

Resilient Navigation & Timing US Government Policy & Decisions - Summary

While reliance on a single source for precise navigation and timing information has been a recognized as a potential problem since the 1980's, the United States first began addressing it in a more deliberate way in the early years of this century. Innumerable studies, presentations, and policies have been published on the issue.

The first policy action and direction were taken by President Bush in 2004 in NSPD-39. As of this writing, many of its provisions have yet to be fulfilled.¹

October 1997 – **Report of Presidential Commission on Critical Infrastructure Protection**

‘Evaluate disruption risk impact on decision to base all aviation navigation on space assets by 2010.’

May 1998 – **PDD-63 Critical Infrastructure Protection** – DoT and DoD evaluate dependency of transportation infrastructure on GPS, especially the National Airspace System.

August 29, 2001 – **Volpe Transportation System Center Report – Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System**² – ‘Cancel plans for all space-based air navigation, investigate navigation and timing alternatives, enhanced Loran looks promising.’

December 2004 – **NSPD 39, U.S. Space-Based Position, Navigation, and Timing Policy** (Classified).³

- Goals included:
 - Maintain PNT “...augmentation and backup...” capabilities
 - “...provide uninterrupted availability of (PNT) services...”
- Established National Space-Based Positioning, Navigation, and Timing Executive Committee (PNT EXCOM), National Coordination Office, & PNT Advisory Board
- Tasked DOT and DHS to “Develop, acquire, operate, and maintain backup position, navigation, and timing capabilities...” per HSPD 7 dtd 17 Dec 2003⁴

Note: President Obama ratified this NSPD when he came into office as did President Trump. It is still in force.

March 2007

- **DOT & DHS accepted the Institute for Defense Analysis report** recommending enhanced Loran (eLoran) as national backup system⁵.
- **PNT EXCOM supported this approach** and tasked DOT & DHS with developing an action plan that included designating an executive agent.

¹ Much of the early portion of this timeline is documented in the 2010 Federal Radionavigation Plan available at: http://www.navcen.uscg.gov/pdf/2010_FRP_FINAL_Signed.pdf

² https://www.navcen.uscg.gov/pdf/vulnerability_assess_2001.pdf

³ Unclassified parts summarized: <https://www.fas.org/irp/offdocs/nspd/nspd-39.htm>

⁴ <https://www.dhs.gov/homeland-security-presidential-directive-7>

⁵ http://ntl.bts.gov/lib/31000/31300/31359/24_2009_IAT_Summary_of_Initial_Findings_on_eLoran.pdf

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February 2008

- **A DHS press release stated that the department would implement eLoran**, using the old Loran-C infrastructure (7 February)⁶
- **The DHS “2009 Budget in Brief” proposed transferring the legacy Loran-C systems and \$34.5M/yr from Coast Guard to NPPD**, stating:

“The FY 2009 budget transfers the budget authority for the LORAN C system from the United States Coast Guard to the NPPD. The Department, acting as Executive Agent, will begin development of enhanced eLORAN as a backup for the Global Positioning System (GPS) in the homeland.”

March 2008 - **PNT EXCOM endorsed DOT/DHS decision** to transition Loran to eLoran

September 2008 -

- **“National PNT Architecture Study – Final Report”** was published. This public document was prepared by the National Security Space Office. It called for decreased reliance on GPS as a single source for navigation and timing information.⁷
- **Continuing Resolution that provided funding for DHS in FY 2009 did not include an excursion** to transfer funding and authority for Loran to NPPD. Members of Congress and staff expressed support for eLoran, but were concerned at the lack of a documented transition plan for the move between agencies. Staff indicated that the request should be resubmitted with the next year’s budget, along with a transition plan, and that it would be approved.

January 2009 – **Institute of Defense Analysis** Report “Independent Assessment Team (IAT) Summary of Initial Findings on eLoran”. Provided to the two deputy secretaries in 2007, it is published two years later, strongly recommends eLoran as national complement to GPS.⁸

June 2009 – **PNT Advisory Board** recommends adopting eLoran as backup for GPS⁹

October 2009 – **DHS FY-10 Appropriations Act** directed termination of Loran-C signal in Jan 2010¹⁰. No funds were provided to establish a new system.

⁶ <http://rntfnd.org/wp-content/uploads/DHS-Press-Release-GPS-Backup-2008.pdf>

⁷ <https://rosap.ntl.bts.gov/view/dot/34816>

⁸ http://ntl.bts.gov/lib/31000/31300/31359/24_2009_IAT_Summary_of_Initial_Findings_on_eLoran.pdf

⁹ <https://www.gps.gov/governance/advisory/recommendations/2009-06-finalreport.pdf>

¹⁰ <http://www.gpo.gov/fdsys/pkg/PLAW-111publ83/pdf/PLAW-111publ83.pdf>

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November 2009 – **US DoT Volpe Center Final Report** *Benefit-Cost Refresh, The Use of eLoran to Mitigate GPS Vulnerability for Positioning, Navigation, and Timing Services*¹¹

January 2010 – **National PNT Advisory Board** “Jamming the Global Positioning System – A National Security Threat: Recent Events and Potential Cures” This white paper includes numerous recommendations, one of which is prompt execution of the US decision to implement eLoran as a terrestrial backup for GPS.¹²

July 2010 – **National PNT Architecture Implementation Plan** approved.¹³

October 2010 - **USCG Authorization Act (Sect 219)** required **DHS to determine if a single domestic GPS backup for navigation** was needed before dismantling Loran infrastructure.

November 2010 – **PNT Advisory Board** **whitepaper**¹⁴ on GPS jamming recommends eLoran or similar as backup for GPS

September 2011- **DHS report to Congress** “**Analysis of Whether a Single Domestic Backup Navigation System is Needed for the Global Positioning System (GPS)**” Report labeled “For Official Use Only.” A redacted copy of the report¹⁵ was obtained in 2015 under FOIA by the RNT Foundation. It stated that Loran was not needed for a universal navigation backup, but that 15 of 18 critical infrastructure sectors used GPS timing, there may not be adequate backup, and more study was needed. However, since the department certified Loran was not needed for a navigation backup, per congressional direction. Dismantling and disposal of infrastructure began.

November 2011 – **DHS National Risk Estimate** concluded “U.S. critical infrastructure sectors are increasingly at risk from a growing dependency on GPS for positioning, navigation, and timing (PNT) services; such dependencies are not always apparent.” Redacted report obtained under FOIA in 2105.¹⁶

February 2012 - **Wireless Precise Time project** began by DHS (through US Coast Guard) through Cooperative Research and Development Agreement (CRADA) with UrsaNav, Inc. using some of the remaining Loran infrastructure.¹⁷

February 2013 – **PPD-21 Critical Infrastructure Security and Resilience**

¹¹ <https://rntfnd.org/wp-content/uploads/Benefit-Cost-of-eLoran-Volpe-Center-2009.pdf>

¹² <http://www.gps.gov/governance/advisory/recommendations/2010-11-jammingwhitepaper.pdf>

¹³ <https://rosap.ntl.bts.gov/view/dot/18293>

¹⁴ <https://www.gps.gov/governance/advisory/recommendations/2010-11-jammingwhitepaper.pdf>

¹⁵ <http://rntfnd.org/wp-content/uploads/Sec-219-redacted-Non-FOUO.pdf>

¹⁶ <http://rntfnd.org/wp-content/uploads/DHS-National-Risk-Estimate-GPS-Disruptions.pdf>

¹⁷ <https://www.nautelnav.com/in-the-news/ursanav-tests-loran-lf-timing-potential/>

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August 6, 2013 – **Progress brief on Wireless Precise Time CRADA** to DHS & interagency staff. Project confirmed eLoran meets needs of almost all users & is very hard to disrupt.

December 2013 – **National Defense Authorization Act for 2014** directed the administration to report to Congress on how, in the event space systems are disrupted, DOD and the intelligence community “...**plan to provide necessary national security capabilities through alternative space, airborne, or ground systems...**”¹⁸

August 2014 – **PNT Advisory Board recommends** establishing GPS backup with eLoran.¹⁹

December 2014 – **President signs S.2444, the Howard Coble US Coast Guard Authorization Act for 2014 into law.** It contains the provisions cited above regarding a GPS backup system and eLoran.

SEC. 221. E-LORAN.

(a) IN GENERAL.—The Secretary of the department in which the Coast Guard is operating may not carry out activities related to the dismantling or disposal of infrastructure that supported the former LORAN system until the later of—

(1) the date that is 1 year after the date of enactment of this Act; or

(2) the date on which the Secretary provides to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate notice of a determination by the Secretary that such infrastructure is not required to provide a positioning, navigation, and timing system to provide redundant capability in the event GPS signals are disrupted.

(b) EXCEPTION.—Subsection (a) does not apply to activities necessary for the safety of human life.

(c) AGREEMENTS.—The Secretary may enter into cooperative agreements, contracts, and other agreements with Federal entities and other public or private entities, including academic entities, to develop a positioning, timing, and navigation system, including an enhanced LORAN system, to provide redundant capability in the event GPS signals are disrupted.

January 2015 – **The US Army issues a Request for Information** regarding purchase of 50,000 eLoran receivers for use by DOD units around the world.

¹⁸ <http://rntfnd.org/2014/01/01/us-congress-focuses-on-space-vulnerability-in-defense-act/>

¹⁹ <https://www.gps.gov/governance/advisory/meetings/2014-12/minutes.pdf#page=41>

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March 2015 –

- The **Department of Transportation announces in the Federal Register that the government is considering eLoran for a backup to GPS** and asking for public comment by the 22nd of May. See footnote for link to notice and summary of responses.²⁰
- **Congressman Garamendi introduces a bill that would amend the GPS section of Title 10** to also require the Secretary of Defense to work with the Secretary of Transportation and build a difficult to disrupt terrestrial system to complement and backup GPS.
- **DHS issues a press release announcing resumption of the CRADA** examining the use of eLoran signals.
- **NIST Lack of Effective Timing Signals Could Hamper IOT Development**²¹

August 2015 - **Five Congressmen write to the Deputy Secretaries of Transportation and Defense** expressing concern over the lack of action on its commitment to a complementary and backup system for GPS and the threat over-dependency on GPS poses to the nation.²²

November 2015 – **NDAA for 2016** - DoD provide HASC briefing on DoD requirements for backup position, navigation, and timing capabilities, including the plan and estimated cost to address such requirements January 15, 2016.

December 2015 – The Deputy Secretaries of Transportation and Defense sent a letter to the five Congressmen stating that the **administration will first build an eLoran timing system** and then a larger network to provide positioning, navigation and timing.²³

January 2016 – **A software error in a GPS** control system caused 15 of the 31 satellites to transmit timing signals that were in **error by 13.7 microseconds**. This minor problem caused alarms, activation of backup systems, and other faults in many receivers around the world. Digital radio broadcasts were disrupted in Europe, public safety communications systems, telecommunications systems, and aviation ground systems were all impacted. The incident was widely observed by the electric power and science communities.²⁴ See blog posts at RNTFnd.org for more information on the incident.

April 2016 - DASD-Space provides incorrect and misleading testimony regarding DoD readiness for GPS denied environments, status of GPS signals, and status of Loran systems worldwide. He is subsequently chastised by Cong. Garamendi in a multi-page letter.²⁵

²⁰ <http://rntfnd.org/wp-content/uploads/Summary-of-Public-Comments-with-Links-to-Submissions.pdf>

²¹ <https://www.nist.gov/news-events/news/2015/03/lack-effective-timing-signals-could-hamper-internet-things-development>

²² <http://rntfnd.org/wp-content/uploads/Congressional-Letter-to-PNT-Executive-Committee.pdf>

²³ <http://rntfnd.org/wp-content/uploads/DSD-and-Dep-DOT-reply-to-Mr.-Garamendi.pdf>

²⁴ <http://rntfnd.org/2016/02/15/us-govt-gps-errors-felt-around-the-globe-across-industries/>

²⁵ <https://rntfnd.org/2016/04/28/pentagon-confusion-on-gps-backupeloran/>

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June 2016 –

- Congressmen Duncan Hunter and John Garamendi introduce **HR 5531 with provisions that would make the US Coast Guard responsible for establishing an eLoran system**²⁶. The bill passes the House in September but is bundled with a number of other miscellaneous provisions for Coast Guard and does not pass the Senate before the end of the session.
- The Dept of Homeland Security continues to focus on assured time as a research goal with a project announcement.²⁷
- PNT EXCOM statement that the nation will “backup GPS”²⁸

July 2016 – NIST “Networks of Things” report discusses need for good time throughout.²⁹

August 2016 –

- Continuing efforts by some to use frequencies adjacent to GPS for high power transmissions. Widespread concern that this will disrupt many receivers.³⁰
- DOT Volpe Report “GPS Dependencies in the Transportation Sector”³¹

September 2016 – Dept of Homeland Security established PNT Program Management Office. Requests help from the public identifying timing requirements for various industry sectors.³²

October 2016 – National Institutes of Standards holds first of a series of workshops on Timing and Smart Grid. It shows that electrical grids use timing extensively now and this will greatly increase in the future.³³

November 2016 – Department of Transportation issues RFI seeking technologies that could provide complementary and backup service for GPS. Also asks about business models that could have primary responsibility rest with private sector.³⁴

²⁶ <http://rntfnd.org/wp-content/uploads/HR-5531-22-June-2016.pdf>

²⁷ <https://www.fbo.gov/index?s=opportunity&mode=form&id=6574302fd2d6352c9abc6920f5f127ae&tab=core&cvview=0>

²⁸ <https://insidegnss.com/pnt-excom-to-write-requirements-for-gps-backup/>

²⁹ <https://rntfnd.org/wp-content/uploads/NIST-SP-800-183.pdf>

³⁰ <http://rntfnd.org/2016/08/02/dueling-government-studies-gps-interference-the-new-lightsquared-ligado/>

³¹ <https://rosap.ntl.bts.gov/view/dot/12386>

³² <http://rntfnd.org/2016/09/23/new-dhs-pmo-for-pnt-request-for-help/>

³³ <http://rntfnd.org/2016/10/27/timing-smart-grid-quotes-fm-nist-workshop/>

³⁴ <https://www.gpo.gov/fdsys/pkg/FR-2016-11-30/pdf/2016-28805.pdf>

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December 2016 –

- National Defense Authorization Act for 2017 report language;
 - Requires the Secretaries of Defense, Transportation and Homeland Security to “...study to assess and identify the technology-neutral requirements to backup and complement the positioning, navigation, and timing (PNT) capabilities of the Global Positioning System for national security and critical infrastructure.”
 - “The committee is also aware that a **complementary PNT tiger team recommended eLoran as the leading candidate for fulfilling the maximum number of PNT user needs within the next 5 years for certain sectors, but that there is currently no planned funding for this capability.**”
- **National Cyber Commission** identifies need to protect PNT³⁵
- **Telecom industry** presentation at National PNT Advisory Board identifies need for stronger PNT, addresses eLoran.³⁶
- DHS solicits for Interference Detection & Mitigation technology, announces jamming exercise³⁷

January 2017 –

- **DHS announces recommended mitigation measures** to counter jamming and spoofing including mounting fake antennas.³⁸
- **DOT releases forward looking “Beyond Traffic 2045”** which identifies GPS dependency and vulnerability as a critical issue going forward.³⁹
- FCC seeks comment about allowing Galileo use in the US acting on a 12 year old request from the EU.⁴⁰
- DHS allows release of 2016 eLoran test results⁴¹
- **DHS official says that reports of US adversaries wanting to harm nation by disrupting GPS are increasing.**⁴²
- **US Drones to Ukraine to vulnerable to GPS spoofing/ jamming**⁴³

³⁵ <https://www.nist.gov/cybercommission>

³⁶ <http://rntfnd.org/2016/12/12/telecom-industry-comes-down-hard-for-better-pnt/>

³⁷ <https://www.fbo.gov/index?s=opportunity&mode=form&id=5fc205b8d974de2f27a371d69f1dea15&tab=core&cvview=0>

³⁸ https://ics-cert.us-cert.gov/sites/default/files/documents/Improving_the_Operation_and_Development_of_Global_Positioning_System_%28GPS%29_Equipment_Used_by_Critical_Infrastructure_S508C.pdf

³⁹ https://www.transportation.gov/sites/dot.gov/files/docs/BeyondTraffic_tagged_508_final.pdf

⁴⁰ <http://www.insidegnss.com/node/5295>

⁴¹ <http://rntfnd.org/2017/01/25/eloran-time-results-fm-2016-tests-demos/>

⁴² <http://rntfnd.org/2017/02/08/threats-to-damage-us-via-gps-disruption-increasing-dept-of-homeland-security/>

⁴³ <https://rntfnd.org/2017/01/01/millions-in-us-supplied-drones-for-ukraine-disappoint-too-vulnerable-to-jamminghacking/>

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February 2017 -

- **Senator Blunt asks DOT Inspector General** at a hearing where the department is on providing a complementary and backup capability for GPS. Other questions submitted to be answered for the record.⁴⁴
- DHS invites GPS receiver manufacturers to April event to test equipment in a live jamming environment.⁴⁵
- **Performance standard for maritime eLoran** receivers issued⁴⁶

March 2017 -

- **Senator Cruz** questions USCG Commandant, ADM Zukunft, on GPS backup/eLoran⁴⁷
- **House Armed Services Strategic Forces Subcommittee and House Homeland Security Committee joint hearing** - "Threats to Space Assets and Implications for Homeland Security."⁴⁸

April 2017 - **Senator Cruz** questions USAF GEN Hyten about GPS reliance⁴⁹

May 2017

- Space Weather Act passes Senate⁵⁰
- **Director National Intelligence** 'US adversaries focusing on jamming GPS, other satellites'⁵¹

June 2017

- **Navy League** testifies at Congressional hearing on need for GPS backup/ eLoran⁵²
- **UK Govt** study says nation will suffer \$1.3B/day damage w/o GNSS⁵³
- **USAF press release** says "GPS near perfect" in 2016 despite major timing problem⁵⁴
- **Dr B. Parkinson, "Father of GPS"** calls for immediate eLoran build⁵⁵

⁴⁴ <http://rntfnd.org/2017/02/10/sen-roy-blunt-at-hearing-where-are-we-on-gps-backp/>

⁴⁵ <https://www.fbo.gov/index?s=opportunity&mode=form&id=bbd0ff24da6a8ad8e3d0e6122a5f71ec&tab=core&cvview=0>

⁴⁶ <https://rntfnd.org/2017/02/01/performance-std-for-marine-loran-receivers-issued/>

⁴⁷ <https://rntfnd.org/2017/03/24/senator-cruz-admiral-zunkunft-on-gps-backupeloran/>

⁴⁸ <https://rntfnd.org/2017/03/30/congress-hearing-focuses-on-gps-disruption-homeland-security/>

⁴⁹ <https://rntfnd.org/2017/04/13/gen-hyten-sen-cruz-gps-reliance-threats-to-space/>

⁵⁰ <https://rntfnd.org/2017/05/04/with-2t-in-damage-looming-senate-passes-space-weather-act/>

⁵¹ <https://www.dni.gov/files/documents/Newsroom/Testimonies/SSCI%20Unclassified%20OSFR%20-%20Final.pdf>

⁵² <https://rntfnd.org/2017/06/09/video-navy-league-to-congress-gps-a-single-point-of-failure-loran/>

⁵³ <https://rntfnd.org/2017/06/19/1-32bday-damage-wo-gnss-new-uk-study-points-to-loran-satelles/>

⁵⁴ <https://rntfnd.org/2017/06/20/gps-performance-near-perfect-usaf-press-release-ignores-problems/>

⁵⁵ <https://rntfnd.org/2017/06/29/father-of-gps-calls-for-immediate-loran-build/>

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September 2017

- **Air Traffic Control Newsletter** supports establishment of eLoran⁵⁶
- **US MARAD issues Global GPS disruption reminder**⁵⁷
- **Telecom Std Organization**, ATIS, recommends eLoran to govt⁵⁸

October 2017 - **Hon Michael Griffin tells National Space Council GPS disruption** could bring economy to near collapse.⁵⁹

November 2017 - **Sen Cruz questions DOT** nominee about GPS backup⁶⁰

December 2017 -

- **NDA 2018 signed - requires GPS Backup Tech Demo**⁶¹
- **AF Secretary worried about losing GPS**⁶²

January 2018 -

- DHS released best practices for GNSS users⁶³
- DHS “Threats to GPS real and relevant”⁶⁴

February 2018 -

- DHS RFI “Alternative PNT for GPS Degraded Environment”⁶⁵
- **National Space Council** presentation – “Holistic thinking like eLoran needed”⁶⁶

March 2018 -

- **Dept of Defense Approps \$10M** for GPS backup tech demo⁶⁷
- **US MARAD Advisory GPS interference** Eastern Mediterranean⁶⁸

⁵⁶ <https://rntfnd.org/2017/09/11/air-traffic-control-newsletter-supports-eloran-legislation/>

⁵⁷ <https://rntfnd.org/2017/09/13/us-marad-gps-disruption-reminder/>

⁵⁸ <https://rntfnd.org/2017/09/17/telecom-organization-recommends-eloran-system/>

⁵⁹ <https://rntfnd.org/2017/10/22/adversary-can-bring-our-economic-system-near-collapse-presidents-national-space-council-panel/>

⁶⁰ <https://rntfnd.org/2017/11/01/sen-cruz-discusses-gps-vulnerability-eloran-at-hearing/>

⁶¹ <https://rntfnd.org/2017/12/13/president-signs-law-requiring-demo-of-gps-backup-system/>

⁶² <https://rntfnd.org/2017/12/20/what-if-we-lost-gps-thats-one-thing-worrying-the-air-force-secretary-la-times/>

⁶³ <https://ics-cert.us->

[cert.gov/sites/default/files/documents/Improving the Operation and Development of Global Positioning System %28GPS%29 Equipment Used by Critical Infrastructure S508C.pdf](cert.gov/sites/default/files/documents/Improving_the_Operation_and_Development_of_Global_Positioning_System_%28GPS%29_Equipment_Used_by_Critical_Infrastructure_S508C.pdf)

⁶⁴ <https://rntfnd.org/2018/01/23/threats-to-gps-real-relevant-us-dept-of-homeland-security/>

⁶⁵ <https://rntfnd.org/2018/02/26/dhs-looking-for-gps-complementary-and-backup-systems/>

⁶⁶ <https://rntfnd.org/2018/02/27/holistic-thinking-such-as-eloran-needed-to-protect-space-assets-testimony-at-national-space-council/>

⁶⁷ <https://rntfnd.org/2018/03/30/10m-funds-gps-backup-tech-demo-gps-gov/>

⁶⁸ <https://www.maritime.dot.gov/content/2018-014-eastern-mediterranean-sea-gps-interference>

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May 2018 -

- USAF C-TRAC Design Sprint for PNT Signals⁶⁹
- Congressional Hearing – “GPS jamming and spoofing a major maritime concern”⁷⁰

July 2018 - NASA Administrator “Space Force to guard GPS”⁷¹

August 2018 -

- New DHS Risk Center to deal with GPS, PNT issues⁷²
- **NDA for 2019** reaffirms interest in GPS Backup Tech Demo, authorizes +\$5M

September 2018 -

- USCG posting GPS disruption reports on website⁷³
- SAE publishes standards for eLoran signals⁷⁴
- **DOD Approps** for 2019 provides +\$5M for GPS Backup Tech Demo
- **PNT Advisory Board** recommends eLoran timing system backup for GPS⁷⁵

October 2018 -

- **USCG Strategy** ‘GPS Reliance is a cyber threat to maritime commerce’⁷⁶
- **GAO Report** “GPS hackers could send weapons to wrong target.”⁷⁷
- **FCC votes to allow Galileo use** in United States

November 2018 - **DHS Secretary** “GPS Disruption threat high on worklist”⁷⁸

December 2018 - **National Timing Resilience and Security Act** – requires DoT to establish terrestrial backup for GS timing by 2020, funds permitting.⁷⁹

⁶⁹ <https://insidegnss.com/c-tracs-advanced-signals-design-sprint-focuses-on-pnt-signals/>

⁷⁰ <https://rntfnd.org/2018/05/10/gps-jamming-and-spoofing-a-major-concern-in-maritime-congressional-hearing/>

⁷¹ <https://www.bloomberg.com/news/articles/2018-07-12/trump-s-space-force-will-guard-u-s-from-above-nasa-chief-says>

⁷² <https://rntfnd.org/2018/08/12/new-dhs-risk-center-to-deal-with-gps-pnt-issues/>

⁷³ <https://rntfnd.org/2018/09/14/gps-problem-reports-now-available-to-public-us-coast-guard/>

⁷⁴ https://www.prweb.com/releases/sae_international_issues_transmitted_enhanced_looran_signal_standards/prweb15770639.htm

⁷⁵ <https://www.gps.gov/governance/advisory/recommendations/2018-09-topic-papers.pdf>

⁷⁶ <https://rntfnd.org/2018/10/12/gps-reliance-is-cyber-threat-to-maritime-commerce-us-coast-guard-strategy/>

⁷⁷ <https://insidegnss.com/gps-hackers-could-send-weapons-to-wrong-target-gao-report/>

⁷⁸ <https://rntfnd.org/2018/11/10/gps-risk-high-on-dhs-work-list-secretary-nielsen/>

⁷⁹ <https://www.gpsworld.com/gps-to-get-terrestrial-backup-system/>