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U.S. POLICY DECISIONS THAT SHAPED CIVIL AND COMMERCIAL USE OF GPS

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Summary

The Global Positioning System (GPS) is one of several global navigation satellite services (GNSS) that are used, knowingly and unknowingly, by billions every day. Their ubiquity and importance have led to incredible benefits but also to an increasingly congested radiofrequency spectrum environment and deliberate attacks on GPS signals, primarily from jamming and spoofing, that threaten those benefits. This current situation was heavily shaped by policy decisions made during three U.S. presidential administrations—Ronald Reagan, Bill Clinton, and George W. Bush—that opened up GPS to broader civil and commercial uses but also unintentionally laid the groundwork for the increased threats. An analysis of those decisions and their long-term impacts yields important lessons for future decisions on dual use technologies that must similarly balance military and nonmilitary applications. While there is no easy answer, policymakers should recognize the difficulty in determining the future impact of such decisions, avoid making assumptions about the future direction and pace of technological change, focus on developing broad guidance and institutional structures instead of specific direction, and be clear-eyed about what they can and cannot control.

Introduction

Fifty years after it was first announced, the Global Positioning System (GPS) is today a global utility that is used, knowingly and unknowingly, by billions every day. GPS is one of the few space capabilities that has become so ubiquitous that it is commonly used as a generic term for space-based position, navigation, and timing (PNT) services, despite the existence of multiple other global navigation satellite services (GNSS) in operation today. This ubiquity and importance have a downside in that GPS relies on an architecture that is increasingly challenged by the rise in harmful interference from a more congested radiofrequency spectrum environment and deliberate attacks on GPS signals, primarily from jamming and spoofing.

While much has been written about the technologies behind GPS, much less has been written about the policy decisions that also influenced the evolution of the program. Specifically, policy decisions made during three presidential administrations—Ronald Reagan, Bill Clinton, and George W. Bush—opened up GPS to broader civil and commercial uses, thus becoming part of the fabric of modern-day life. Two of those decisions are largely unknown, while the third is more widely known but in a way that belies what actually happened. This paper provides an overview of those three decisions and discusses how they influenced the current state of GPS. It draws on the history of the GPS program from public records, as well as previous primary research.

The Ubiquity and Importance of GPS in 2025

It is hard to fully capture the breadth of impact that the Global Positioning System (GPS) has on our modern lives. A 2019 study sponsored by the U.S. National Institute of Standards and Technology estimated that GPS has delivered more than $1.4 trillion in economic benefits to the United States alone, as shown in Figure 1.[2] Yet, even the authors of that study caution that their estimate should be considered a rough order of magnitude estimate, given how difficult it is to measure the impacts and how rapidly the situation is changing with the increased pace of innovation in the broader category of information technology. The most economically impactful part of GPS is likely not the navigation signals themselves but rather the extremely accurate timing embedded in them, which are used across transportation, communications, and financial sectors.[3]

GPS also remains one of the few space applications that the public uses daily, even if they are actually using an intermediary mapping device and not the satellite signals themselves. GPS is now ingrained in the global consciousness and has become eponymous with space-based positioning, navigation, and timing (PNT) services in the same way that Kleenex and Google have for tissue paper and internet search. This is despite the fact that today the U.S. owned and operated GPS is but one of several global navigation satellite services (GNSS). The Russian Global Navigation Satellite System (GLONASS), European Galileo, the

Sector	Specific Analytical Focus	Benefits ($ million)
Agriculture	Precision agriculture technologies and practices	$5,830
Electricity	Electrical system reliability and efficiency	$15,730
Location-based services	Smartphone apps and consumer devices that use location services to deliver services and experiences	$215,702
Mining	Efficiency gains, cost reductions, and increased accuracy	$12,350
Maritime	Navigation, port operations, fishing, and recreational boating	Negligible
Oil and gas	Positioning for offshore drilling and exploration	$45,922
Surveying	Productivity gains, cost reductions, and increased accuracy in professional surveying	$48,124
Telecommunications	Improved reliability and bandwidth utilization for wireless networks	$685,990
Telematics	Efficiency gains, cost reductions, and environmental benefits through improved vehicle dispatch and navigation	$325,182
Total		**$1,354,830**

Note: Economic benefits were measured relative to a counterfactual that specified that preexisting positioning, navigation, and timing (PNT) systems continued to be available in the absence of GPS. Thus, the relative benefit for some sectors is negligible but substantial for those with applications that have a requirement for GPS's accuracy and precision. We recommend interpreting the $1.4 trillion estimate as a rough order of magnitude. The range of benefits to date is estimated to be between $903 billion and $1.8 trillion.

Figure 1: *Economic benefits of GPS for private sector use, 1984 to 2017. (Reproduced with permission from RTI.)*[1]

Chinese BeiDou Navigation Satellite System, the Japanese Quasi-Zenith Satellite System (QZSS), and the Indian Regional Navigation Satellite System (IRNSS) all offer operational services globally or regionally to billions of users, and many modern smartphones receive and use signals from all these constellations at the same time.

The ubiquity and importance of GNSS to the global economy are especially noticed when they are lost.

How GNSS Works

GPS and other GNSS constellations work by using satellites to broadcast radio signals on specific frequencies that contain encoded messages. The messages contain the precise time the signal was sent, the orbital trajectory of the transmitting satellite, and other information about its health and status. A receiver on the ground that receives at least four different signals can use the encoded information to calculate their position on Earth and synchronize their local time. Multiple calculations over time can be used to calculate speed and heading, which, when combined with an accurate map, allow for navigation.

The GPS constellation consists of at least 24 satellites in circular orbits 11,000 miles (22,000 km) above Earth. Other constellations use satellites in similar orbits but also highly elliptical orbits as well as both equatorial and inclined geostationary orbits. Each GNSS satellite broadcasts multiple signals on different frequencies. Some signals, commonly referred to as *civil signals*, are freely available for anyone to receive. Other signals, commonly referred to as *military or protected signals*, are encrypted and only available to specific users with the decryption codes. Most GNSS signals are only one-way broadcasts from the satellites to end users, although some newer constellations are adding limited two-way text messaging to support safety and rescue missions.

GNSS services have increasingly been disrupted or challenged by nondestructive attacks such as jamming and spoofing. Jamming is the broadcasting of radiofrequency (RF) signals in the same or nearby frequencies to drown out other signals, akin to shouting in an attempt to overwhelm a nearby conversation. Spoofing is the deliberate creation of false signals that can be manipulated by an attacker, usually to either confuse end users or provide them with the wrong information. While GNSS jamming and spoofing incidents are proliferating globally and usually associated in regions of conflict, more incidents are now happening even in peacetime for such diverse situations as truck drivers trying to avoid corporate monitoring,[4] militaries testing their counterspace capabilities,[5] and widespread spoofing of maritime ship tracking services that are still unsolved.[6]

However, the most dangerous incidents to date have resulted from GNSS attacks that impact commercial aviation, largely in or near regions with armed conflicts involving the use of electronic warfare counterspace capabilities. A 2024 report published by OpsGroup, a membership organization of individuals involved in international flight operations, found that more than 1,500 flights per day were being impacted, mostly in the Middle East, Black Sea, and Russian regions.[7] While the report concludes that the impacts on commercial aviation were unintended side effects of the armed conflicts, it highlights the downside of our societal reliance on GNSS: There is unprecedented interest in finding ways to disrupt GNSS, and disruptions often have wider impacts beyond their intended effects.

The concern over these threats and the overall vulnerability of society to GNSS disruptions, especially GPS, has recently led the U.S. government to increase efforts to find potential alternatives. In 2021, the Department of Transportation released the results of a study that examined several commercial technologies that

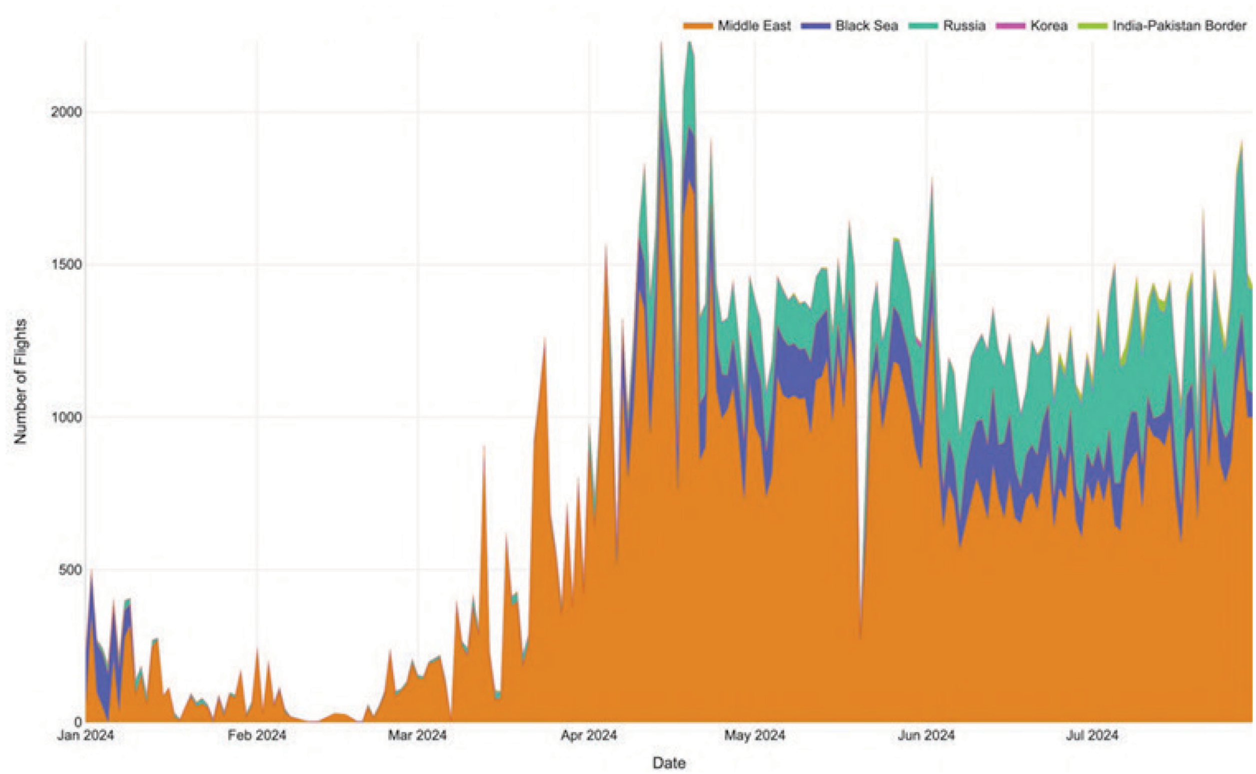

Figure 2: *Daily estimated number of flights affected by GPS spoofing by spoofed-to-region. (Reproduced with permission from OpsGroup)*[10]

could serve as backups or alternatives to GPS.[8] In April 2025, the Federal Communications Commission launched a Notice of Inquiry to receive public comments on how the agency can encourage the development of complementary and alternative PNT technologies to ensure continuity and resilience in critical operations.[9]

The modern-day ubiquity and reliance on GPS, and resulting positive and negative impacts, were not foregone conclusions and in many respects were unexpected by even its more ardent supporters. GPS started, and remains funded today, primarily as a military system that was designed to deliver specific military requirements, including warfighting applications. Yet, as is often the case, a technology developed for one application or set of users often has beneficial applications for a broader set of users. The ability to provide extremely accurate and reliable timing signals anywhere in the world has proven to be hugely beneficial for not only military applications but also many civil and commercial applications.[*]

The following section details three decisions by U.S. presidential administrations that shaped the evolution of GPS and global GNSS capabilities into what we know today. A key concept in this analysis is that of *dual-use technology* and the inherent challenges it causes for public policy. In this context, dual use refers to technologies that have

[*]Within the GPS policy community, "civil" is used to refer to all nonmilitary applications, including nonmilitary government and private sector use for commercial and noncommercial applications. Henceforth, this paper will use the term "civil" to refer to all nonmilitary applications and uses of GNSS.

both military and nonmilitary applications.[†] For the last several decades, a significant amount of U.S. government policy and law have attempted to control access to and spread of dual-use technologies that were considered potential threats to national security. At the same time, efforts have been made by other parts of the U.S. government and the private sector to increase the ability to use dual-use technologies for broader societal and economic benefits. These two approaches are antagonistic with each other: Examples of this natural tension can be found in the policy debates on nuclear power, cryptography, and genetic engineering.

Policy decisions on space technologies often face the same challenge as other sectors that also must balance restriction and openness on dual-use technologies. In fact, many space technologies stem from national security or military investments and are increasingly used and further developed by others. GPS exemplifies this phenomenon: It began as, and is still, a military program largely funded and operated by the U.S. Department of Defense (DOD) that has become widely employed for nonmilitary purposes. However, that could not occur without policymakers facing the tension between national security and economic growth, and decisions they made to shape the program's evolution.

Three Presidential Policy Decisions That Shaped GPS

The Reagan Administration—Cold War Public Diplomacy Tool

The most well-known presidential policy decision on GPS is also the decision with the most misunderstood details and impact. Many histories of GPS give the Reagan administration credit for making the major policy change to "open up" GPS for civil use, especially by commercial aviation, on the heels of the tragic downing of Korean Airlines (KAL) flight 007 by a Soviet fighter interceptor on September 1, 1983.[11] KAL 007 was on a routine flight from Anchorage, Alaska, to Seoul, South Korea, but drifted off its planned course into prohibited airspace over Soviet military facilities. The Soviets, believing it to be an intruding American spy plane, fired warning shots and eventually destroyed the aircraft with air-to-air missiles, killing all 246 passengers and 23 crew.

Two weeks after the incident, the White House released a statement declaring that President Reagan had decided "the United States is prepared to make available to civilian aircraft the facilities of its Global Positioning System when it becomes operational in 1988" and offered the support of the U.S. delegation to the International Civil Aviation Organization (ICAO).[12] Subsequent news articles and multiple histories cite this decision by President Reagan as the moment civil use of GPS was created.[13]

However, this conclusion is not supported by the historical evidence. First, aside from the formal press release, no records exist that any presidential policy decision document or other written directive was produced that substantively changed policy on the GPS program.[14] Former U.S. officials across multiple administrations have also stated that they could not recall a specific aspect of the GPS program or policy that was changed as a direct result of the statement.[15]

Moreover, specific GPS signals were publicly available for civil users, including commercial aviation, as a core part of the program from the very beginning. An April 1973 memo from then Deputy Secretary of Defense William Clements establishing the Defense Satellite Navigation Development

[†]There are communities, such as nuclear, that have slightly different definitions for the term *dual-use*, and the terms "dual use," "dual-use," and "dual purpose" are often used interchangeable.

Program, the precursor to what became GPS, stipulated that civil user needs should be considered in program design.[16] In 1978, a study conducted by the General Accounting Office found that GPS could greatly enhance civil aviation navigation and Congress directed the executive branch to study how this might happen.[17] In 1981, the DOD announced a policy to allow civil access to GPS.[18] Thus, there is clear evidence that civil use of GPS was planned from the very beginning and explicitly part of the program well before the KAL 007 tragedy and subsequent Reagan White House statement.

However, it is true that the statement by the Reagan White House had an impact on the *perception* of GPS. While it was not the genesis for civil use of GPS, the statement nonetheless changed how GPS and the United States were perceived in the context of the Cold War and Soviet hostility toward KAL 007. GPS emerged from a relatively obscure military system into the global consciousness and became an important soft power tool to contrast American openness and technological innovation with the USSR.

It is also true the White House statement likely accelerated the existing plans for civil aviation to use GPS and found long-term support amongst U.S. interagency policymakers.[19] The public statement had a subtler but still important impact on subsequent interagency debates on civil use of GPS and the tension between civil and military perspectives. Several former U.S. officials have said that the Reagan administration's statement was repeatedly referenced in future interagency policy debates as the foundational goal for civil use of the system.[20] Thus, while President Reagan did not create the civil use of GPS, he very likely ensured it would have strong public and political support for decades to come.

The Clinton Administration—Enabling Commercial Innovation

The second presidential policy decision to have lasting impact on GPS was made during the Clinton administration. The decision was impactful and yet largely unknown outside those who participated in the process. During the 1990s, GPS finally transitioned from a development program into an operational capability. At the same time, a policy debate broke out within the federal government over whether civil interests should have equal voice as the military interests in the ongoing management, development, and operation of GPS.[21] In particular, there was a vigorous debate over how to restrict the ability of hostile actors to use GPS against the United States, most notably through selective availability (SA). SA was a random error the U.S. military deliberately added to the publicly available GPS signal that degraded its accuracy to prevent it from being used by adversaries for hostile purposes. However, as proponents of civil uses of GPS came to believe that SA was hindering growth and innovation in wider nonmilitary uses of GPS, workarounds such as differential GPS emerged and policymakers from civil agencies considered other approaches.[22]

This debate came to a head with the establishment of a Department of Transportation (DOT) program called the Wide Area Augmentation System (WAAS). WAAS was a signal broadcast from geostationary satellites over the United States that could be used to undo the SA error.[23] Effectively, one federal agency was running a program to undo a program run by another federal agency. The DOT's rationale for doing so was that civil GPS signals were critical to improving aircraft navigation and increasing the safety and efficiency of the national airspace system, but that was difficult to do with the deliberate errors introduced by SA. The DOD, meanwhile, viewed WAAS as a threat to national security, as they did other types of civil augmentation systems being developed within the United States and Europe.[24]

To address SA and other issues, the Clinton administration began a formal interagency working group in early 1995 to develop an official U.S. policy on GPS. After nearly a year of often contentious debates, the Clinton administration issued the first national GPS policy in March 1996.[25] The policy not only clarified that GPS was to be used for both military and peaceful civil, commercial, and scientific uses worldwide but also decided to discontinue SA within 10 years, allowing the DOD time to develop alternative ways to deny adversaries the ability to use GPS in what became known as the Navigational Warfare (NAVWAR) program.[26] The policy also created a formal Interagency GPS Executive Board (IGEB), co-chaired by the DOD and DOT, to help improve coordination on the GPS program and ensure military and nonmilitary users had equal voice in its management and oversight.

The Clinton GPS policy also laid the foundation for what would become known as the "gold standard" policy for GPS. It set a goal of encouraging acceptance and integration of GPS into peaceful civil, commercial, and scientific applications worldwide and advocated for the acceptance of GPS and additional U.S. government controlled augmentations as standards for international use. The core idea was to make GPS as accurate and reliable as possible so that everyone in the world would use it. However, this was an aspirational goal, and the debate continued within the U.S. government over how realistic the gold standard policy was.

The 1996 Clinton GPS policy had arguably the biggest commercial and economic impact of any space policy decision made to this day.[‡] The work of the IGEB, albeit not without considerable additional debate, led to the creation of additional civil GPS signals that allowed for higher accuracy (L2C) and dedicated safety-of-life services (L5).[27] To the surprise of many, including those within the U.S. government, the DOD decided to turn off SA in May 2000, nearly six years earlier than the policy intended, for reasons that will be discussed in the next section.[28]

The policy goal of promoting global adoption of GPS led to significantly increased international engagement and eventually GPS being adopted as the global standard we know today. A huge part of that adoption was continued development of the GPS interface control document (ICD), which established, defined, and controlled communications interface designs for users,[29] and performance standard, which specified the expected level of accuracy, availability, integrity, and continuity.[30] These documents, coupled with the ending of SA and the coinciding boom in the broader information technology sector, enabled tremendous innovation of commercial GPS receivers that rapidly progressed from truck-sized units to those that can today fit in nearly every electronic device imaginable.

However, there was an additional national security motive to this widespread use of GPS as the gold standard for the world: It could also enable the United States to potentially control global access to PNT services. The U.S. government's campaign to establish GPS as the main global PNT system might

[‡] Other leading candidates for most impactful space policy decisions would be the efforts to commercialize satellite communications in the 1970s and Earth remote sensing in the 1990s. However, it is hard to pin either to a specific policy decision and to date their total societal and economic impacts are less than that from GPS.

remove incentive for other countries to create competing GNSS systems, leaving everyone reliant on a system controlled by the U.S. military. At the same time, the need to be able to deny adversaries the ability to use GPS (NAVWAR) also created a disincentive for the DOD to shore up the civil signals against deliberate attacks.

This perception that the United States could control global PNT capabilities was linked to a belief among many U.S. national security decisionmakers at the time that we were entering an era of American dominance over all domains, including space.[31] The lack of another superpower competitor meant the United States would have far greater space capabilities than any other country and would likely be the only country capable of implementing effective NAVWAR capabilities. This "nobody but us" (NOBUS) mentality is most commonly associated with U.S. policies in the signals intelligence world but is also prevalent in the space domain.[32]

The Bush Administration—Foreign Competition, Budget Debates, and Spectrum Protection

While the Clinton administration made several important changes to GPS policy, not all the problems were resolved and new ones quickly emerged or increased in prominence. In particular, the attempt in the 1996 GPS policy to forestall competing international GNSS systems was not successful. Additionally, while the creation of the IGEB did bring civil GPS users closer to equality with military users, disparities still remained, most prominently over the lack of adequate funding for civil requirements. Finally, there were new concerns about the protection of the radiofrequency (RF) spectrum used by GPS, from both space and terrestrial services that planned to use frequencies adjacent to, or sometimes the same as, those used by GPS.

The U.S. concern over international PNT competition was primarily, but not solely, driven by the European Union's (EU) Galileo system.[§] Europe had been interested in GNSS since the 1980s and had explored both creation of an international GNSS system and participation in GPS, both of which were blocked by the United States.[33] Eventually, the desire to have an independent European GNSS capability led to the creation of the Galileo program in 1999 as one of several pan-European space projects designed to fulfill sovereignty goals and bolster a European space industry and economic development.[34] Multiple attempts by Washington to dissuade the Europeans from pursuing an independent GNSS backfired and only solidified the support, particularly as the European Union started focusing more on national security matters.[35]

One particular aspect of Galileo created the most concern for Washington: the plan to place the Galileo protected regulated service (PRS) on top of M-code, the newest GPS military signal being developed and a key component of its NAVWAR goals. M-code was a separate military signal that would allow the U.S. military to deny civil signals in specific areas without impacting military operations. In order to sell Galileo as "jam-proof," the EU planned to overlay Galileo's PRS on DOD's M-code, with the theory that the U.S. military could not jam it without also jamming M-code. Although the technical feasibility of this plan remains uncertain, the concern was high enough that, in December 2001, then Deputy Secretary of Defense Paul Wolfowitz sent a letter to several European Ministers of Defense asking them to intervene and help change the Galileo signal plans.[36] Although

[§]While the Russian GLONASS system had already existed prior to Galileo, the GLONASS signals used a set of frequencies that did not impinge on GPS as Galileo PRS was planned to do.

several of the recipients expressed agreement with the U.S. position, they were not part of the decisionmaking process on Galileo and were unable to change the program's plans.[37]

Separate from the challenge presented by Galileo, internal frustrations within the U.S. government had grown over the inability of the IGEB to fully address the dual use questions on GPS. Civil agencies were still frustrated that the DOD retained complete control over the GPS budget and was moving slowly on decisions it did not like.[38] The DOD, meanwhile, felt that discussions of technical and programmatic requirements were not part of the IGEB mandate and changes made for civil users, including new civil signals and other functionality, should not be funded by the military. The DOT did not have anywhere near the budget of the DOD to be able to fund the civil aspects of the program nor the power to force agreement on civil requirements between all the civil agencies.

Related to this question of funding, some within the DOD also floated the idea of charging fees to use GPS as a way to recoup some of the billions of dollars in programmatic costs. This was not new as Congress had directed a study on user fees back in 1984.[39] However, the concept never gained traction, largely because it could undermine the goal of widespread use and unintentionally create incentives for competitive international alternatives.[**] Yet the growing costs of the GPS program, and the belief by some in the DOD that civil users were "free riders," reignited interest during the Bush administration.[40]

Also during this time, protection from RF spectrum interference was a new challenge that had not been considered in the 1996 Clinton GPS policy.[41] But almost immediately after the Clinton policy was issued, the growing demand for spectrum to enable new terrestrial and space services had begun to encroach on spectrum used by GPS, in part because of its desirable characteristics. A major challenge came from a proposal by the United Kingdom, on behalf of the U.K.-based satellite communications operator Inmarsat, at the 1997 World Radiocommunication Conference to allocate RF spectrum adjacent to GPS for new broadband communications services provided by large constellations in low Earth orbit. Another challenge came from domestic sources; multiple companies within the U.S. proposed using GPS-adjacent spectrum for ultra-wideband signals for indoor geolocation services.[42] The DOD was concerned that these proposed services adjacent to GPS spectrum could cause interference with GPS.

The resulting presidential policy published by the Bush administration in December 2004 on "U.S. Space-Based Positioning, Navigation, and Timing" was heavily influenced by the parallel U.S.-E.U. agreement made earlier that year on GNSS.[43] The "Agreement on the Promotion, Provision and Use of Galileo and GPS Satellite-based Navigation Systems and Related Applications" stipulated that the civil signals used by GPS and Galileo shall be *radio frequency compatible* and interoperable for nonmilitary users (including moving PRS off a direct overlap with M-code).[44] The agreement also stipulated continuation of a free, open service. The 2004 Bush GPS policy reflected both this approach of "coopetition," a portmanteau of cooperation and competition, and reiterated that GPS would be provided free of user fees.[††] On the governance side, the Bush policy replaced the IGEB with the National PNT Executive Committee (PNT ExCom), still

[**] While never formally implemented in policy, the concept of user fees or other methods of "offsetting" the DOD's costs to manage GPS continue to return through the life of the program.

[††] This concept of coopetition is not unique to GPS and is used to describe the concept of cooperation between competitors. See Brandenburger, Adam M., and Nalebuff, Barry J. *Co-Opetition*. United States, Doubleday, 1996.

co-chaired by the DOD and the DOT but elevated to the deputy secretary level, and explicitly included civil funding to support augmentations that would benefit civil, commercial, and scientific users.

The Bush GPS policy also made a small, but crucial change to the "gold standard" concept. It established a goal to remain the preeminent *military* space-based PNT service while continuing to provide civil services that exceed or are competitive with foreign civil space-based PNT and remain essential *components* of international PNT services. The additional modifiers of "military" and "components" were a recognition that controlling global PNT capabilities was infeasible and that GPS had to compete with other GNSS services for users.

The coopetition approach in Bush GPS policy laid the groundwork for how the United States would respond to the proliferation of space-based GNSS systems and civil signals available today. The dual goals of ensuring "interoperability" (the ability to use multiple signals from different GNSS constellations) and "compatibility" (that multiple signals will not interfere with each other and will not impact the ability to do NAVWAR) were carried forward in development of the EU's Galileo and other GNSS systems. Follow-on cooperative efforts took place in the form of joint statements, working groups, and/or technical consultations with Russia in December 2004, India in 2005, and China in 2014 on how their own GNSS constellations would be compatible with GPS.[45] These discussions continue today within the United Nation's International Committee on Global Navigation Satellite Systems, created in 2005 to promote voluntary cooperation on matters of mutual interest related to civil satellite-based PNT and value-added services.[46]

As a result of this coopetition approach, today there exist more than two dozen compatible civil GNSS signals from multiple constellations used by smartphones and other devices for precise position fixes and timing. The end benefit to commercial and civil users is hugely positive: More GNSS satellites broadcasting interoperable PNT signals means a higher likelihood of acquiring enough satellites for a position fix in less time and with more refined accuracy.[47] Additionally, an error in any one satellite or even one entire GNSS constellation can be more easily detected, and signals from other unaffected GNSS can be used until the problem is resolved.

However, while compatibility of GPS with foreign GNSS was a success, there was a downside from the interoperability mandate of the Bush GPS policy. A key element of making civil GNSS signals interoperable is placing them within the same or similar frequency bands, especially the well-known L1 band centered on 1575.420 MHz, and designing the signals with similar waveforms (the technical term for the shape of the signal). To meet the interoperability goals, the United States and subsequently other GNSS systems have separated their encrypted or protected military GNSS signals from the civil signals, either by using a different frequency band or different waveforms. The result is that all civil GNSS signals are clustered together, making it easier to jam, or deny service, to all of them at once without impacting military signals. Moreover, none of the GNSS constellations, including GPS, have yet added encryption or other anti-spoofing measures to their civil signals, leaving them vulnerable to such attacks.[‡‡] This means that the benefits from having interoperable civil signals

[‡‡]Both the United States and the EU have plans to add encryption features to future civil signals, specifically the Chimera enhancement as part of GPS L1C signal and the Galileo Open Service Navigation Message Authentication (OSNMA).

fail in the face of a determined attacker. It also raises the concern that any one of the GNSS constellations could mimic the signals from another, potentially for nefarious purposes.[48]

Where Do We Go from Here?

The policy decisions made by the Reagan, Clinton, and W. Bush administrations helped create a set of civil GNSS capabilities that have developed far beyond what many imagined possible at the time, in both positive and negative ways, as summarized in Table 1. On the positive side, the societal and economic benefits have far outstripped even the most optimistic forecasts made over the last few decades. GPS, and the other GNSS, are truly fundamental infrastructures for our modern society. But on the negative side, those essential services and missions are reliant on GNSS signals that are increasingly brittle to disruption from deliberate attacks such as jamming or spoofing from government and nongovernment actors. At the same time, the growing global use of GNSS has incented the proliferation of jamming and spoofing capabilities across both government and nongovernment actors.

Table 1: Summary of Key Presidential Policy Decisions on GPS, Their Main Drivers, and Current Impacts

Administration	Policy Driver(s)	Policy Decision	Current Impact
Ronald Reagan (1983)	Leverage KAL 007 tragedy to showcase global benefits of American technology.	Public statement pledging GPS for use to increase safety of civil aviation.	• Changed the public perception of GPS. • Gave political support to expansion in civil applications of GPS.
Bill Clinton (1996)	Tension between military and civil users over selective availability (SA).	• Turn off SA within 10 years. • Create NAVWAR program to develop alternative means to deny adversary use of GPS. • Create IGEB to give civil agencies a voice in GPS program decisions. • Promote GPS as the "gold standard" for global PNT.	• Greatly increased accuracy of civil GPS signals. • Sparked rapid innovation in civil/commercial applications and miniaturization of GPS receivers. • Widespread global adoption of GPS. • Creation of additional civil GPS signals.
George W. Bush (2004)	• Competition from Europe's Galileo. • Continued frustration over civil/military imbalance in program decisions. • Increased threat of RF spectrum interference.	• "Coopetition" approach of interoperable civil signals and separate military signals. • Elevated IGEB to National PNT ExCom; explicitly included budget issues. • Clarified "gold standard" applied to military PNT.	• Multiple civil GNSS signals contributing to increased availability, faster acquisition, and greater accuracy. • Proliferation of jamming/spoofing capabilities that can attack civil GNSS signals.

The commercialization of GNSS receivers and applications has similarly outstripped the stated policy goals, in both positive and negative ways. On the positive side, the establishment of ICDs and policy that enables end user equipment for commercial innovation has reaped enormous benefits in reduced costs, increased capabilities, and miniaturization. However, U.S. government export controls restrict the sale of commercial GPS receivers that utilize well-known methods to toughen them against jamming and spoofing, hindering efforts to combat these types of attacks.[49]

The situation is compounded by delays in operationalizing already planned civil signals and services that could address some of these issues. Chief among these is the L5 civil signal, which was specifically designed to meet critical "safety of life" needs. While some GPS satellites have been testing L5 since 2014, the signal will not be fully operational until enough of the next-generation GPS III satellites are operational and deployment of the Space Force's next-generation ground system, which is now planned for delivery by the end of 2025.[50] Additionally, the new GPS L1C civil signal, which is explicitly designed to be more interoperable with foreign GNSS signals, has experienced similar delays and is not expected to be operational until the late 2020s at the earliest.[51]

The combination of overreliance, weak resilience against interference and attacks, and delayed upgrades has led to warnings that the United States is at risk of falling behind in leadership of GNSS. In July 2024, the Space-Based Positioning, Navigation and Timing National Advisory Board (PNTAB) submitted a public memorandum to DOD and DOT leadership calling attention to several critical challenges.[52] The letter warned that the continued overreliance on GPS for PNT posed a threat to U.S. critical infrastructure and called for the examination of alternative technologies to augment GPS and increase resilience. The letter also warned that U.S. leadership in global GNSS is slipping as other systems, notably the EU's Galileo and China's BeiDou, are now offering more advanced services and protections against jamming and spoofing than GPS. The PNTAB argued for a clear U.S. national strategy on PNT resilience, bolstered by a revised governance framework, to address these concerns.

Lessons from Historical GPS Policy Decisions

Determining the future impact of policy decisions is difficult, especially when they involve dual-use technologies.

Avoid making assumptions about the future direction and pace of technological innovation.

Broad guidance and institutional structures are better than specific direction.

Ensure key interagency stakeholders are involved and invested in the decision to drive effective implementation.

Be clear-eyed about what can and cannot be controlled.

As the U.S. government considers what its approach should be to this challenge, it is useful to keep in mind the lessons from past GPS policy decisions, which are summarized in the sidebar. Despite seemingly just a "piece of paper," presidential space policy decisions can have lasting impact, but often far beyond what is knowable at the time they are made. To paraphrase a famous quote popularized by the Danish physicist Niels Bohr, it's tough to make predictions, especially about the future. This is especially true for the impact of policy decisions made in the face of the unpredictable future. In the case of GPS, while there was some appreciation for what civil applications could be, the end result today is far beyond what anyone in the Reagan, Clinton, or Bush administration thought possible. Yet, the policy decisions they made had a lasting impact largely because they provided broad guidance and avoided making specific predictions. Likewise, future policy decisions on dual-use technologies should understand this inherent unpredictability and seek to provide general guidance and structures rather than specific direction that relies on specific futures happening.

A second important consideration is that space policy decisions that involve dual-use technologies, including GNSS, are more likely to have outsized and unpredictable impacts due to their dual-use nature. As space technologies continue to globalize and commercialize, they are increasingly used in unpredictable ways for a wide array of benefits that may go far beyond the system owners and intended users. In 1996, when the Clinton GPS policy was released, let alone in 1973, when the GPS program was devised, it was impossible to know that one day hundreds of millions of people would carry around smartphones that would allow them to get realtime traffic and driving directions and accurate weather forecasts.[53] Thus, it is wise to avoid assumptions about how far or in what direction technological innovation might occur and the ability of a government to control that technological innovation or how a space capability might be used.

Managing the different needs of both military and nonmilitary users and applications of a space capability creates many complications for policymaking and implementation. This is a large challenge and rooted in differences in how those two groups approach risk. A recurring theme across the history of GPS policy is the programmatic tension between military and nonmilitary users over funding, requirements, and oversight, even after the Clinton and Bush GPS policies created formal structures to resolve those issues. While this difference cannot be easily resolved, making policy decisions on dual-use technologies through an interagency process that includes all the key stakeholders helps get them more invested in the eventual decision that will in turn help make policy implementation more effective.

Finally, the historical policy decisions on GPS show that governments, even those as powerful as the United States, have limited ability to control both technological innovation and how dual-use capabilities will be used. As the user base and applications for dual-use space capabilities grow and diversify, their societal benefits similarly grow and diversify, while the ability of any government to control the process diminishes. When making future decisions on dual-use space technologies, policymakers should be clear-eyed about the limits of their control and put their energies toward trying to manage a more limited scope of issues.

Conclusion

Making policy decisions on dual-use technologies such as GPS is difficult and complex, particularly because of the need to balance competing interests between military and civil communities. There is no simple recommendation that will magically cause those challenges to fall away and provide an easy path to resolving similar future decisions. While broad, the conclusions from this paper provide guidance to policymakers to help make future policy decisions on dual-use technologies more easily, more effective, and more impactful.

References

[1] O'Connor et al, p. ES-2.

[2] O'Connor, A. C., Gallaher, M. P., Clark-Sutton, K. B., Lapidus, D., Oliver, Z., Scott, T. J., Wood, D. W., and Brown, E. G. (2019). *Economic benefits of the Global Positioning System (GPS)*. RTI International, https://www.rti.org/publication/economic-benefits-global-positioning-system-gps.

[3] Office for Science (2018). *Satellite Derived Time and Position: A Study of Critical Dependencies,* Government of the United Kingdom, pp. 34-65. Available from https://assets.publishing.service.gov.uk/media/5a82c84ced915d74e34038ab/satellite-derived-time-and-position-blackett-review.pdf.

[4] "FCC fines operator of GPS jammer that affected Newark Airport GBAS." *InsideGNSS*, August 31, 2013, https://insidegnss.com/fcc-fines-operator-of-gps-jammer-that-affected-newark-airport-gbas/.

[5] Charpentreau, C. "French Air and Space Force conducts live GPS jamming exercise." AeroTime, June 3, 2024, https://www.aerotime.aero/articles/french-air-and-space-force-conducts-live-gps-jamming-exercise.

[6] Harris, M. "Ghost ships, crop circles, and soft gold: A GPS mystery in Shanghai." *MIT Technology Review,* November 15, 2019. https://www.technologyreview.com/2019/11/15/131940/ghost-ships-crop-circles-and-soft-gold-a-gps-mystery-in-shanghai/.

[7] "GPS Spoofing: Final report of the GPS spoofing workgroup." *OPS Group*, September 6, 2024. https://ops.group/dashboard/wp-content/uploads/2024/09/GPS-Spoofing-Final-Report-OPSGROUP-WG-OG24.pdf.

[8] Hansen, A., Mackey, S., Wassaf, H., Shah, V., Wallischeck, E., Scarpone, C., Barzach, M., Baskerville, E. "Complementary PNT and GPS Backup Technologies Demonstration Report." *U.S. Department of Transportation Volpe Center*, January 2021, DOT-VNTSC-20-07. https://www.transportation.gov/sites/dot.gov/files/2021-01/FY%2718%20NDAA%20Section%201606%20DOT%20Report%20to%20Congress_Combinedv2_January%202021.pdf

[9] "FCC Fact Sheet: Promoting the Development of Positioning, Navigation, and Timing Technologies and Solutions." *Federal Communications Commission,* WT Docket No. 25-110, March 6, 2025. https://docs.fcc.gov/public/attachments/DOC-410031A1.pdf.

[10] OPS Group, p. 13.

[11] So-hyun, K. "How KAL007 tragedy gave civilians access to GPS." *The Korea Herald*, July 2, 2023 (updated April 16, 2025). https://www.koreaherald.com/article/3162458.

[12] Office of the Press Secretary. (1983, September 16). Statement by the principal deputy press secretary to the president. The White House. Retrieved from http://www.reagan.utexas.edu/archives/speeches/1983/91683c.htm.

[13] For example, see https://www.gps.gov/policy/, https://www.theatlantic.com/technology/archive/2014/11/the-plane-crash-that-gave-americans-gps/382204/ https://nssaspace.org/wp-content/uploads/2024/07/NAVWAR-FINAL.pdf

[14] Easton, R. (2013) *GPS declassified: From smart bombs to smartphones* (1st Ed.). Lincoln, NE: Potomac Books Inc.

[15] Weeden. B. C. "Case Study of the Interagency Process for Making Presidential Policy Decisions on Dual-Use Space Technology: The Global Positioning System and Space Traffic Management." 2017. George Washington University, Ph.D. dissertation, p. 119. scholarspace.library.gwu.edu/etd/z890rt36k.

[16] Clements, W. P. "Memo on Defense Navigation Satellite Development Program." United States Department of Defense. April 17, 1973.

[17] McLaughlin, G. D. "The Commercialization of the Global Positioning System." 1997. Air Command and Staff College, pp. 11. https://apps.dtic.mil/sti/pdfs/ADA397851.pdf.

[18] Ibid, p. 12.

[19] Witkin, R. "Air experts work on a new safety plan." *The New York Times*, September 23, 1983, Section A, Page 3. Retrieved from https://www.nytimes.com/1983/09/23/world/air-experts-work-on-a-new-safety-plan.html.

[20] Weeden, p. 119.

[21] Weeden, pp. 116-117.

[22] Chivers, M. "Differential GPS explained." *Esri.com*, 2003, https://www.esri.com/about/newsroom/arcuser/differential-gps-explained.

[23] "Satellite Navigation – WAAS – How it Works." *Federal Aviation Administration.* https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/waas/howitworks (accessed April 19, 2025).

[24] Weeden. pp. 150-152.

[25] "Fact Sheet: U.S. Global Positioning System Policy." *The White House*, March 29, 1996. Available from

https://csps.aerospace.org/sites/default/files/2021-08/Global%20Positioning%20System%20Policy%20fact%20sheet%20Mar96.pdf.

[26] "1998 Biennial Report to Congress on the Global Positioning System." *United States Department of Defense*, 1998. Available from https://www.gps.gov/congress/reports/1998/biennial/.

[27] "New Civil Signals." *National Coordination Office for Space-Based Positioning, Navigation, and Timing,* GPS.gov. Updated August 10,2020. https://www.gps.gov/systems/gps/modernization/civilsignals/.

[28] "Statement by the President regarding the United States' decision to stop degrading Global Positioning System Accuracy." *Office of Science and Technology Policy*, May 1, 2000. Available from https://clintonwhitehouse3.archives.gov/WH/EOP/OSTP/html/0053_2.html.

[29] "Interface Control Documents." *National Coordination Office for Space-Based Positioning, Navigation, and Timing,* GPS.gov. Updated February 6,2025. https://www.gps.gov/technical/icwg/.

[30] "Performance Standards and Specifications." *National Coordination Office for Space-Based Positioning, Navigation, and Timing,* GPS.gov. Updated September 2, 2020. https://www.gps.gov/technical/ps/.

[31] Krauthammer, C. "The Unipolar Moment." *Foreign Affairs*, vol. 70, no. 1, 1990, pp. 23–33. *JSTOR*, https://doi.org/10.2307/20044692.

[32] Buchanan, B. "Nobody but us: The rise and fall of the Golden Age of signals intelligence." *Lawfare,* September 7, 2017, https://www.lawfaremedia.org/article/nobody-us-rise-and-fall-golden-age-signals-intelligence-0.

[33] Gleason, M. "Galileo power, pride and profit: The relative influence of realist, ideational, and liberal factors on the Galileo satellite program." 2009. George Washington University. Ph.D. dissertation, pp. 113. Available from https://archive.org/details/DTIC_ADA495023.

[34] Weeden, p. 240.

[35] Weeden, p. 241.

[36] "US warns against European satellite system." *BBC News*, December 18, 2001. Available from: http://news.bbc.co.uk/2/hi/europe/1718125.stm.

[37] Weeden, p. 245.

[38] Weeden, p. 217.

[39] "Global Positioning System User Charges." *U.S. Department of Defense*, Report to the Senate and House of Representatives Committees on Appropriations and Armed Services, May 1984.

[40] Weeden, p. 247.

[41] Weeden, p. 231

[42] Evans, D. "Assessment of compatibility between ultrawideband (UWB) systems and Global Positioning System (GPS) receivers." *National Telecommunications and Information Administration*, NTIA Special Publication 01-45, February, 2001, https://www.ntia.doc.gov/files/ntia/publications/ntiasp_01_45.pdf.

[43] "U.S. Space-Based Positioning, Navigation, and Timing Policy: Fact Sheet." *The White House*, December 15, 2004. Available from https://csps.aerospace.org/sites/default/files/2021-08/NSPD-39%20PNT%20fact%20sheet%2015Dec04.pdf.

[44] Agreement On the Promotion, Provision and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications." *U.S. Department of State*, June 26, 2004. Available from https://www.state.gov/wp-content/uploads/2023/08/11-1212-Multilateral-Space-Satellites-6.26.2004.pdf.

[45] "International Committee on Global Navigation Satellite Systems: The Way Forward, 10 Years of Achievement 2005-2015." *United Nations Office for Outer Space Affairs*, January 2016, p. 10, https://www.unoosa.org/res/oosadoc/data/documents/2016/stspace/stspace67_0_html/st_space_67E.pdf.

[46] "International Committee on Global Navigation Satellite Systems (ICG)." *United Nations Office for Outer Space Affairs*, https://www.unoosa.org/oosa/sk/ourwork/icg/icg.html (retrieved April 20, 2025).

[47] Raquet, J., and Burruss, W.T. "More is more: Using multiple global national satellite systems to improve geolocation accuracy, performance, and resilience." February 2025. Available from https://cdn.everythingrf.com/live/GNSS_White_Paper_REVISED_ws_15_638774632541279425.pdf.

[48] Goward, D. "America is at risk of high impact GPS jamming and spoofing from space." *SpaceNews*, October 24, 2024, https://spacenews.com/america-risk-high-impact-gps-jamming-spoofing-from-space/.

[49] Parkinson, B. "Toughen GPS to resist jamming and spoofing." *GPS World,* March 21, 2022, https://www.gpsworld.com/toughen-gps-to-resist-jamming-and-spoofing/.

[50] Erwin, S. "Experts raise concerns about U.S. commitment to GPS modernization." *SpaceNews*, December 8, 2023, https://spacenews.com/experts-raise-concerns-about-u-s-commitment-to-gps-modernization.

[51] "Fourth Civil Signal: L1C." *National Coordination Office for Space-Based Positioning, Navigation, and*

Timing, GPS.gov. Updated August 10, 2020, https://www.gps.gov/systems/gps/modernization/civilsignals/#L1C.

[52] Allen, T. "Report of the 30th National Space-based PNT Advisory Board Meeting and Associated Activities." *Space-based Positioning Navigation and Timing National Advisory Board,* July 19, 2024. Available from https://www.gps.gov/governance/advisory/recommendations/2024-07-PNTAB-chair-memo.pdf.

[53] Mussoline, M. "Decoding radio occultation, the cornerstone of accurate weather forecasting." *Spire*, December 17, 2024, https://spire.com/blog/weather-climate/decoding-radio-occultation-the-cornerstone-of-accurate-weather-forecasting/.