanimously recommended: “*Retain eLoran (enhanced Loran) as a primary backup for critical GPS applications.*” After studying the situation, the PNT AB unanimously concurred and made the same recommendation to the PNT EXCOM in 2007. The PNT EXCOM, with participation from all represented Federal departments, also unanimously concurred. Unfortunately, due to competing fiscal priorities, eLoran was cut from the budget in 2009 and its existing infrastructure is being dismantled. The PNT AB believes that existing Loran sites and antennae could provide an affordable path to a National GPS back-up system, and restated its recommendation at the last PNT EXCOM meeting held on March 14, 2014. We believe that the deployment of a national PNT back-up is now even more urgent due to the rapidly evolving threats to GPS-based PNT services. The PNT AB therefore reaffirms its previous recommendation and requests urgent action to preclude further dismantling of existing infrastructure that could be used as a GPS back-up to prevent disruptions to the U.S. economy, public safety, and security.

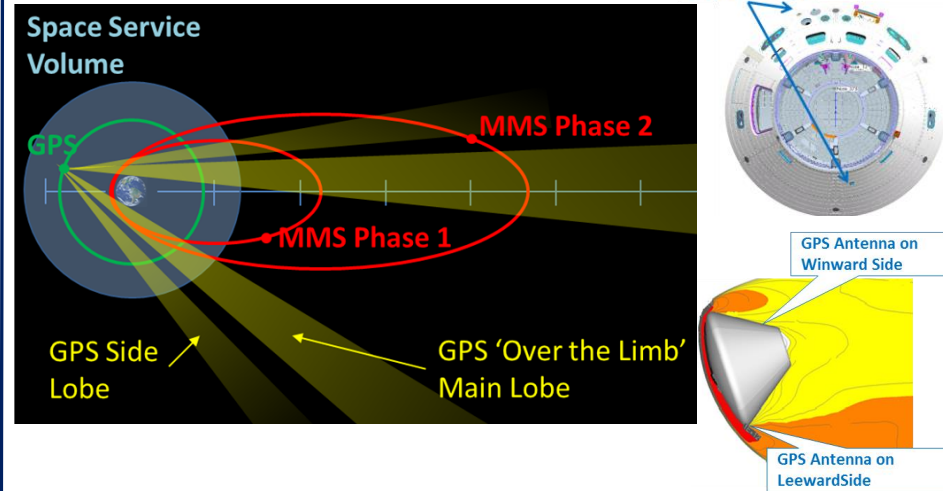


NASA's Involvement in GPS Modernization

- Laser ranging to GNSS satellites enables the comparison of optical laser measurements with radiometric data, identifying systemic errors
- Post-processing this data allows for refining station coordinates, satellite orbits, and timing epochs
- The refined data enables improved models and reference frames
- This results in higher PNT accuracies for all users, while enhancing interoperability amongst constellations
- NASA Administrator Bolden worked with Air Force leaders Gen Shelton & Gen Kehler to approve Laser Reflector Arrays (LRAs) onboard GPS III
- Plans are now underway to deploy LRAs on GPS III starting with Space Vehicle 9 for launch in the 2020 timeframe



Receiver Development (MMS, Orion, etc.)



SAR/GPS Search and Rescue-Global Positioning Satellite System

Global Search and Rescue System

System Overview Diagram: The fully operational MEOSAR constellation SAR/GPS will provide world-wide coverage with the ability to detect and locate emergency distress beacons accurately in as little as one beacon burst.

With a footprint over seven times larger than a LEO satellite, the MEOSAR constellation allows for real-time alerting worldwide without the need to store information in the satellite to relay at a later time. This capability equates to faster alert notices and thus more lives saved.

Activated 406 Emergency Locator Transmitter (ELT)

Local User Terminal

SAR Response

Mission Control Center

US Coast Guard Rescue Coordination Center

Activated 406 Emergency Position Indicating Radio Beacon (EPIRB)

US Air Force Rescue Coordination Center

SAR Response

National Security Presidential Directive-38 (NSR 38)

The GDGPS System is uniquely equipped to monitor the GPS civil signals in compliance with the Civil Signal Monitoring Requirements developed by the DoT

- CSM monitoring by GDGPS was recommended by the PNT Advisory Board in December 2013
- Endorsed by USAF Space Command (Gen. Shelton) in early 2014

JPL has worked with the DOT CSM Trade Study Team to analyze the GDGPS capability for cost effective monitoring of the GPS civil signals

In March 2014 the CSM Trade Study Team recommended that the vast majority of the civil signal requirements be monitored by GDGPS

In 2014 2SOPS expanded its contract with JPL to include some monitoring of L2C and L5

- More complete CSM is still pending

INSIDE GNSS NEWS

The Global Differential GPS System

FAA May Tap Three Reference Networks to Monitor Civil GPS Signals

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Dee Ann Divilo
March 18, 2014