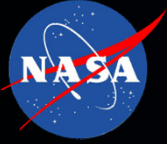




Update from U.S. National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board

***James J. Miller, as Exec Dir. of PNT Board
Space Communications and Navigation Program
Human Exploration and Operations Mission Directorate
NASA Headquarters***

**International Committee on GNSS (ICG)
16th Providers Forum, Vienna, Austria
June 6, 2016**



NASA's Role: U.S. PNT & Space Policy

- The 2004 U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy tasks the *NASA Administrator, in coordination with the Secretary of Commerce, to develop and provide requirements for the use of the Global Positioning System (GPS) and its augmentations to support civil space systems*

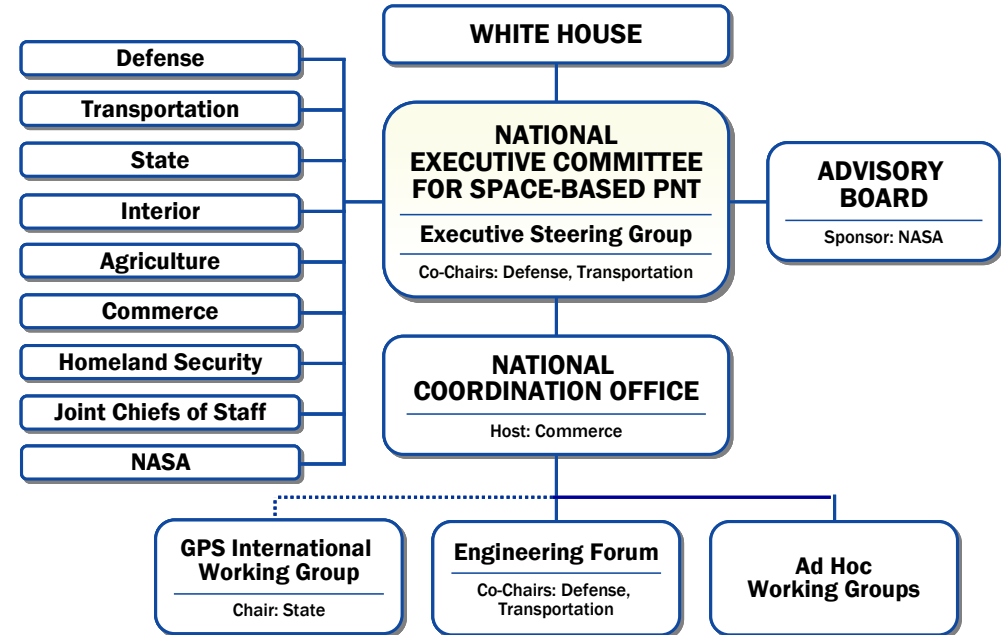
- NASA seeks to contribute fulfilling governmental policy goals through technology application

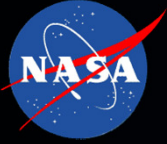
“The U.S. maintains space-based PNT services that:

- Meet growing national, homeland, economic security, civil requirements, and scientific and commercial demands;
- Continue to provide civil services that exceed or are competitive with foreign civil space-based PNT services;
- Remain essential components of internationally accepted PNT services;
- Promote U.S. technological leadership in applications involving space-based PNT services
- The 2010 National Space Policy reaffirms PNT Policy commitments to GPS service provisions, international cooperation, and interference mitigation

- *Foreign PNT services may be used to augment and strengthen the resiliency of GPS*

- Besides direct collaboration with interagency partners & foreign space agencies, NASA international engagement is very active to ensure global interoperability





U.S. PNT Advisory Board & International Committee for GNSS (ICG)

- NASA's sponsorship of PNT Board and active engagement at fora such as ICG supplements technical contributions to GPS Enterprise and strengthens policy advocacy
 - RNSS spectrum protection
 - GPS-based science applications (radio-occultation, geodesy, earthquake/tsunami warning, etc.,)
 - GPS/GNSS civil signal monitoring (operational performance)
 - GPS MEOSAR (search and rescue)
 - Laser Retro-reflector Arrays (LRAs) on GPS III
 - GNSS space receivers (GSFC "Navigator" & JPL "TriG" families)
 - Interoperable GNSS Space Service Volume (SSV)
- 16th U.S. Space-based Positioning, Navigation, and Timing (PNT) Advisory Board meeting held on Oct. 30-31, 2015 – in conjunction with ICG-10 in Boulder, Colorado, Nov. 1-6, 2015
 - Agenda/Briefings: <http://www.gps.gov/governance/advisory/meetings/2015-10/>



16th PNT Advisory Board



ICG-10 Delegates



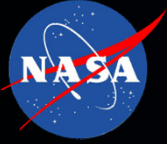
2015-2017 PNT Board Membership

- **John Stenbit (Chair)**, former DoD Chief Information Officer
 - **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 United States 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
 - **Ann Ciganer**, VP Trimble Navigation, Director of GPS Innovation Alliance
 - **Per K. Enge**, Stanford University, Head of Stanford Center for PNT
 - **Martin C. Faga**, MITRE, Retired CEO, NRO Director
 - **Dana A. Goward**, Resilient Navigation & Timing Foundation, Founder
 - **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
- 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)
 - **Rafaat M. Rashad**, Chairman, Arab Institute of Navigation (Egypt)



PNT Board Member Structure & Appointments

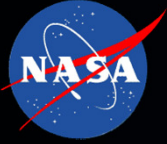
- The PNT Board shall consist of not more than 25 members who will serve as Special Government Employees (SGEs), although Representative members from critical industry sectors, academia, international organizations, or space-based PNT user application areas may also serve
- PNT Board members are nominated by PNT EXCOM departments and appointed by NASA Administrator in consultation with PNT EXCOM Co-Chairs (DoD & DOT)
 - PNT EXCOM departments determine individual merit and prioritize subject matter expertise
 - Sponsor agency (NASA) maintains a balanced membership that ensures diversity with multi-agency representation, sector expertise, and points of view to be reflected
 - International members play a key role
- PNT Board member rotations may occur with each charter renewal (every 2 years) and shall not exceed six members to ensure a core institutional membership is maintained and ongoing PNT Advisory Board activities are not impacted
- PNT Board agenda topics comprise PNT EXCOM taskings as well as independent issue areas as decided by the Chair, PNT Board Steering Group, and Working Group leads
- Recommendations are formally presented to PNT EXCOM for discussion and action



Previous PNT Board Engagement Activities & Recommendations

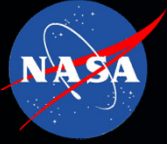
- Eliminate S/A capabilities from GPS III
 - Officially announced by DoD DepSec England on Sep. 18, 2007
- Implement Laser Retro-reflector Arrays on GPS III
 - MOU signed by Gen Shelton (AFSPC), Gen Kehler (USSTRATCOM), and C. Bolden (NASA) on Aug. 22, 2013
- Incorporate NASA worldwide civil-signal monitoring into OCX for verification of GPS signal performance
 - Cost effective, early satisfaction of up to 96% of requirements
 - On-going discussions with DOT for longer term solution alternatives
- Ensure balanced, transparent, and comprehensive participation by agencies, manufacturers, and users in spectrum studies impacting GPS/GNSS
 - Full understanding and agreement of assumptions, alternatives & impacts
 - Multiple on-going Adjacent Band Compatibility assessments being revisited
 - PNT Board fully supports DOT test approach & methodology (time/resources!)





Ongoing PNT Board Engagement Activities & Recommendations

1. Formally Designate GPS as a Critical Infrastructure Sector for the United States
 - 14 of 16 current Critical Infrastructure sectors are deeply dependent
2. Develop a Formal National Threat Model for PNT Applications in Critical Infrastructure
 - Build on earlier effort at the Department of Transportation (DOT)
3. Prevent the Proliferation of Licensed Emitters in GPS Frequency Bands
 - Threat continues, slippery slope on Gold Code and/or spectrum use
4. Establish a Nationwide CONUS Back-Up to GPS with Existing Infrastructure *(eLoran) as example for timing*
 - Previously adopted by PNT EXCOM, requires designated authority and budget resolution



Spectrum Valuation arguments by comm world triggered GPS Economic Benefit Assessment

ExCom Directed Study Results:
 GPS Annual Economic Benefits exceed \$37B-\$74B:

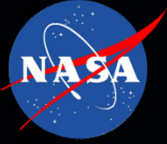
- US Only
- Only a Subset of User Sectors were included

Table 10. Preliminary 2013 U.S. GPS Economic Benefit Estimates

| | Application Category | Range of Benefits (\$billions) | Mid-range Benefits (\$billions) |
|---|---|--------------------------------|---------------------------------|
| A | Precision Agriculture – grain* | 10.0-17.7 | 13.7 |
| A | Earthmoving with machine guidance in construction* | 2.2-7.7 | 5.0 |
| A | Surveying | 9.8-13.4 | 11.6 |
| A | Air Transportation | .119-.168 | 0.1 |
| C | Rail Transportation – Positive Train Control | .010-.100 | 0.1 |
| C | Maritime Transportation – private sector use of nautical charts and related marine information* | .106-.263 | 0.2 |
| A | Fleet Vehicle Connected Telematics* | 7.6-16.3 | 11.9 |
| A | Timing 1 – Loran | .025-.050 | 0.0 |
| A | Timing 2 – GEOs | .025-.075 | 0.1 |
| B | Consumer Location-Based Services 1 – vehicle – willingness-to-pay* | 4.7-6.3 | 5.5 |
| A | Consumer Location-Based Services 2 – vehicle – value of time | 9.8-31.4 | 20.6 |
| | TOTAL (with alternative estimates for timing and consumer LBS averaged) | 37.1-74.5 | 55.8 |

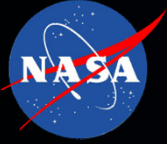
C=confident, B=indicative and C=notional.

*Includes indirect benefits from cost savings.



Present-day PNT Board Objectives

- Primary PNT Board Objective (ongoing major focus)
 - **Assured PNT for all Users**
- Current Assessment
 - No current or foreseeable alternative to GNSS
 - **Selected** Addressable Threats
 - **Potential Interference from Adjacent RF Bands** (e.g. strong communication signals)
 - **Deliberate Jamming** (e.g. inexpensive small jammers)
 - **Deliberate Spoofing** (e.g. misleading signals causing false GNSS measurements)
- PNTAB Advocated Strategy - the **PTA Program**
 - **P**rotect the radio spectrum + identify + prosecute interferers
 - **T**oughen GPS receivers against natural and human interference - (Spoofing and Jamming)
 - **A**ugment with additional PNT sources and Techniques



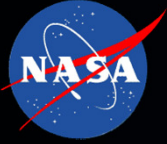
17th PNT Advisory Board Meeting: GPS Threats & Opportunities = Spectrum!

- 17th PNT Board meeting held May 18-19, 2016 at the Gaylord Convention Center, National Harbor, near Washington D.C.
 - Agenda/Briefings: <http://www.gps.gov/governance/advisory/meetings/2016-05/>
- **Priority Focus is on GNSS Spectrum Protection as strategic foundational effort**
 - U.S. Department of Transportation (DOT) update on GPS Adjacent Band Compatibility (ABC) assessment
 - *Roberson* results on behalf of *Ligado*, on separate GPS / Adjacent Band co-existence study
 - **PNT Advisory Board discussions led to development of Criteria for Spectrum Assessments**



NASA Deputy Administrator
Dr. Dava Newman





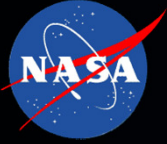
PNT Board Recommended Criteria for Assessing Interference to GPS and GNSS Applications (1)

1. Adhere to 2012 PNT EXCOM letter guidance to ensure that new spectrum proposals “are implemented without affecting existing and evolving uses of space-based PNT services”
2. Strictly apply the 1 dB degradation Interference Protection Criterion (IPC)
 - Backed by decades of regulatory precedence and has been used to protect GPS and other radio systems such as radars
 - Most recently, the 1 dB IPC was mandated by NTIA for testing in 2011, the results of which were cited in the January 2012 PNT EXCOM letter to NTIA
3. Protect all classes of GPS receivers, including precision and timing receivers
 - Over half the US\$55B annual benefit of GPS comes from the Precision class of GPS receivers
 - These Precision receivers provide sub-centimeter-level positioning accuracy and require picosecond-level measurement precision, which must be protected
 - Most high-precision receivers utilize more accurate carrier phase measurements and differential networks of receivers, in which interference to one receiver can severely degrade accuracy
 - In addition, thousands of precision timing receivers are used throughout the U.S. critical infrastructure such as cellular networks and electrical power grids



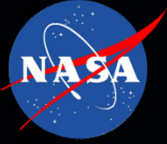
PNTAB Recommended Criteria for Assessing Interference to GPS and GNSS Applications (2)

4. Protect GPS receivers in all receiver operating modes, including signal acquisition/reacquisition
 - GPS receiver metrics such as position error are products of the receiver’s navigation algorithms, not the radio “front end” of the GPS device where harmful interference first occurs
 - GPS and GNSS receivers must be protected in all phases of operation, including signal acquisition and reacquisition, when receivers are most susceptible to interference
5. Protect all uses of emerging Global Navigation Satellite System (GNSS) signals
 - Signed treaties require the United States to protect the entire Radio Navigation Satellite Service (RNSS) bands, not just the portions used by GPS
 - This will enable the full future potential of multi-constellation GNSS receivers, which promise increased availability, accuracy, and integrity for all classes of space-based PNT users
6. Use maximum authorized transmitted interference powers and propagation models that do not underrepresent the maximum power of the interfering signal
 - In particular, consider the impact of multiple transmitters creating additive interference
 - One company / entity should not “eat up” entire safety margin established for aggregate environment of users, not or planned in the future



Recommendation for GNSS Providers to Establish Advisory Boards

- At the 9th meeting of ICG, PNT Board Vice-Chair, Dr. Bradford Parkinson presented on how to “Protect, Toughen, and Augment” GNSS to ensure future worldwide PNT user needs are met
- The briefing highlighted the importance of interoperability and compatibility, and how the U.S. PNT Board benefits from international participation and collaboration
- He concluded by recommending that other GNSS providers consider establishing similar citizen-based user advisory boards that build on this model and strengthen collaboration amongst user groups around the world
- The 18th PNT Board meeting is tentatively scheduled for Dec 7-8, 2016 near the GPS-Directorate in Los Angeles, CA. The PNT Board would welcome an update on the progress of this Recommendation pending the results of ICG-11.



Closing Remarks

- The U.S. will maintain GPS as the “gold standard” as other international PNT constellations come online. It is recognized that all PNT service providers share the same values in wanting to provide the best services to their users
- As we move forward in our ICG work, all participants share a collective responsibility to shape the operating environment so that PNT services reach their full potential and national investments are protected from disruption.
- Citizen-based PNT Advisory Boards are a critical tool to support policy makers in assessing strategic GNSS threats and opportunities and for formulating responses. The National Space-based PNT Advisory Board looks forward to working with ICG partners in doing this on a global scale.

The screenshot shows the GPS.gov website with the following content:

- Header:** GPS.gov logo, "Official U.S. Government information about the Global Positioning System (GPS) and related topics", and a search bar.
- Navigation:** Home, What's New, Systems, Applications, **Governance**, Multimedia, Support.
- Breadcrumbs:** Home » Governance » Organization » Advisory Board
- Left Sidebar (GOVERNANCE):** Policy & Law, Organization (National Executive Committee, Federal Agencies, National Coordination Office, **Advisory Board**, Civil GPS Service Interface Committee), Program Funding, Congress, International Cooperation, Spectrum & Interference, Privacy.
- Left Sidebar (TAKE ACTION):** Bookmark this page, Share this page, Print this page, Get website updates via RSS, Comment on this page, Get help and support.
- Main Content:**
 - Title:** National Space-Based Positioning, Navigation, and Timing Advisory Board
 - Image:** A photograph of a meeting in progress.
 - Text:** The National Space-Based Positioning, Navigation, and Timing (PNT) Advisory Board provides independent advice to the U.S. government on GPS-related policy, planning, program management, and funding profiles in relation to the current state of national and international satellite navigation services.
 - Meetings:** Next Meeting: May 18-19, 2016. Location: Gaylord National Resort & Convention Center, National Harbor, Maryland. Includes a button for "View agenda & presentations" and a link for "VIEW OFFICIAL ANNOUNCEMENT".
 - Membership:** Includes a group photo of the board members and a link for "VIEW PREVIOUS MEETING INFORMATION".
 - Establishment & Sponsorship:** The Advisory Board is one of three national...

www.gps.gov/governance/advisory/