DIPLO SPACE · FIELD NOTE 01

When GPS Lies

A largely invisible dependency, a cross-border operational threat, and the range of resilience choices states have made — translated for the officials who must weigh them

Applied-research field note · Edition 2.0 · Diplo Space, Inc. (Virginia 501(c)(3), EIN 99-1402470) · Every claim traced to a public primary source · The lab takes no policy position

By Brandon N. Eickhoff · CEO, Diplo Space · howdy@diplospace.org

Start here — the plain-English version. GPS does something simpler than most people assume: it broadcasts the time. Atomic clocks aboard satellites about 20,000 km (12,500 miles) up send down the exact time, and a receiver on the ground works out where it is from how long each signal took to arrive. GPS is the American system; Europe runs Galileo, Russia GLONASS, and China BeiDou — collectively these are called **GNSS** (Global Navigation Satellite Systems). That free signal from space has quietly become load-bearing far beyond driving directions: it timestamps financial trades, keeps mobile networks in step, and tells the power grid when to act. The catch is that by the time it reaches the ground the signal is fainter than the background radio noise around you — about as faint as a car headlight seen from orbit. Overpower it and a receiver goes deaf; that is **jamming**. Feed it a convincing counterfeit and the receiver is confidently wrong; that is **spoofing** — the more dangerous of the two, because nothing looks broken. The rest of this note quantifies what depends on that signal, shows how interference became a daily and cross-border reality, and lays out the resilience choices governments face — every figure traced to a public source, no policy position taken.

ABSTRACT The Global Positioning System is critical infrastructure disguised as a convenience. A 2019 study prepared by RTI International for the U.S. National Institute of Standards and Technology (NIST) estimated approximately $1.4 trillion in U.S. private-sector benefit from GPS between 1984 and 2017, and modeled a sustained-outage cost on the order of $1 billion per day — a figure its authors describe as “at best a rough estimate.” This field note translates that dependency for non-specialist officials. It quantifies the economic stakes; documents how GNSS radio-frequency interference (RFI) has moved from wartime contingency to a daily civil-aviation reality — GPS signal-loss events rose roughly 220% between 2021 and 2024 in IATA’s flight-data record, and in early 2026 interference around the Strait of Hormuz affected more than a thousand vessels in a single day — with interference emitted near conflict zones spilling across borders into the airspace and sea lanes of non-belligerent states; and lays out, without prescribing a remedy, the range of resilience choices states have made. Because civil-aviation and maritime harm is reported through ICAO, EASA, EUROCONTROL, IATA, and IMO channels, GNSS interference is now an inherently international governance question — which is the lens this note adopts.

How to read this note. Sections 1–2 establish what GPS is worth and who depends on it. Sections 3–4 show how the threat became a daily, cross-border reality, drawing on two 2026 episodes. Sections 5–7 survey the resilience choices, the backup-technology landscape, and the policy record. Section 8 explains why this is a space-governance question. Section 9 poses the questions a policymaker must weigh. A glossary precedes the references. Every headline figure is sourced to a public primary document; figures marked illustrative depict structure, not measured values.

$1.4T	~$1B/day	+220%	1,100+
U.S. GPS benefit, 1984-2017 (NIST)	modeled sustained-outage cost	aviation interference, 2021-2024	vessels' GPS jammed in 24h, Hormuz 2026

1 Introduction: the invisible utility

Most critical infrastructure is visible. A bridge, a power line, a pipeline — each announces its own importance and, when it fails, the cause is rarely a mystery. The Global Positioning System is different. It is a faint signal broadcast from medium Earth orbit, freely available to any receiver, that has quietly become a load-bearing element of the modern economy: it synchronizes telecommunications networks, timestamps financial transactions to the microsecond, guides aircraft along performance-based routes, and steers precision agriculture. Its invisibility is precisely what makes its fragility consequential. A dependency few people can see is a dependency few institutions are organized to manage, and one whose failure is diagnosed slowly because the symptoms — a desynchronized network, a drifting position, a mistimed transaction — do not obviously point back to a lost satellite signal.

This field note advances three observations and deliberately stops at their edge. First, the economic dependence on GPS is large and has been quantified by the U.S. government's own standards body. Second, the threat to it is no longer a wartime hypothetical but a daily operational reality that crosses national borders and is documented through international channels. Third, states facing the same dependency have made materially different resilience choices — a divergence that is itself a governance question worth seeing clearly. The note describes these facts and the choices they imply; it does not tell any government which choice to make. That restraint is a design commitment, not a limitation: Diplo Space exists to translate contested questions into a form officials can weigh, and translation loses its value the moment it becomes advocacy.

2 The economic dependency, quantified

The authoritative estimate of GPS's economic value in the United States comes from a 2019 study conducted by RTI International for NIST.[1] It found that GPS had generated approximately $1.4 trillion in private-sector benefit over three decades of civil availability:

$$B_{\text{GPS}} \approx \$1.4 \text{ trillion} \quad (1984\text{-}2017,\ \text{RTI/NIST})$$

The same study modeled the cost of a prolonged outage. Its headline figure — which the authors are careful to frame as a rough estimate rather than a precise forecast — is on the order of $1 billion per day, a figure the U.S. Cybersecurity and Infrastructure Security Agency (CISA) independently cited to Congress in 2020.[1,2] The estimate's value is not its false precision but its order of magnitude: the daily cost of losing GPS is measured in billions, and the cumulative benefit in trillions.

That dependence is not distributed evenly across the economy. Some sectors rely on GPS chiefly for its positioning signal; others, less obviously, for its timing signal, which disciplines the clocks that order transactions and synchronize networks. Telecommunications and the electricity grid are the most timing-critical; precision agriculture is the most positioning-critical and, because planting and harvest are time-bound, bears the sharpest seasonal shock.

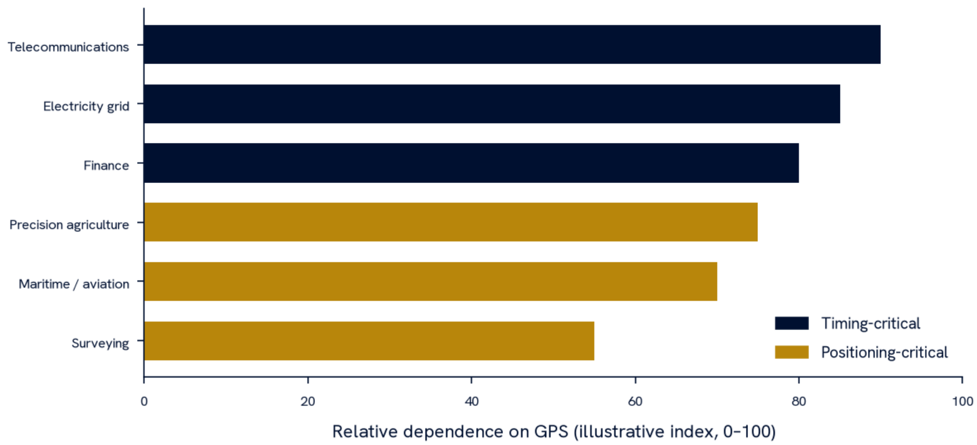

Figure 1. Relative dependence on GPS timing or positioning across major economic sectors (illustrative index ranking the reliance the RTI/NIST study describes qualitatively; not a measured quantity). Timing-critical sectors fail differently from positioning-critical sectors — a distinction that matters for which resilience measures help whom.

Agriculture illustrates how the cost of an outage is itself timing-dependent. Because the U.S. planting window is compressed into a few spring weeks, an outage in April or May imposes losses well above the daily baseline; the NIST study estimated agricultural losses during that window could reach roughly $15 billion.[1] The lesson for a governance audience is that "the cost of a GPS outage" is not a single number but a distribution — concentrated in specific sectors, specific functions (timing versus positioning), and specific weeks of the year.

The timing dependency deserves particular emphasis because it is the least intuitive. GPS satellites carry atomic clocks, and the free civilian signal is, in effect, a globally available source of precise time. Telecommunications networks use it to keep base stations synchronized; financial markets use it to timestamp and sequence trades; and, as Field Note 02 examines in detail, the electricity grid uses it to synchronize the measurements that protect against cascading failures. A positioning outage is visible and self-announcing; a timing outage can propagate silently through systems that never mention GPS in their user manuals.

Finance is the clearest case of a timing dependency written into regulation. Rules governing modern electronic markets require trading events to be timestamped and sequenced to fine tolerances so that transactions across venues can be reconstructed in order — a synchronization that traceable, precise time makes possible and that a widespread timing disruption would degrade. The point for a governance audience is not the specifics of any one rule but the pattern: precise time has become a silent input to regulatory compliance, not merely to operational convenience.

3 From contingency to daily reality — and across borders

For most of GPS's history, the risk of large-scale denial was treated as a wartime contingency. That framing is now obsolete. GNSS radio-frequency interference comes in two forms: *jamming*, which overpowers the satellite signal until a receiver can no longer use it, and *spoofing*, which broadcasts a counterfeit signal that causes the receiver to compute a false position or time — often without triggering any cockpit warning. European regulators now judge spoofing the more dangerous of the two precisely because it is harder to detect and can corrupt several aircraft systems at once.

The trend is unambiguous. According to IATA's Global Aviation Data Management Flight Data eXchange — which aggregates reporting from more than 300 operators — the number of GPS signal-loss events rose approximately 220% between 2021 and 2024.[3] The U.S. FAA's own data show GNSS signal-loss events per 1,000 flights rising 65% in the first half of 2024 relative to the same period a year earlier.[7] More than a thousand flights a day now operate through some degree of jamming or spoofing.

$$R_{\text{interference}} = \frac{\text{events}_{2024}}{\text{events}_{2021}} \approx 3.2\times \quad (+220\%)$$

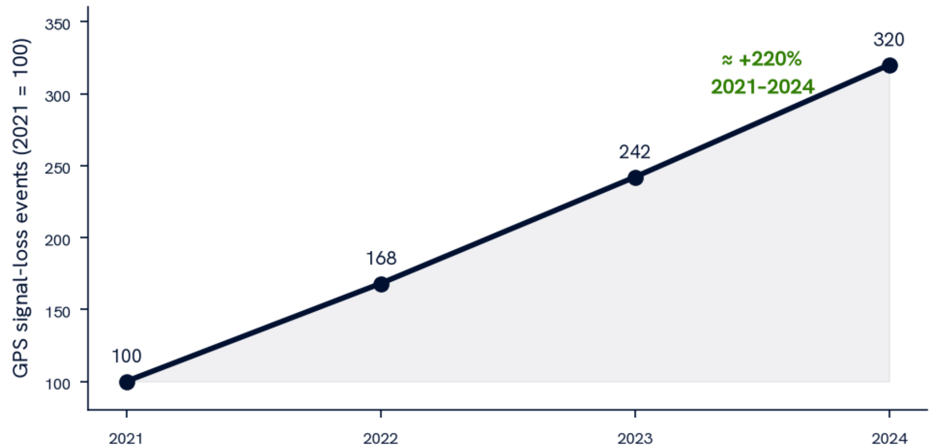

Figure 2. GPS signal-loss events reported through IATA's GADM Flight Data eXchange, indexed to 2021 = 100. The roughly 220% increase across 2021–2024 tracks the spread of interference from conflict zones into adjacent civil airspace. (Intermediate years interpolated between IATA's reported endpoints.)

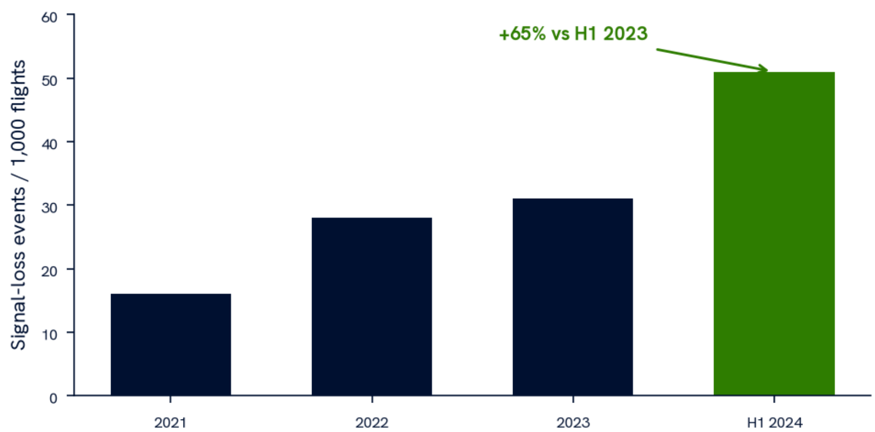

Figure 3. FAA-reported GNSS signal-loss events per 1,000 flights. The first-half-2024 value is 65% above the same period in 2023.

The decisive fact for a governance audience is that this interference does not respect borders. EASA's Safety Information Bulletin 2022-02R3 identifies sustained interference across the Baltic Sea, Black Sea, eastern Mediterranean, Middle East, and Arctic — regions surrounding conflict zones, where the emitter and the affected aircraft are frequently in different countries.[4] Interference radiated near a war zone degrades the navigation environment of neighbouring states that are not parties to the conflict.

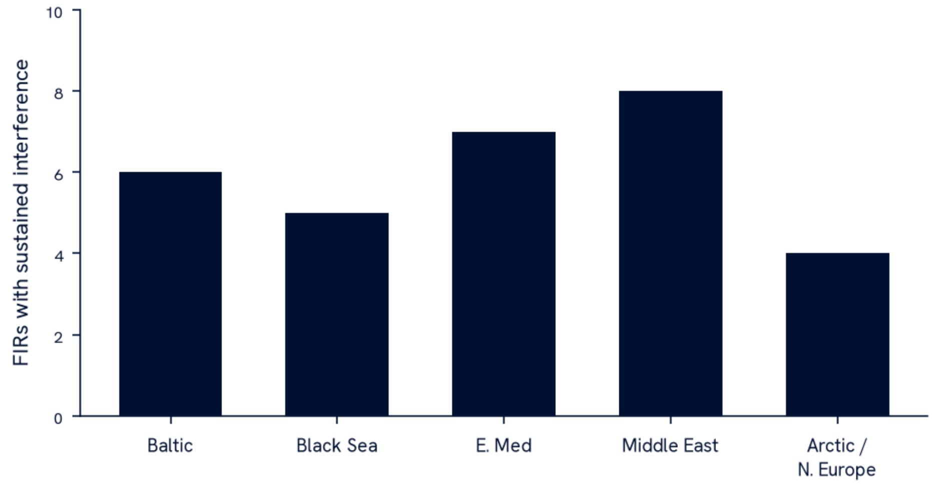

Figure 4. Flight Information Regions with sustained GNSS interference, grouped by theatre, per EASA advisories (illustrative counts). Because an FIR is an international air-traffic jurisdiction, interference that crosses FIR boundaries is by definition a cross-border governance problem.

The maritime domain shows the same pattern. Ships rely on GNSS for navigation and for the Automatic Identification System (AIS) that lets vessels and shore authorities see one another; interference degrades both at once. In June 2025, a collision between two tankers near the Strait of Hormuz was linked in press reporting to GNSS interference in the area — a foreshadowing of the far larger episode that followed months later.

4 Two 2026 episodes: a strategic waterway and an American city

Two recent events make the abstract concrete — one international, one domestic — and together they show that the exposure is neither hypothetical nor confined to distant conflict zones.

The Strait of Hormuz, early 2026. Shipping through the Strait of Hormuz was largely blocked from 28 February 2026, when the United States and Israel launched air operations against Iran and the Islamic Revolutionary Guard Corps issued warnings against passage. Alongside the physical threat came GNSS interference on a scale not previously documented in a commercial waterway. Maritime-intelligence firm Windward reported that more than 1,100 vessels were affected by GPS and AIS interference within a single 24-hour period at the outset.[14] Lloyd’s List Intelligence, tracking the pattern into early March, recorded roughly 600 GNSS-jamming incidents involving vessels off the UAE alone, with more than 80 off Iran, about 50 off Oman, and around 10 off Qatar[14] — an interference footprint spanning the waters of several non-belligerent Gulf states. Ships were shown on tracking systems piled atop one another, moving at impossible speeds, or stranded on land. The Strait normally carries roughly a fifth of the world’s seaborne oil; during the episode, transits collapsed. Lloyd’s List reported shipping’s risk appetite for the route being severely tested, with owners weighing the hazard of ‘dark’ transits — sailing with AIS switched off — and reopening efforts making little headway in the weeks that followed. Precise transit counts during the disruption vary by source and tracking method, but traffic through one of the world’s most strategic waterways fell sharply and remained depressed. The interference did not distinguish between belligerent and neutral traffic — it degraded the navigation environment for every ship in the strait, regardless of flag.

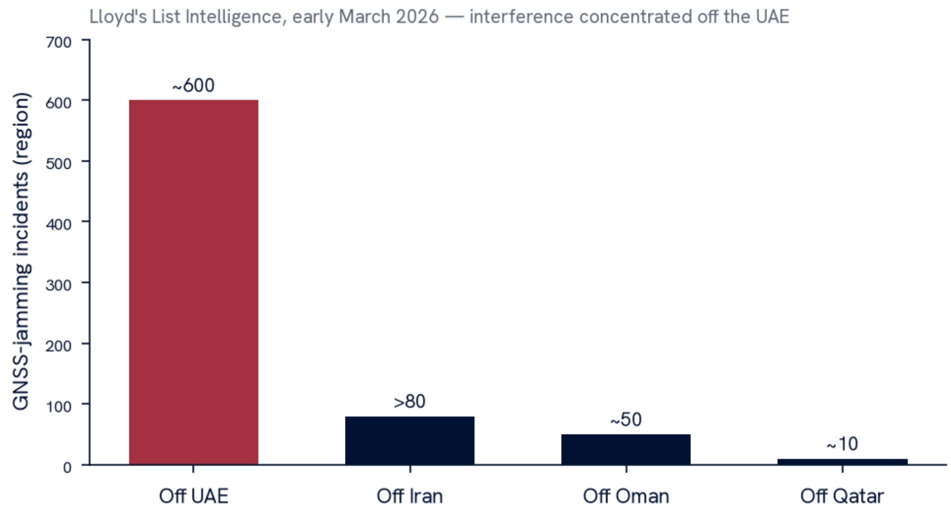

Figure 5. GNSS-jamming incidents by location during the early-March 2026 Strait of Hormuz episode, as tracked by Lloyd's List Intelligence. The interference was concentrated off the UAE but reached the waters of Iran, Oman, and Qatar — a cross-border footprint in one of the world's most strategic waterways.

The Hormuz episode is a governance case study in miniature. The band GNSS uses for radionavigation is internationally allocated and protected under the ITU framework, which prohibits harmful interference with the radionavigation-satellite service.[12] A disruption of this scale in an international strait therefore implicates not only the states directly involved but the international spectrum-governance regime — a connection this note returns to in Section 8.

Denver, Colorado, January 2022. Interference is not only a feature of overseas conflict. In January 2022, a GPS disruption around Denver International Airport persisted for roughly 33 hours and affected an area on the order of 8,000 square miles, reaching aircraft at altitudes up to 40,000 feet. The FAA issued advisories; the source was ultimately identified and terminated by the FCC's Enforcement Bureau as an unauthorized transmitter operating on a GNSS frequency.[15] The episode is a reminder that a single emitter — accidental or deliberate — can deny GPS across a metropolitan region for more than a day, and that detection and attribution can take many hours even inside a country with a well-resourced spectrum regulator. It also illustrates the cross-sector reach of a timing disruption: interference in the Denver area was reported to affect terrestrial users, not only aircraft.

5 A divergence in resilience choices

Faced with the same dependency and the same rising threat, states have made materially different choices about resilience. Some have invested in terrestrial backup timing and positioning; others have chosen to rely on the space signal alone, whether by deliberate cost-benefit judgment or by default. The United States decommissioned its LORAN-C terrestrial navigation system in 2010, and the question of whether and how to field a modern terrestrial complement has been the subject of policy activity ever since. Several other states and regions have retained or are re-examining terrestrial timing infrastructure.

It is important to be precise about what this divergence is and is not. It is not evidence that one state is "ahead" and another "behind"; a terrestrial backup carries costs — spectrum, capital, maintenance — that a government may rationally decline to bear given its particular risk profile. What the divergence does mean is that the world's critical infrastructure is converging on a shared dependency while its resilience arrangements diverge. That combination — common exposure, uncommon protection — is exactly the kind of asymmetry that becomes a governance question when interference crosses borders, because the least-protected link shapes the risk faced by its neighbours.

6 The technology landscape: why there is no single answer

Part of what makes GPS resilience a hard governance problem is that there is no drop-in replacement. The signal's combination of global coverage, free access, and precise timing is difficult to reproduce with any single alternative. Instead, the emerging consensus — reflected in the U.S. Department of Transportation's 2021 demonstration of eleven complementary-PNT technologies and in the FCC's 2025 framing of a "system of systems" — is that resilience will come from layering several imperfect options rather than adopting one perfect one.

The main candidates each solve part of the problem and leave part unsolved. *Terrestrial low-frequency systems* such as eLoran offer a strong, hard-to-jam timing and positioning signal with wide area coverage, but require ground infrastructure and spectrum.[11] *Broadcast Positioning Systems (BPS)* would embed timing in existing television broadcast signals, reusing infrastructure but with limited coverage. *Terrestrial 5G-based positioning* leverages cellular networks but is confined to areas with dense coverage. *Low-Earth-orbit (LEO) PNT* — from commercial constellations — promises strong signals and broad coverage but is still maturing. *Fiber-based time distribution* offers extremely precise timing to fixed sites but cannot serve mobile users. The policy implication is that a resilient PNT architecture is a portfolio decision, and portfolio decisions require an authority able to weigh options across domains — precisely the kind of cross-domain translation that is scarce.

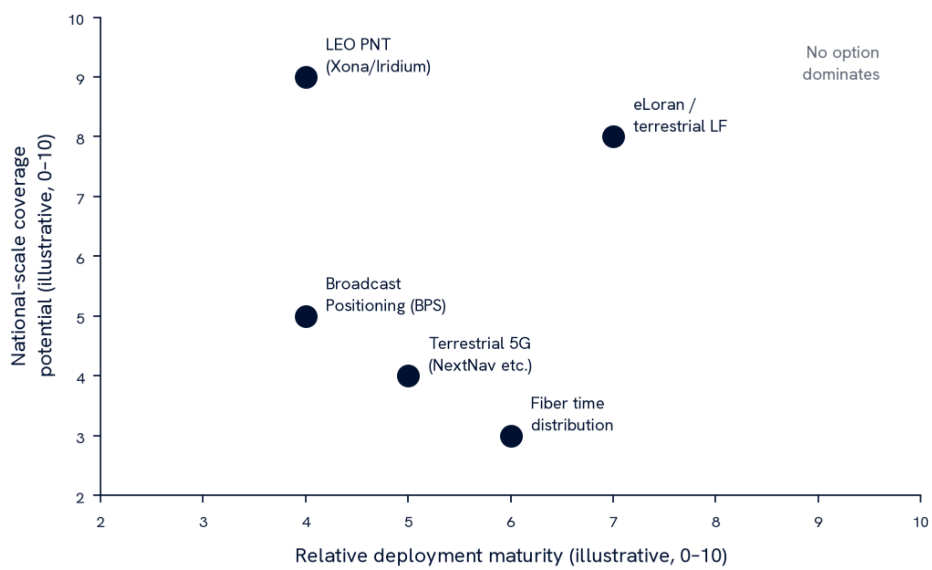

Figure 6. Complementary-PNT options positioned by relative deployment maturity and national-scale coverage potential (illustrative, to show trade-off structure rather than measured values). No single option occupies the high-maturity, high-coverage corner — which is why the policy conversation is about a layered mix, not a winner.

7 The policy record

The policy response has been substantial but diffuse, spread across many agencies and instruments. In the United States, Executive Order 13905 (February 2020) directed a government-wide approach to responsible PNT use;[8] the national space-based PNT policy issued as Space Policy Directive-7 in January 2021 updated the framework governing the service;[13] the Department of Transportation demonstrated eleven complementary technologies and later let vendor contracts to advance them;[11] the Department of Homeland Security published Resilient PNT best practices; and in March 2025 the Federal Communications Commission opened a Notice of Inquiry (WT Docket 25-110) explicitly framing PNT resilience as a "system of systems."[9] In May 2025 the

National Telecommunications and Information Administration filed an inventory of complementary, alternative, and augmentative PNT solutions.[10] In Europe, EASA and IATA announced a joint GNSS-interference mitigation plan in June 2025 organized around reporting, monitoring, dissemination, and coordination workstreams;[3] thirteen EU member states wrote to the European Commission the same month pressing for cross-domain action;[6] and EASA and EUROCONTROL issued a joint operational action plan in March 2026.[5]

Date	Action	Body
Feb 2020	Executive Order 13905 — strengthen responsible use of PNT	White House
Jan 2021	National space-based PNT policy (Space Policy Directive-7)	White House
2021	Demonstration of 11 complementary-PNT technologies	DOT / Volpe
2024	Federal PNT acquisition guidance	CISA
2024	Follow-up solicitations; 9 vendor contracts; Rapid Phase II	DOT
Feb 2025	Resilient PNT Best Practices	DHS S&T
Mar 2025	Notice of Inquiry, WT Docket 25-110 (system-of-systems)	FCC
May 2025	Inventory of complementary/alternative PNT solutions	NTIA
Jun 2025	Joint GNSS-interference mitigation plan (4 workstreams)	EASA / IATA
Jun 2025	13-member-state letter on cross-domain RFI action	EU states
Feb 2026	Strait of Hormuz GNSS-interference episode (1,100+ vessels/24h)	(event)
Mar 2026	Joint operational action plan on GNSS interference	EASA / EUROCONTROL

Table 1. A partial chronology of PNT-resilience policy actions, 2020–2026. The record is substantial, but it is distributed across many agencies and two continents — which is itself part of the governance challenge: no single body holds the cross-domain, cross-border picture.

The pattern in the record is as important as any single entry. The response is real, but it is fragmented — spread across aviation regulators, spectrum regulators, transport departments, security agencies, and standards bodies, on at least two continents. Each addresses a slice of the problem from within its own mandate. No single institution holds the whole picture: the cross-domain, cross-border view of a dependency that is simultaneously economic, aviation-safety, maritime, spectrum, and security in nature. That gap between a distributed response and an integrated problem is precisely the space a neutral translation layer is built to occupy.

The current administration has kept PNT on the active agenda. In December 2025 the White House issued Executive Order 14369, *Ensuring American Space Superiority*, which directs, among other aims, greater U.S. spectrum leadership across space applications;[17] within months the National Telecommunications and Information Administration stood up a Space Launch Frequency Coordination Portal as an early deliverable under it. The Federal Communications Commission's PNT inquiry, meanwhile, has drawn a substantial and contested record: by mid-2026 its docket held more than 250 filings — comments, ex parte notices, letters, and replies — from device makers, positioning-industry groups, standards bodies, and toll-road operators alike,[18] a sign that the resilience question is now being argued out in public by the industries that depend on the signal.

8 Why this is a space-governance question

It would be easy to file GPS interference under aviation safety, or telecommunications, or national security, and many institutions do exactly that. But the signal originates in space, the spectrum it uses is allocated and protected through an international body (the ITU), and the interference crosses the borders that national regulators are bound by. Those three facts make it a space-governance question in the fullest sense — one that sits above any single national regulator and touches the international regime directly.

The Hormuz episode makes the connection concrete. A disruption of that scale in an international strait implicates the ITU framework that protects the radionavigation-satellite service from harmful interference; it implicates the maritime-safety regime under the International Maritime Organization; and it implicates the norms governing state conduct in and from space. These regimes were built separately and rarely speak to one another. A dependency that spans all of them needs a translation layer that can hold the whole picture at once — not to adjudicate it, but to render it legible to the officials in each regime who see only their own slice. That is the role this note, and the series it belongs to, is designed to play.

> **Four lenses on one dependency.** The same GPS-interference problem reads differently through each instrument of national power, and a governance audience needs all four at once. **Diplomacy:** harm is reported and negotiated through international bodies — ICAO, EASA, EUROCONTROL, IMO, and the ITU spectrum regime — none of which was built to hold the whole picture. **Information:** the signal degrades from more than one cause — deliberate jamming and spoofing, but also natural space weather, which regularly perturbs GNSS independent of any adversary. **Military:** the interference concentrates around conflict — the Baltic and Black Sea, the Strait of Hormuz — and the U.S. Congress now examines space and PNT in explicitly strategic terms, including a December 2025 hearing on China's space rise and a November 2025 hearing on deterrence along NATO's eastern flank.[19] **Economics:** the dependency is measured in trillions of dollars of benefit and roughly a billion dollars a day of outage exposure. Diplo Space's role is to translate across all four lenses at once — the view no single-instrument institution is positioned to offer.

9 Questions for policymakers

In the tradition of legislative-reference analysis, this note closes not with recommendations but with the questions a responsible official should be able to answer. They are offered to structure deliberation, not to steer it toward any particular conclusion.

Q1. How much of your jurisdiction's critical infrastructure depends on a single space-based source for timing, and where — telecom, grid, finance — would a timing disruption propagate first and least visibly?

Q2. Is GNSS interference in your region being tracked through a channel that crosses domains (aviation, maritime, telecom), or is each sector reporting in isolation? If the latter, who would notice a cross-domain pattern?

Q3. Where does your state sit on the spectrum of resilience choices — from a single dependency to a layered system of complementary sources — and was that a deliberate decision or an inherited default?

Q4. If GPS were denied for 33 hours over a metropolitan area (as in Denver, 2022) or across a strategic waterway for weeks (as in Hormuz, 2026), which services degrade first, and who is responsible for detecting and attributing the cause?

Q5. Because no single technology replaces GPS, what is the right layered mix for your jurisdiction's geography and budget — and which trade-off (coverage, cost, spectrum, independence from space) is the binding constraint?

Q6. GNSS bands are allocated and protected at the ITU. Is your state's spectrum position on RFI protection coordinated with its domestic PNT-resilience plans, or are the two handled by different agencies that do not consult?

Q7. Who bears the cost of a national-scale complementary PNT backup — a public good with no obvious commercial buyer — and what institutional arrangement (public, regulated-private, or multilateral) fits that cost structure?

10 Conclusion

GPS is a utility so reliable that its users have forgotten it is there — and that forgetting is now the risk. The economic dependency is measured in trillions; the threat has moved from wartime contingency to daily reality;

and the interference crosses the borders that national regulators cannot. States have made different choices about how much resilience to buy, and there is no single technology that resolves the problem for them. What is missing is not data or even policy activity, both of which are abundant, but an integrated, neutral view that spans the domains and borders the problem does. Diplo Space offers that view — translating a dependency few can see into terms the officials responsible for it can weigh, and stopping there, deliberately, so that the weighing remains theirs.

Glossary of key terms

GNSS. Global Navigation Satellite System — the general category of satellite positioning and timing services. GPS is the U.S. system; others include Europe's Galileo, Russia's GLONASS, and China's BeiDou.

PNT. Positioning, Navigation, and Timing — the three services a GNSS provides. Timing (precise time) is as critical as positioning, and is what synchronizes networks and grids.

Jamming. Overpowering the satellite signal with radio noise until a receiver can no longer use it. The receiver knows it has lost the signal.

Spoofing. Broadcasting a counterfeit satellite signal so the receiver computes a false position or time — often without any warning. Regulators judge it the more dangerous of the two.

RFI. Radio-Frequency Interference — the umbrella term for both jamming and spoofing of a radio signal.

FIR. Flight Information Region — an internationally defined block of airspace within which a state provides air-traffic services. Interference crossing FIR boundaries is by definition a cross-border problem.

Complementary PNT. Backup or alternative timing and positioning sources — terrestrial or otherwise — that reduce reliance on a single satellite system. No single one replaces GPS; resilience comes from layering several.

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14. Windward, reporting on Gulf maritime disruption during the 2026 Iran conflict (1,100-plus vessels affected by GPS/AIS interference within 24 hours); Lloyd's List, coverage of the 2026 Strait of Hormuz crisis ('Strait of Hormuz transits collapse as shipping's risk appetite is tested,' March 2026, and related reporting).
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16. *Primary-source verification (July 2026): Executive Order 13905 confirmed via the U.S. Federal Register API at 85 Fed. Reg. 9359 (signed Feb. 12, 2020; published Feb. 18, 2020). The FCC PNT Notice of Inquiry is corroborated as WT Docket No. 25-110 (FCC 25-20) via FCC records.*
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About Diplo Space. Diplo Space is a neutral, nonprofit translation layer for space governance: we turn contested, technical, space-dependent systems into material a non-specialist official can navigate — every claim traced to a public primary source, and no policy position taken. This note applies that method to the positioning, navigation, and timing (PNT) signal carried by GPS: what depends on it, how the interference threat has moved from wartime contingency to daily reality, and the governance choices that dependency now forces. Its companion, *The Grid Has a Heartbeat*, does the same for the power grid's reliance on GPS time.