Communications and External Relations Subcommittee

US National Space-based PNT Advisory Board

Subcommittee Mandate:

- *User & industry outreach*
- *Messaging to U.S. public*
- *Inform & educate government stakeholders*

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US National Space-based PNT Advisory Board

Value of GPS, impacts of loss

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USG change how it describes impacts of an extended GPS outage

- **Title of Recommendation: USG change how it describes impacts of an extended GPS outage**
- **Finding:**
  - The finding by a 2019 RTI/Department of Commerce study that a long-term disruption to GPS would damage the U. S. economy by one billion dollars a day represents less than a 1.7% degradation to GDP. This appears to be a gross underestimation.
  - By way of a benchmark infrastructure failure, the 2021 winter power outage in Texas caused almost $28B/day of property damage, and the loss of least 57 lives. The US power grid is reliant upon GPS. While the Texas grid failure was not caused by a GPS failure, an extended GPS outage would likely have a similar impact.
  - Quantitative methods of describing such an event may well be ineffective
- **Recommendation:**
  - EXCOM to develop a compelling qualitative way to accurately express the economic damage to the nation of extended disruptions to GPS services.
- **Rationale for Recommendation:**
  - Use of inaccurate loss figures for GPS will cause analysts and policy makers to under appreciate impacts in risk-based decision processes.
- **Consequences of No Action on the Recommendation:**
  - Erroneous risk analyses, policy, budget, and investment decisions.

USG change how it describes impacts of an extended GPS outage (supp)

Additional information:

- U.S. annual GPD is $22+ trillion a year. $60B+ a day. One billion dollars is approx. 1.7%.
- GPS provides both timing and location information.
- GPS is primary location source for geo-spatial services
  - 2012 Boston Consulting Group report on US: "Geospatial services drive $1.6T in revenue and $1.4T of cost savings" per year (1)
- GPS use has propagated across every sector from agriculture, to energy and transportation, to the wheels of economy. GPS is now part of the fabric of daily life of our society. Putting a value on daily loss of GPS, while informative, can be compared to a pandemic or a tsunami, that we know is coming, yet waiting for a more definitive observation which will be embarrassing for the Government and frankly be another reactive response as opposed to being proactive.
- GPS is primary time source for networks, all critical infrastructure.
- 'What's the value of GPS? What's the value of oxygen?" (2)
- Performing scientific and probabilistic analysis about the value of the loss of GPS while required, can come from initiatives that Government can undertake immediately with a directive requiring assessment, cost, and roadmap.
- "In February 2021, an extreme winter storm event caused a massive electricity generation failure in the state of Texas, which resulted in a loss of power for more than 4.5 million homes. This failure has resulted in at least 57 deaths across 25 Texas counties and over $195 billion in property damage…" **Note: Does not address non-property damage economic loss.** (4)
- Unavailability of GPS could be paralleled to inadequate infrastructure. Two more incidents have been in the Electric Energy sector. 1996 (Pacific Northwest) and 2003 (North East) cascading outages. This resulted in reliability policy and nearly $ 85B in infrastructure, which included $35B for Green Energy, "Smart Grid" deployment, situational awareness, and resilience systems. (3)
- RTI Report only addressed GPS use in 10 industries. (5)

(1) "Putting the U.S. Geospatial Services Industry On the Map," Boston Consulting Group December 2012
(2) "Pinpoint – How GPS is Changing Technology, Culture and Our Minds," Greg Milner, W. W. Norton, 2016
(3) "ARRA, Its Details, With Pros and Cons", US and World Economics, https://www.thebalance.com/arra-details-3306299
(4) https://energy.utexas.edu/ercot-blackout-2021
(5) https://www.rti.org/news/new-report-reveals-economic-benefits-private-sector-use-gps

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Government communications during and after GPS disruption events

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Technology
Hyperdrive

Dallas Air Traffic Rerouted as FAA Probes Faulty GPS Signals

- Pilots, controllers using older technology to navigate
- 'Very unusual' air navigation glitch, says flight-track expert

By Alan Levin and Mary Schlangenstein
October 18, 2022 at 9:54 AM PDT *Updated on October 18, 2022 at 12:40 PM PDT*

From **Hyperdrive**

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Flights into the Dallas area are being forced to take older, cumbersome routes and a runway at Dallas-Fort Worth International

GPS WORLD GNSS POSITIONING NAVIGATION TIMING

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What happened to GPS in Denver?

September 21, 2022 - By Dana Goward

Est. reading time: 3 minutes

Photo: YayaErnst/iStock/Getty Images Plus/Getty Images

Something big happened to GPS service in the Denver area on Jan. 21.

Notice To Airmen 21 January 2022
NAV GPS UNREL(INCLUDING WAAS, GBAS, AND ADS-B) MAY NOT BE AVBL WI A 50NM RADIUS

DOT Issue public warnings during GPS disruptions

- **Title of Recommendation:** Dept. of Transportation issue public warnings during GPS disruptions
- **Finding:**
  - The Denver area experienced a powerful, widespread GPS disruption between 21 & 23 January 2022 that lasted 33.5 hours.
  - A similar event occurred in Dallas on 17 & 18 October.
  - Aviation & other users were impacted. It appears only aviation users were provided warnings while the outage was underway.
- **Recommendation:**
  - US DOT issue public warnings as soon as possible after the beginning of significant disruption events.
- **Rationale for Recommendation:**
  - Users will be better able to protect themselves if they are advised of the outage.
  - Less time wasted trying to diagnose problems.
  - Alert for possible hazardously misleading information.
  - US Government has a fundamental duty to protect citizens.
- **Consequences of No Action on the Recommendation:**
  - Potential loss of life and property that could have been avoided.

DOT Issue public warnings during GPS disruptions (supp)

Considerations for Govt in Execution:

- Warnings should be issued as soon as possible after beginning of event
- Likely many agencies, including non-DOT help with public notification
- FAA has been doing this for aviation. Should they be the model or lead in some way?
- Need to determine impacted area(s) to issue good warnings
- Method(s) to cancel when event is over
- Include standard info on GPS outage impacts with warnings
- Request feedback on observed impacts
- Request feedback from those with complementary systems and ability to carry on
- Funding personnel required to implement
- Some methods of dissemination available now:
  - Amber Alerts
  - Notices to Mariners, Notices to Airmen, Highway digital signs
  - Local Media Press Releases

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PNT disruption as cyber, vs electronic warfare, vs other?

Image: Shutterstock

Include PNT Security in National & Agency Cybersecurity Portfolios

- **Title of Recommendation:** Include PNT Security in National & Agency Cybersecurity Portfolios
- **Finding:**
  - PNT sources and end-use devices are forms of computers
  - GPS as the US's primary source of PNT is particularly vulnerable to accidental interference & malicious manipulation
    - Extensive data transport by RF, weak signals, open signal specification
  - Many GPS & other PNT devices now in use have little to no protection against disruption
  - Govt leaders & public recognize & understand need for Cyber security. Much lower level of understanding of PNT security
- **Recommendation - EXCOM to recommend:**
  - Include PNT security s a clear part of National Cyber Director's responsibilities
  - Departments and agencies to include PNT security in cyber portfolios
- **Rationale for Recommendation:**
  - Reinforces/ alerts official recognition of the criticality of PNT in national networks and infrastructure, supports Zero Trust
  - Improve senior leadership awareness and attention to PNT
- **Consequences of No Action on the Recommendation:**
  - GPS continues to be a "single point of failure" for the U.S.

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Federal government protecting itself w/ resilient PNT equipment and sources.

Image: DOT

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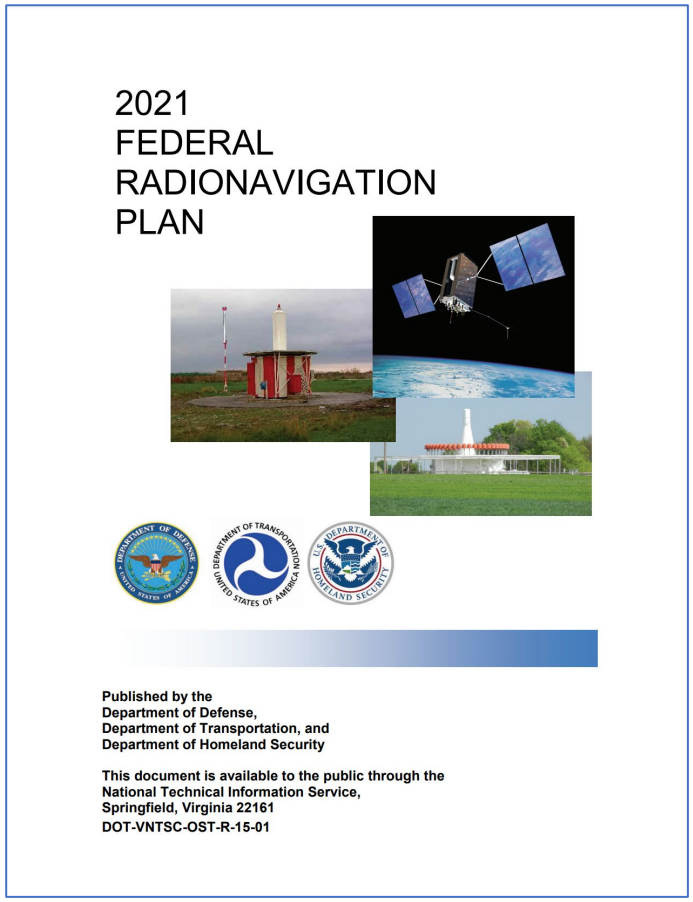
Federal Radionavigation Plan (2021) NTRSA Language

- Value of GPS timing, value of protecting it
- Free-to-user GPS impact on market for sufficient complementary timing / PNT
- Impact of:
  - Economic benefit of ensuring “uninterruptable” timing/ PNT, devices, sources, applications
  - Strategic value of making GPS a much less attractive target
  - US adversary capabilities to cause and weather disruptions to GNSS



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Public views/knowledge about PNT resilience

Image: Shutterstock

National PNT Advisory Board – 27th Meeting, Nov. 2022 Finding and/or Recommendation (1)

- **Title of Recommendation:** Implement a GPS High Accuracy and Resilience Service (HARS)
- **Finding:**
  - GPS is falling behind Galileo and Beidou by not providing high accuracy and authentication services.
  - This risks GPS losing current status as the primary GNSS used in most GNSS chips
  - There are U.S. agencies/organizations that already generate the data products needed and assisted GPS services that deliver similar types of data to users via the internet.
- **Recommendation:**
  - The U.S. government should develop and implement a GPS high accuracy and resilience service (HARS) delivered to users on the internet with performance initially comparable to that of other constellations.
  - The service should provide both corrections to support PNT at the <1m level and satellite NAV data bits.
- **Rationale for Recommendation:**
  - This action will rapidly improve the quality of GPS real-time performance and resilience for users and enhance GPS-based applications, based on existing U.S. capabilities, and without any changes to GPS satellite operations.
- **Consequences of No Action on the Recommendation:**
  - GPS is likely to lose its relevance in the hierarchy of satellite navigation systems.
  - GPS users will suffer from lower quality data and be more vulnerable to spoofing than users of other GNSS.

National PNT Advisory Board – 27th Meeting, Nov. 2022 Finding and/or Recommendation

- **Title of Recommendation:** Invest in the future of US PNT education and training
- **Finding:**
  - China and other countries are gaining on the U.S. or are already ahead in general R&D investment
  - Specifically true for PNT with the emergence of Galileo, Beidou, QZSS, etc.
  - To be competitive, the U.S. needs to expand PNT education.
- **Recommendation:**
  - Need to invest in the future of US PNT education and training
- **Rationale for Recommendation:**
  - Need to expand GNSS Curriculum at US universities.
  - Promote and expand Industry-University partnership
  - Benefit from international partnership
- **Consequences of No Action on the Recommendation:**
  - The US PNT skills gap with continue to grow to potentially critical levels

SPACE-BASED POSITIONING
NAVIGATION & TIMING
NATIONAL ADVISORY BOARD

PTA Subcommittee Recommendations

PTA Subcommittee
16 November 2022

National PNT Advisory Board Protect, Toughen, Augment Subcommittee Recommendation (11/15/2022)

Title of Recommendation: Establishing the Extent That We Should Rely on GPS Infrastructure

Finding:

There are no authoritative assessments of the likelihood and extent (temporal, geographic) that the GPS Infrastructure (monitoring and control, constellation and satellites, signals) could fail in different time frames, due to any cause.

Recommendation:

The U.S. Government establish, publish, and maintain estimates of the likelihood that GPS would not provide sufficient useful civil signals, from any cause. These estimates would describe the likelihood of GPS Infrastructure failure for different durations in different time frames.

Reasons for Recommendation:

There currently are wildly diverse opinions concerning the likelihood and extent that the GPS Infrastructure could fail in different time frames. Those making risk management decisions, and those investing in Protecting, Toughening, and Augmenting GPS lack the information needed to select the right approaches and how urgent it is to implement them. Only a team with the right expertise and information can assess the aggregate likelihood of such failures due to various causes—benign, natural, and malicious.

Consequences of No Action on the Recommendation:

Currently, the U.S. risks inconsistent development and fielding of Protecting, Toughening, and Augmenting GPS. Some may be investing in Protect and Toughen when Augment is more appropriate, or vice versa. Some may be undertaking greater expense and disruption than is needed, while others may risk experiencing a problem before they are ready for it.

National PNT Advisory Board Protect, Toughen, Augment Subcommitee Recommendation 16 November 2022

Title of Recommendation: Deploy National GNSS Interference Detection and Reporting Network based on Mobile Wireless Technology

Finding:

All mobile wireless devices (a.k.a. smartphones) produce GNSS signal quality metrics which, when aggregated, can be applied for effective crowd-sourcing methods of GNSS interference detection and geolocation.

Recommendation:

Rapidly deploy a National GNSS Interference Detection and Reporting system based on mobile wireless technology

Reasons for Recommendation:

With collaboration of wireless service carriers, GNSS interference detection could be deployed to collect and process smartphone interference observables, geolocate interference sources, and provide timely notification to regulatory or enforcement authorities. Such a system would have been very beneficial in responding to multiple interference events at major US airports in 2022.

Consequences of No Action on the Recommendation:

Without a reliable, automated means of detection and locating sources of GNSS interreference, space-based PNT applications, and the general US public, will continue to be plagued by potentially life-threatening and/or costly service disruptions that take days or weeks to resolve

National PNT Advisory Board Protect, Toughen, Augment Subcommitee Recommendation 19 May 2022

Title of Recommendation: Modify Export Controls for GNSS Adaptive Antennas (AA)

Finding:

Current export control regimes are outdated, ineffective at limiting availability of AA technology outside the US, and are unduly hampering development of AA products of potentially great benefit in toughening GNSS.

Recommendation:

Recommend through ExCom to Departments of State and Commerce: Modify or eliminate current export controls to enable civil, commercial “Interference Protection/Suppression” and “Signal Manipulation Protection” antenna and receiver antenna electronics while maintaining national security critical GPS anti-jam/anti-spoofing controls..

Reasons for Recommendation:

Manifold: 1) Current controls are hampering civil applications of the technology. 2) Civil community has a need for AA technology to protect Critical Infrastructure and Safety applications. 3) Current controls are not meaningfully preventing the proliferation of the technology outside the US. (See white paper)

Consequences of No Action on the Recommendation:

Currently, the U.S. risks losing any lead we had in this technology. Civil Critical Infrastructure and Safety Applications will remain vulnerable. US companies will continue to be disadvantaged in the market and hence will be reticent to invest in needed product developments.

Preliminary Options for Review
(from draft white paper based on views/information collected by TSC)

Two potential proposals for modifying the current ITAR controls are offered for consideration.

1) Remove adaptive antenna systems from the ITAR, section XI(c)(10) completely or with a specific carve out for satellite navigation system antennas:

> (10) Antenna, and specially designed parts and components therefor, that:
>
> (i) Employ four or more elements, electronically steer angular beams, independently steer angular nulls, create angular nulls with a null depth greater than 20 dB, and achieve a beam switching speed faster than 50 milliseconds;
>
> (ii) Form adaptive null attenuation greater than 35 dB with convergence time less than one second;

2) If recommendation 1 is not acceptable, it may be feasible and reasonable to decrease the convergence time to much less than1 second in section XI(c)(10)(ii). We would recommend either 1 ms or 10 ms in place of one second. We recommend decreasing the time parameter of section XI(c)(10)(ii) as opposed to the null attenuation parameter because it is difficult to limit the null attenuation of an anti-jam system.

If either recommendation (1) or (2) is implemented, controls could remain in place under the EAR (Department of Commerce) section 7A005. Most aviation companies could live with this level of control, and it still leave government control in the areas of NS (National Security), MT (Missile Technology) and AT (anti- terrorism).

National PNT Advisory Board – November 2022 Recommendation – **White House Summit: Future GPS & PNT Infrastructure for National Security & Economic Growth** (50 years on)

- **Finding:**
  - GPS is America's gift to the world – first approved 1973.
  - The PNT services it provides are fundamentally embedded in our national security and the successful functioning of our economy.
  - China's BeiDou system and the EU's Galileo surpass US PNT in both resilience and capability.
  - Adversaries are able to deny GPS service to America.
  - GPS & PNT modernization requires holistic systems approach, including protecting signals, toughening receivers, and augmenting services.
  - Needed technologies are mature and readily available.
  - U.S. Government efforts appear disparate and unfocused. Industry cannot fill gaps without clearer governmentleadership and support.
  - PNT decision-making authority is diffuse and lacks a clear locus of leadersip.
- **Recommendation:**
  - Convene a White House summit celebrating U.S. achievements with GPS and launch new era of innovation and prosperity.
    - Goal: Sharpen, improve agility of PNT governance
    - Goal: Facilitate, enable, direct implementation of systems approach to resilient National PNT Architecture
- **Reason for Recommendation:**
  - GPS & PNT services are essential yet face significant threats.
  - Enormous economic benefits (services, device manufacture, R&D, new applications, ex: autonomy, spectrum efficiency)
- **Consequences of No Action on the Recommendation:**
  - U.S. competitiveness suffers; U.S. leadership in PNT technology will be unsustainable.
  - U.S. becomes increasingly vulnerable to GPS and/or PNT disruption impacting infrastructure, economic activity including supply chains.

Additional information:

China's "Comprehensive PNT" per presentation at 2019 Stanford PNT Symposium and other intel includes:

- PNT satellites at GEO, MEO, and LEO
- Precisely measured fiber infrastructure to enable highly accurate time transmission
- Plans to use 5G infrastructure for PNT
- eLoran across entire nation to "insure against loss of space signals"
- Aggressive research into IMUs, CSACs, other

China PNT Architecture shown 2019 Stanford

Russia PNT architecture, per Commonwealth of Independent States Radionavigation Plan 2019 -2024:

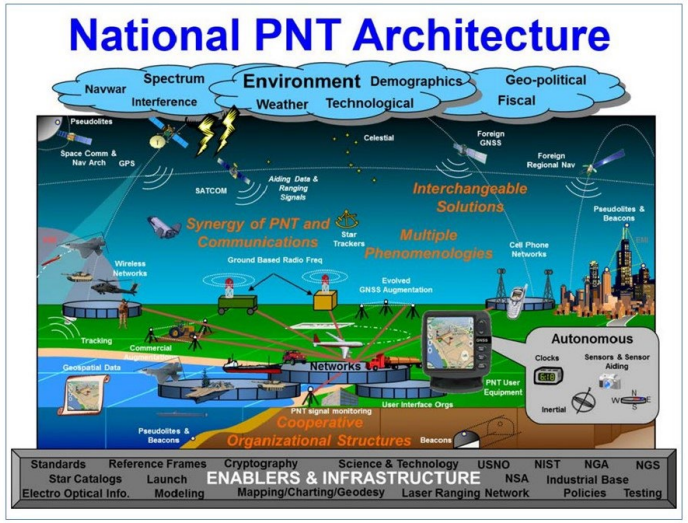
- GLONASS at MEO
- Chayka (version of Loran-C) east, west & Arctic
- "Skorpion" – poss mobile & tactical version of Chayka

Significant Hostile Threats to GPS use:

- China – cyber, jamming, spoofing, grappling satellites, directed energy
- Russia – cyber, jamming, spoofing, nesting doll satellites, directed energy, poss nuke powered space jammer
- Iran – cyber, noteworthy spoofing and jamming, space capable
- North Korea – cyber regular jamming, space capable
- Non-state actors – cyber, jamming, spoofing

Non-Hostile Threats to GPS use:

- Human error, system malfunction (ex: Jan 2016)
- Space debris & Kessler Event – 19% of tracked debris is in MEO
- Coronal Mass Ejection, other solar – Carrington+ Event est 4%/yr
- Non-Hostile Threats Σ(p) >0 (sum of probabilities of devastating non-hostile events is greater than zero)



US National PNT Architecture 2008
Image also copied & used by Chinese

National PNT Advisory Board – 27th Meeting, Nov. 2022 Finding and/or Recommendation

Conduct Administration-Wide Review of Spectrum Allocation Process

- **Title of Recommendation:** Conduct Administration-Wide Review of Spectrum Allocation Process

- **Finding:**
  - By statute, spectrum allocation decisions for commercial users in the U.S. are exclusively the responsibility of the FCC, an independent regulatory agency.
  - Executive Branch agencies are represented in FCC proceedings by the National Telecommunications and Information Administration.
  - Recent FCC decisions have been issued despite the strong objections of Executive Branch agencies, who warned of potentially adverse consequences for America's national security, national defense, aviation safety, and other equities for which those other federal agencies are responsible.
- **Recommendation - The Executive Office of the President should undertake an Administration-wide review of our spectrum allocation process.**
  - Among the issues to be explored should be:
    - whether a statutory amendment should be proposed to protect the integrity of critical spectrum-reliant systems;
    - whether it remains appropriate to treat federal agencies reliant on clean spectrum as mere "interested parties" in FCC spectrum proceedings; and
    - whether, at a time when the spectrum is increasingly crowded, the need for state-of-the-art receivers is getting sufficient attention.
- **Rationale for Recommendation:**
  - FCC spectrum allocation decisions must be consistent with the requirements of national security and the safety of life.
  - The beneficiaries of FCC decisions will enjoy greater certainty regarding the sustainability of those decisions.
- **Consequences of No Action on the Recommendation:**
  - More instances of the FCC permitting commercial uses of spectrum that interfere with critical systems for which Executive Branch agencies have responsibility, thereby potentially compromising national security and the safety of life.