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The 50th Anniversary of GPS:

New Avenues for Cooperation with Europe's Galileo

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Executive Summary

This paper delves into the evolution and future prospects of Global Navigation Satellite Systems (GNSS), with a particular focus on the United States' Global Positioning System (GPS) and Europe's Galileo. As GPS celebrates its 50th anniversary, it is a timely moment to assess its historical trajectory, current status, and future directions, especially considering the emergence of new competitors like China's BeiDou. Based on interviews with two GNSS experts from the European Commission, this study aims to analyze the potential for cooperation between GPS and Galileo, exploring avenues for collaboration and mutual learning.

50 Years of GNSS
Since its inception in 1973, GPS has evolved from a military tool to a ubiquitous global utility, facilitating a wide array of civilian and commercial applications. Despite facing challenges such as signal interference and system vulnerabilities, GPS has remained a silent yet essential infrastructure, generating significant economic benefits. The development of other GNSS systems like GLONASS, Galileo, and BeiDou has further expanded the GNSS landscape, adding new dimensions to great power competition.

Galileo, a Natural Partner for GPS
Galileo, Europe's GNSS constellation, offers an interesting contrast to GPS, emphasizing civilian governance and commercial applications. Unlike GPS, which originated from military interests, Galileo was designed as a civil infrastructure, reflecting the European Union's commitment to technological independence. Its governance model and emphasis on commercial and political objectives present valuable insights for GPS, highlighting potential synergies and avenues for enhanced cooperation between the United States and Europe.

Avenues for Future Cooperation
As the global GNSS landscape evolves, there are several avenues for strengthening cooperation between GPS and Galileo. Renewing the US-EU agreement on satellite-based navigation systems in 2026 provides a crucial opportunity to deepen collaboration and address technical and policy challenges. Opening the E6 frequency to Galileo in the US and increasing dialogue in international forums can further enhance interoperability and mutual benefits. Additionally, exploring new technologies and conducting joint projects, such as lunar PNT experiments, can pave the way for future innovations and partnerships.

In conclusion, the 50th anniversary of GPS can serve as a catalyst for reassessing the future of GNSS and strengthening collaboration between GPS and Galileo. By learning from each other's governance models, leveraging complementary strengths, and exploring new avenues for cooperation, the US and Europe can enhance the resilience, effectiveness, and societal benefits of GNSS technology, for themselves and the world. As the Artemis Program progresses to bring

Mankind back to the moon, GNSS cooperation is as important as ever for advancing global positioning, navigation timing services for the next 50 years to come.

Introduction

Since the inception of the American Global Navigation Satellite System (GNSS), the Global Positioning System (GPS), the constellation's governance has primarily been military. In contrast, China's GNSS, BeiDou, has just reached full global coverage and has an emphasis on political and economic gains, alongside military uses. In her work "China's BeiDou: New Dimensions of Great Power Competition," Dr. Sarah Sewall notes that the Chinese Communist Party (CCP) looks at GNSS capabilities more broadly than the US and is also pushing for other countries to adopt BeiDou for civilian uses.[1]

Europe's constellation, Galileo, much like BeiDou, reached full global coverage in the last few years. From an American perspective, the European GNSS is an interesting case study, as it was conceived with many of the same underlying values as the Americans, but with a different civilian form of governance. From a European perspective, GPS is of interest as the technical gold standard in GNSS, but also because of its military governance. Indeed, in the wake of the war in Ukraine, the European Union (EU) has a renewed interest in defense applications. Both sides have complementary perspectives and can learn from each other to acquire a more holistic perspective of the potential of GNSS capabilities.

As GPS celebrates fifty years of global leadership in GNSS, it is a timely moment to evaluate its past successes, current issues, and future perspectives for successful development in the next half-century. This paper aims to compare the GPS and Galileo systems, drawing insights from an interview with two GNSS experts of the European Commission. It seeks to answer the question of how the United States and Europe could learn from each other and strengthen their GNSS cooperation.

Fifty Years of GNSS

Last December, the United States celebrated the 50th anniversary of the creation of GPS, the world's first GNSS. At the 2023 National Space Council Meeting, Gen. Chris Grady, Vice-Chairman of the Joint Chiefs of Staff, recognized the essential role the technology has played over the last half-century for the United States and the world:

"Since its creation 50 years ago this month, the GPS has grown into a cornerstone of our international community, a utility that each and every one of us use in our everyday life."

Gen. Chris Grady, NASA, 2023 [2]

Originally designed for military purposes, this infrastructure has since then been opened up to civil and commercial uses around the world. As the global GNSS landscape evolves, it introduces new dynamics to great power competition. The following explores in more detail the past developments, current state of affairs, and future outlook of the GNSS landscape.

History of GPS

From its inception, GPS was imagined at the Pentagon by the US Department of Defense in 1973. Five years later, the first satellites were launched.[3]

On September 1, 1983, the civilian Korean Air Lines Flight 007 from New York City to Seoul entered into prohibited Soviet airspace, due to a navigational error. Thinking it was a US spy plane, USSR Air Forces shot the commercial flight down. Tragically, all 269 passengers were killed in the crash, including United States Congressman Larry McDonald. This incident escalated Cold War tensions but also led to the Reagan Administration making GPS PNT data freely available for global civilian use. The immediate intention was to improve civil aviation, which it did, but it especially spurred a leap in civil and commercial uses of PNT data worldwide. This cutting-edge technology, in effect, became a public good overnight, one of America's "Great gifts to the world".[3]

It was only several years later, in the 1991 Persian Gulf War, that GPS demonstrated its true worth on the battlefield. In what was later deemed the first "Space War", PNT data played a critical role in orienting US troops through the desert and guiding precision missile strikes. While the technology proved itself to be a key asset, it also faced the first interference with its signal, called "jamming".[4] While the impetus for the development of these systems was primarily military, the dual-use potential of GNSS was quickly becoming apparent, notably through the introduction of the first in-car navigation systems throughout the 1990s.

At this point, there were two separate signals for military and civilian purposes. The civilian one was intentionally degraded, as part of a policy referred to as selective availability. This policy was discontinued in 2000 by the Clinton Administration. Since then, hundreds of

innovative applications have been invented, so much so that GPS has become a catch-all term for all navigation systems today.[5]

Essential, but Silent Infrastructure

Over the last fifty years of GNSS, the world has far expanded the capabilities and uses of PNT data; it now undergirds so many of the products and services of everyday life. From ATMs to weather forecasts, from search and rescue services to flight control, there are countless applications. While private actors have become involved in other space technologies, GNSS, as a critical infrastructure, has remained a public service space technology. Even though the technology has matured, it is showing no sign of slowing down. As of 2019, it is estimated that the technology has generated over $1.4 trillion in economic benefits for the United States alone.[6]

GNSS in a way is becoming a victim of its success, as the world has a high and increasing reliance on the technology. In addition, as more and more companies and applications rely on these systems, the financial risk of an outage is growing. It is estimated that an outage of the GPS system alone would have an economic impact of $1 billion per day. It is a free public service to the world, yet there is little awareness about the cost incurred by governments to provide global PNT data. As such, it is often considered to be a silent infrastructure.[7]

In the long fifty-year history of the technology, there have not been any large-scale significant accidents or outages of GNSSs. However, it is not because it hasn't yet happened that the risk does not exist. Between jamming, spoofing, and the development of space weapons, the threats posed to GNSS are as high as ever.

Development of other GNSS

Following the United States, the former USSR launched its own GNSS, GLONASS, in 1982.[8] Between the scope of the project and the collapse of the Soviet bloc, it took many years to reach global coverage. In 1995, the Russian Federation saw the full deployment of the world's second GNSS.[8]

Despite some opposition from the United States, Europe was next with the creation of its own constellation - Galileo - which was fully operational in 2016.[9] In 1999, the European Union began imagining creating its own GNSS. The United States at first expressed security concerns about the program and possible interference with GPS, and after funding difficulties, nearly two decades later Galileo was fully operational.

China followed suit and reached global coverage through its GNSS, BeiDou, in 2020.[10] At the time, the world was focused on the COVID-19 pandemic, so the full deployment did not garner much attention. It was no less significant and introduced new dimensions of great power competition between China and the USA. While the United States benefits from a long head start. The Chinese constellation is more modern and has several key features, such as its two-way messaging capabilities, and high-performing ground infrastructure. BeiDou

strengthens China's geopolitical stance on the world stage and sets a contrast to GPS. While the constellation is especially focused on military capabilities, it does take a broader view to include civilian uses as well. BeiDou notably serves as a foundation to undergird 5G telecommunications and critical infrastructure of the Belt and Road Initiative (BRI) and related Digital Silk Road (DSR). As such, the constellation strengthens China's economic and political soft power. Over time, an overreliance on BeiDou could lead to technical manipulations or surveillance risks.[1]

Galileo, a Natural Partner for GPS

Faced with rival BeiDou, taking a broader view of civilian GNSS uses than GPS, Galileo presents an interesting case study for the U.S. of a system designed for civilian uses from its inception.[1]

The Europeans have developed their constellation with particular attention to commercial and political uses of Galileo. As the West reconsiders common defense and security policy, in the wake of Russia's invasion of Ukraine,[11] both Americans and Europeans have very complementary perspectives on GNSS and stand to learn from each other.

Governance

Unlike GPS, GLONASS, or BeiDou, Galileo was designed as a civil infrastructure, which is reflected in its governance structure. At its inception in 2006, the EU even questioned whether there might be potential for commercialization of Galileo's PNT data. At that time, it considered a Public Private Partnership (PPP) governance structure. In the end, the Union opted for full government ownership of the constellation and associated ground infrastructure.

As a supranational entity, the European Commission owns fairly few assets, relative to other government entities; however, in the case of Galileo, it was considered necessary. As one of the most important assets and technological feats of the Union, the program is a strong symbol of European construction.[12]

The original political impetus for the creation of Galileo came from the European Union, which is still reflected in the program's governance to this day with the European Parliament and the Council of the European Union in charge of the political overview of Galileo to this day.[13]

On the program management level, the responsibilities of management, security, and funding reside with the newly formed Defense Industry and Space Directorate General (DEFIS) of the European Commission. On the implementation level, it is also noteworthy that the European Space Programme Agency (EUSPA) has operational responsibilities for other adjacent programs: Copernicus, EGNOS, GOVSATCOM, and Space Situational Awareness (SSA). The grouping of these programs under one umbrella only came to be in 2021. It has led to three main areas of synergies:

- ***Common uses of infrastructure***, e.g. grouping of Copernicus (Earth observation constellation) networks and Galileo Information Centres
- ***Financial planning*** e.g. part of the EU's 7-year multiannual financial framework (MFF), which allows for more stability, security, and freedom in budgeting. From 2021 to 2027, the Commission has allocated €16 billion to EUSPA in total
- ***Shared management resources*** e.g. administrative support functions are mutualized[12]

In contrast, the United States has a far more fractured governance structure of GPS, especially among the civil government agencies. While the Departments of Defense, Transportation,

Commerce, State, NASA, and the Coast Guard each have particular responsibilities, all in all, there are over ten federal agencies involved in the governance of GPS.

In a 2022 report, the National Space-Based Positioning, Navigation, and Timing Advisory Board found that American PNT decision-making authority is "diffuse and lacks clear focus and leadership." It goes on to recommend that the government "sharpen and improve the agility of its PNT governance."[14] Part of the interest in Galileo is that it provides a fresh centralized civil model of governance that starts from a blank slate. The United States could stand to gain in efficiencies from centralizing its governance, and Galileo's model could serve as an interesting case study.[15]

Civilian Uses and Applications

Galileo's functional objectives as defined by EUSPA are: Better positioning and Navigation; Unique timing accuracy; Faster response to emergencies; and Economic growth.[9] These objectives principally serve two overarching purposes: Commercial; and Political goals. ESA for its part plays a support role in the implementation of the program.[16]

From a commercial perspective, Galileo offers a modern infrastructure, which notably differentiates itself by its High-Accuracy Service (HAS). However, it still lacks operational experience, which has already affected its resilience. Indeed, in July 2019, the system suffered a full week outage during which it had to fall back on GPS.[17]

EUSPA is not only offering its PNT services to civil actors but also proactively supporting them in their uses. They offer complementary services such as best practices training, foster a user community, and produce market intelligence on the applications enabled by Galileo. These complementary services are centered on industry and structured around 17 market segments in particular, ranging from biodiversity to transportation.[18] For each of these segments, EUSPA maintains a portfolio of reference projects to showcase use cases.

These market segments are not only relevant for GNSS services but also for Earth observation (EO) services. Having a grouped governance under EUSPA of Galileo's GNSS services, with Copernicus's EO services enables synergies and the identification of shared market uses. Within each of the market segments, the use cases are classified along the value chain, both upstream and downstream. Upstream uses include all space infrastructure providers, such as satellite designers or ground segment constructors. Downstream uses range from component manufacturers (e.g. chipsets, antennas, GNSS receivers), to system integrators (integration of PNT data into larger systems e.g. automobiles), and value-added service providers (e.g. GNSS-enabled software).[18]

In its market intelligence report, EUSPA estimates that GNSS demand will grow tremendously in the years ahead. It projects that between 2021 and 2031 device revenues will close to double from €48.4bn to €87bn.[18] Even more impressive, they expect demand for GNSS services to expand from €150.5bn to €405.2bn.[18] Given the projected commercial potential at hand, the European Union is keen on tapping into it. ESA for its part has strengthened space industrial

capabilities across the continent by distributing design, procurement, maintenance, research, and development contracts to companies of member states.[18]

From a political perspective, Galileo is one of the greatest technological achievements of the European Union and contributes greatly to Europe's global image. In terms of reputation, the United States' GPS remains dominant and has even become synonymous with GNSS. Galileo is often presented as the "European GPS," however, Galileo demonstrates the EU's technological leadership, political independence, and industrial capability. Additionally, Galileo shows a strong example of democracies binding together - and has proved it can act quickly. For instance, the Infrastructure for Resilience, Interconnectivity, and Security by Satellite (IRIS²), the new secure connectivity system was put online in only a year.[12]

Europe's Galileo was the third system to reach global coverage, ahead of China. This was possible in large part thanks to ground infrastructure on French territories spread out around the globe, from French Guiana to the islands of Reunion, Noumea. Some areas, East Asia in particular, may have less coverage than continental Europe. [9]

While the US or Chinese programs may use bases outside their national territory for better coverage, Europe has opted not to. In 2011, Europe made a conscious choice not to expand its network outside of EU member States territory and has stuck to this decision ever since. It has implemented this policy so rigorously, that once the United Kingdom left the Union in 2016, the infrastructure in the Falkland Islands had to move to French Guiana. The only exception to this rule has been Norway, because it is a member of the European Free Trade Association (EFTA), as well as ESA, and has a special agreement with the EU. This policy of EU-only basing has the advantage of better resilience, as well as the mitigation of IP theft.[12]

The Union strongly believes in the defense of its diplomatic interests through cooperation within international institutions such as the ITU, ICG, UNOOSA, COPUOS, and others. This allows it to ensure greater compatibility, interoperability, and transparency of Galileo with other GNSS systems. The EU insists on the benefits of interoperable GNSS services on the multilateral level, which it considers to be key to maintaining a free and open GNSS landscape. As an infrastructure born from international cooperation between European nations, Galileo's position holds strong symbolic weight, as an example of multilateral cooperation for the common good and peace. Not only does Galileo provide European companies with PNT data but improves GNSS globally by decreasing redundancy and increasing resilience.[12]

Emerging Defense Considerations

The newly formed Defense Industry and Space Directorate General (DEFIS) of the European Commission was only established in 2021.[11] It stands out in the history of European construction, as it is the only Directorate General in the history of the European Union that includes the word "Defense." The Union does not have a military element, but there is currently strong momentum for more joint-involvement of the Union in defense affairs, in particular since the outbreak of the war in Ukraine. Placing the governance of space affairs in the same Directorate General as defense may also lead to a stronger consideration of military interests in future developments of Galileo, both in coordination with the North Atlantic Treaty Organization (NATO) and the United States.[12]

Avenues for Future Cooperation

Looking forward there are multiple avenues to reinforce the cooperation between GPS and Galileo. First, the agreement governing cooperation between GPS and Galileo will need to be renewed in 2026.[10] Second, GNSS systems need to evolve from silent to loud infrastructures to garner more public support and funding, on both sides of the Atlantic and across the globe. As the Artemis Program plans to send Humanity back to the Moon in 2026, cooperation between the United States and Europe is poised to increase, in all space ventures but GNSS in particular.[19]

Agreement Renewal in 2026

The EU-United States agreement on the promotion, provision, and use of Galileo and GPS satellite-based navigation systems and related applications concluded in 2011 and renewed for five years in 2021 will be up for renegotiation in 2026.[10] Most of the discussions will likely revolve around technical adjustments and coordination on the parameters of the next generation of GNSS satellites.

There is one specific policy area where the United States and the Union could explore further GPS-Galileo integration and that is the opening of the E6 frequency to Galileo by the Federal Communications Commission (FCC). The Commission determined that allowing receipt in the U.S. might create interference issues and limit options for expanding the use of the neighboring 1300-1350 MHz band.[20]Opening the frequency, however, would enable Galileo's new High Accuracy Service (HAS) to be available in the U.S. HAS only went online at the beginning of 2023, however, it is authorized everywhere else in the world. This is a service that provides more precise PNT data and could benefit American civil actors. Articles 6 on *Non-Discrimination and Trade* and 7 on *Open Access to Civil Satellite-based Navigation on Timing Signals* of the agreement could serve as a solid basis for the opening of the E6 frequency to Galileo HAS.[10]

From Silent to Loud Infrastructure

In the years to come, the European Commission sees a sustained need for government-provided PNT services. It is following with great interest the emergence of New Space private actors but perceives them, especially as complimentary providers, mostly for ultra-high accuracy data of a centimeter or less. The Union does recognize that the relation to the private sector has been an ongoing discussion from the very initial considerations of building Galileo off of a PPP, but government ownership has been the privileged approach to providing free global PNT data so far.

As such, the US and European governments must garner public support for their operation of GNSS, at home and abroad. The advantages of freely available and interoperable GNSS need to be explicitly put forward to partner nations, relative to rival systems such as GLONASS and

BeiDou. Given that GNSS demand is projected to more than double in the next decade, so will reliance on its PNT services.

The outage suffered by Galileo in 2019 should serve as a cautionary tale, as well as an argument for interoperable systems and international cooperation.[17] While GPS has proven itself time and again throughout the years, increasing its number of like-minded partners will improve its PNT services and their resilience. While China is growing the reach of its BeiDou network with possible tie-in effects, the United States should not shy away from putting forward GPS as the partner of choice.

Another interesting avenue could be the current Artemis Accords campaign, the international framework spearheaded by the US for its mission to return to the moon. In 2023 alone, the number of signatories increased from 21 to 33 and already counts one new 34th signatory in 2024, Belgium.[19] Even if the core of these accords is a set of principles for a safe, peaceful, and prosperous future in space, the US could use the platform and associated contacts to put forward partnerships in space more broadly, notably in GNSS.

From MEO to Lunar and Beyond

The significant decrease in cost to orbit by New Space private companies, spearheaded by SpaceX also provides new avenues for cooperation. Indeed, by reducing the costs associated with launch to orbit, navigation satellites may be serviced and replaced more easily, leaving more resources for the development of the technology itself.

Beyond GPS's medium earth orbit (MEO) satellites, there are promising new projects and experiments emerging in cooperation with European actors for the development of lunar PNT satellites, as part of the Artemis p. NASA is currently working with the European Space Agency ESA on Lunar Pathfinder, a project to provide communications services around the Moon.[21] In addition, it is also working with the Italian Space Agency (ASI) on a Lunar GNSS Receiver Experiment (LuGRE).[22]

Several promising cutting-edge technologies may offer complementary sources of PNT data in the future, such as magnetic navigation, muometric navigation, miniaturized atomic clocks, accelerometers, and 5G.[12] However, none of these technologies are as effective at simultaneously providing all three Positioning, Navigation, and Timing data, which will remain a very useful combination, unique to GNSS, for years to come.

Recommendations

Both Europe and the United States stand to learn from each other's GNSS systems and gain from reinforced cooperation. Europe could notably benefit from the GPS's experience in military governance, while the United States could look at Galileo's civil governance as a model to sharpen and improve the agility of its decision-making authorities.

- ***Renew the US-EU satellite-based navigation systems agreement in 2026*** and use the 50th Anniversary of GPS as a catalyst to begin this increased cooperation agreement between GPS and Galileo in 2026.
- ***Include the opening of the E6 frequency*** to Galileo by the Federal Communications Commission (FCC) as part of the 2026 negotiations. This would allow American companies to access Galileo's High Accuracy Service (HAS).
- ***Increase GNSS dialogue in international forums***, such as at the UNOOSA ICG, in particular with European partners and Artemis Accords signatories
- ***Centralize the civil governance of GPS*** within the US federal government to mitigate redundancies and improve agility in decision-making
- ***Raise awareness*** of the multiple benefits of GNSS, GPS in particular, to the United States, and the world to ensure its further development.
- ***Build and federate a community of commercial actors*** with novel uses of PNT data and showcase their most innovative applications
- ***Pursue developments of PNT beyond MEO***, conduct further lunar PNT experiments and projects together with international partners, such as LuGRE with the Italian space agency or Lunar Pathfinder with ESA. This can pave the way for developing the technology and sparking renewed public enthusiasm around PNT infrastructure, even fifty years after the creation of GPS.
- ***Explore the potential of new technologies***, such as magnetic navigation, muometric navigation, miniaturized atomic clocks, accelerometers, and 5G for complementary PNT data services

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