RGIT ASSESSMENT #2
EMERGENT TECHNOLOGICAL SYSTEM

Global navigation satellite system services, overview

Masters in Innovation and Research for Sustainability

RESEARCH, INNOVATION AND GLOBAL TRENDS

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Credit: NovaGeo

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INTRODUCTION

This report provides an assessment on **four issues**:

1. *The usage of global navigation satellite systems;*
2. *Possible difficulties in the commercialization of new systems;*
3. *Future attitudes and reactions to new developments.*
4. *How GPS, as the biggest incumbents, might respond and what could be the approaches.*

The **methodology** is based on the review of four sources of evidence:

a) Technical literature;
b) Current debates in the public sphere;
c) Expert consultations;
d) Available apps.

CONCLUSIONS IN A NUTSHELL

On the basis of a variety of evidence (technical reports and ongoing policy views on geoeconomics) and after consulting with 7 experts (9 were approached).

(1) **Economic competition between GNSS services is technically feasible**. Today, terminals (e.g. smartphones) are able to pick up all GNSS radiofrequencies and agnostic regarding the constellations. Even when the satellite systems in the same frequency bands there are no problems regarding interference. However, the services are not actually competing since they are highly complementary, and this is desirable.

(2) **Outer space is now a key domain for geopolitical competition.** Measures that already recently took place to cut network infrastructure or specific support technologies could be envisioned. Nonetheless, even with the rise of the recent tidal wave of sanctions governments have fell short of implementing a "GNSS decoupling" scenario which could be highly disruptive for all stakeholders given its "public good" characteristics.

(3) **A number of possible initiatives regarding restrictions on GNSS services are considered.** At the point of broadcasting of signals, the measures that can be highly problematic in terms of threats to sovereignty. At the point of reception the measures could lead to a further disruption and reconfiguration of the whole supply chain of electronic communications.

PROBLEM DESCRIPTION

Six Global Navigation Satellite Systems (GNSS) are in existence in operation, although two of them are regional (India and Japan).

GNSS are space-based, earth encompassing, all-weather, continuous radionavigation and time-transfer systems that generate and distribute accurate information on three-dimensional position and velocity.

They are space-based satellite navigation infrastructures owned operated by states (or supra-state entity like in the case of the EU).

They are "**dual-use technologies**" provides a civilian radio-navigation satellite service (standard service for the general public) and are also used by the defense sector (restricted service for government usage).

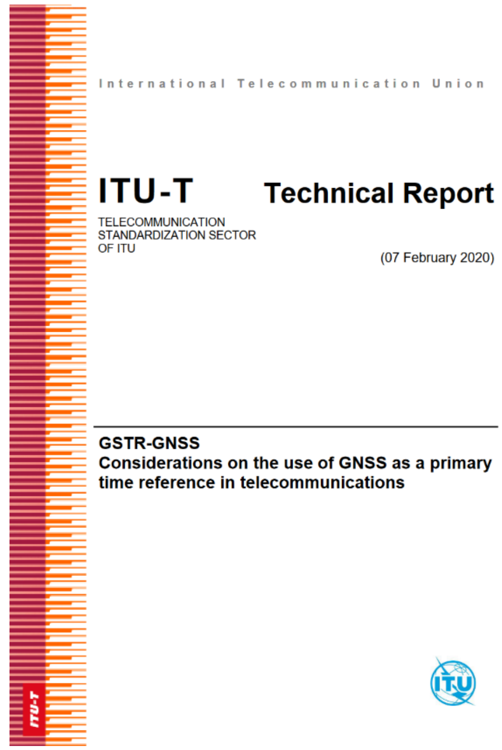
The **civilian services are typically open and not monetized**, but some added-value services may be provided and charged (like in the case of Galileo where additional signal is encrypted in order to control and select access).

Evidence on the fleets of past and present satellites is somewhat elusive, and **sources are sometimes conflicting**. The exact number of satellites may vary as older satellites are retired and replaced.

- **BeiDu** (China) was first made operational in the year 2000 and now counts with 44 satellites.
- **Galileo** (European Union and European Space Agency) came into operation in 2016 and uses 24 satellites;
- **GPSS** (US) was launched in 1978, has been globally available since 1994 (Clinton Administration) and hangs on a constellation of 32 active satellites;
- **Glonass** (Russia) dates from 1982, was established under URSS and counts with 24 satellites;
- NavIC (India) was put into orbit in 2018 and consists of 7 satellites with **regional** capabilities;
- QZSS (Japan) started was up in 2010 and has 4 deployed satellites with **regional** capabilities.

GNSS services are of a unidirectional and broadcasting type. The signal goes down from orbit to illuminate a footprint.

Although finding correct position is the key goal they assist in providing crucial precision data that underpin telecommunications in accurately adjusting their clocks. As such, GNSS services allow for synchronism between equipment and base stations therefore enabling the operation of electronic communications mobile networks. In other words, **GNSS is basic infrastructure for space-time coordinate determination on which the modern digitally-enabled economy relies.**


International Telecommunication Union

ITU-T Technical Report

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

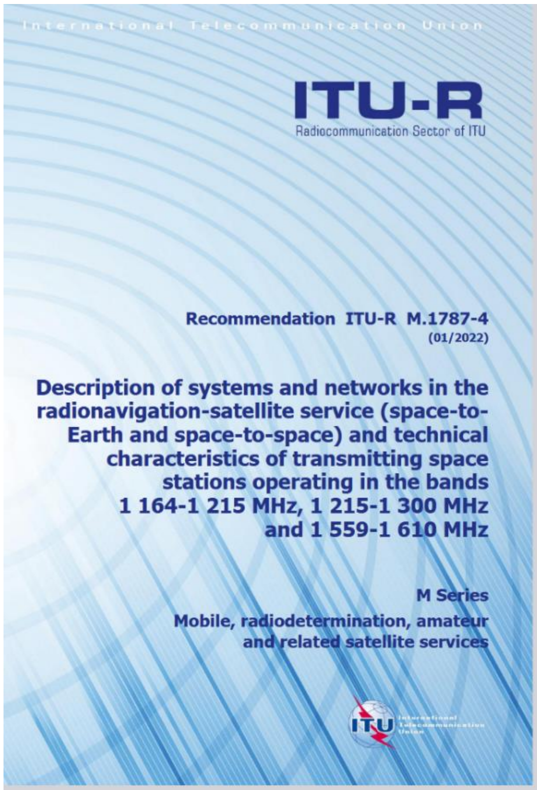
(07 February 2020)

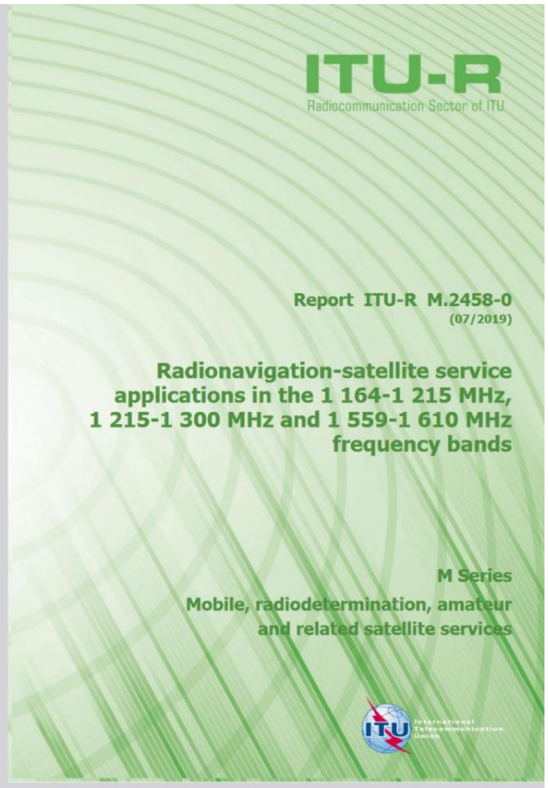
GSTR-GNSS
Considerations on the use of GNSS as a primary time reference in telecommunications

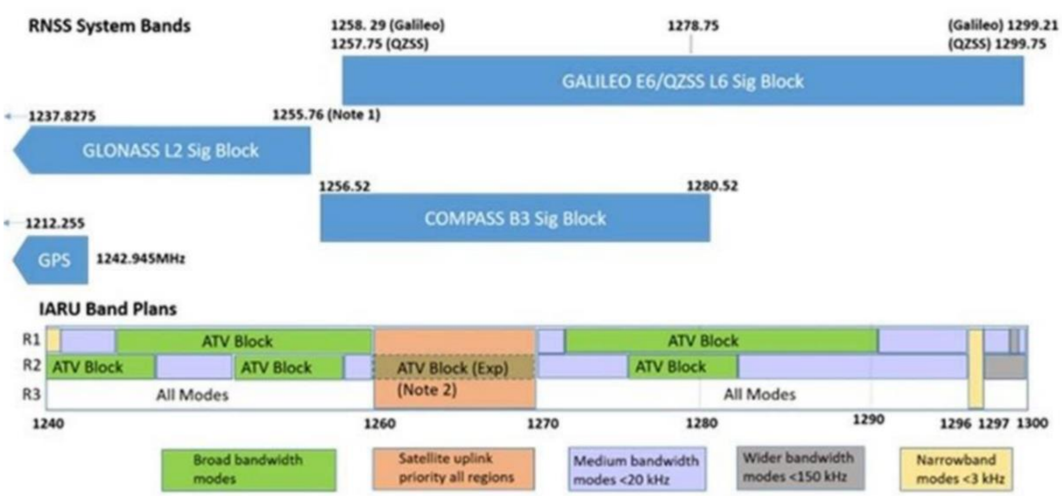
Most of the satellites in a GNSS are of medium earth orbit (MEO) or low-earth orbit (LEO), so **they over above and across many geographies** and not only that of the country that manages it.

Signals of one GNSS are co-usable with other GNSS signals, so that signals can combined by receivers to derive even more high-quality (reliable, precise, etc.) information. GNSS compatibility and interoperability is described in several International Telecommunications Union (ITU) guidelines (see examples below).

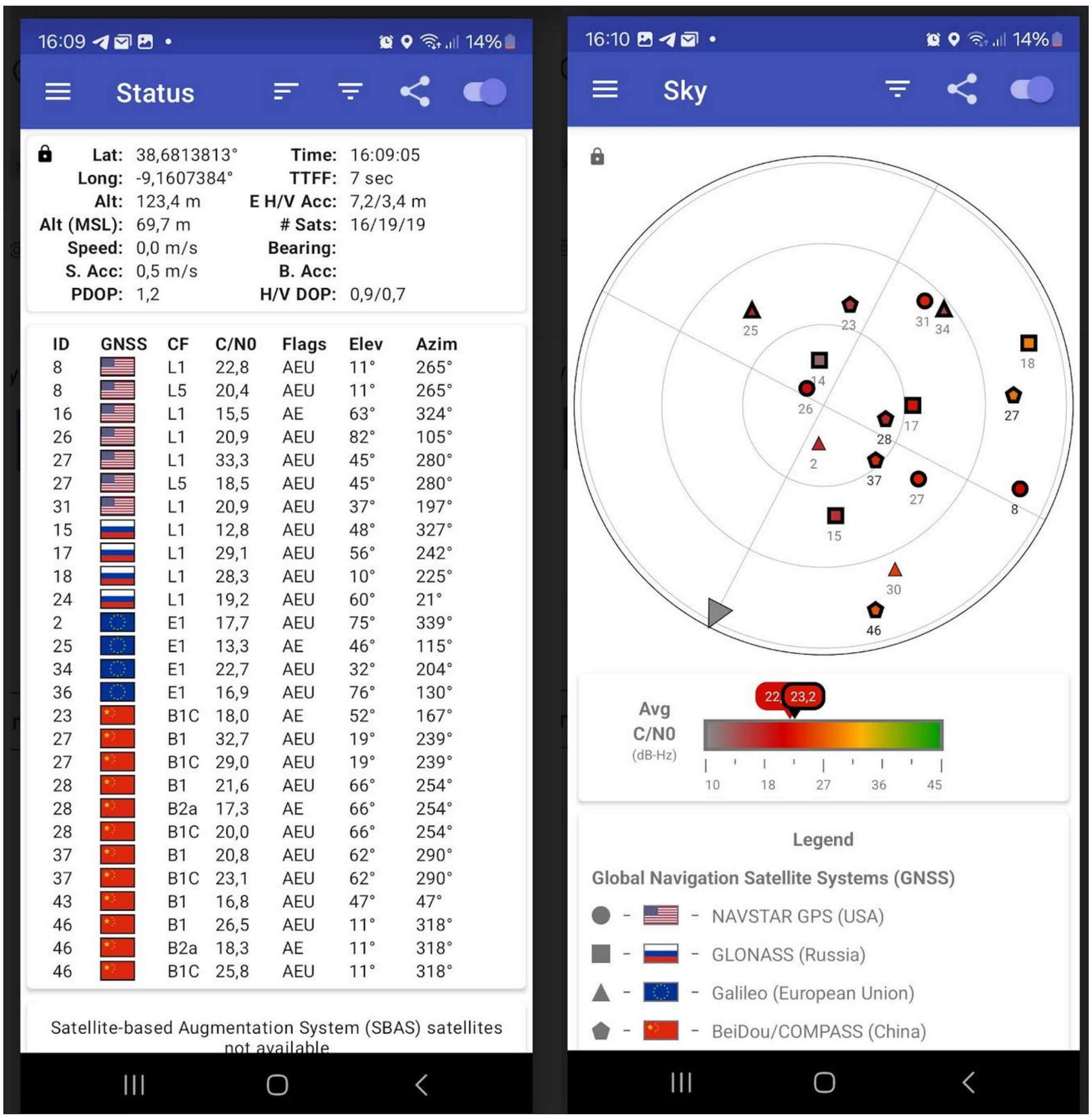
Even when signals travel in the same spectrum bands there are no news of instances of conflict or interference. Either because the precise radiofrequencies channels just co-exist next to one or because terminals are able to distinguish the call-codes or to pick up the one with stronger power (like in the 3G protocol, i.e. the CDMA - Code-Division Multiple Access technology). An example of partial overlap between system bands can be seen in the picture below (GPS/GLONASS, GALILEO/BEIDU) (see also here).







Unlike 10 or 20 years ago, **terminals of today have hardware and software that are agnostic regarding the source of signals**. That is, terminals like e.g. smartphones are suited to pick signals from all constellations. The picture bellow shows two screenshots of a normal smartphone using an up (Samsung and GPStest), and the satellites being picked up are visible.



So, it should be underscored the final service integrated solutions will be possible by which signals from several systems are weaved together in such a seamless way that goes unperceived to the user. **This makes GNSS services not competing but rather highly complementary**, especially for high-safety requirement activities (aviation, maritime, road, rail, etc.).

ISSUE APPRAISAL

GNSS technologies have "public good" characteristics. That is to say, like a beacon they have non-excludability and non-rivalry characteristics. In such cases, the services are not-for-payment and the financing comes from non-market mechanism (sovereign entities).

Since the network services are partially overlapping but no-interfering their co-existing is not only possible but actually desirable from a functionality and general welfare point of view.

These two techno-economic facts (public goods + network redundancy) converge to make a *<u>strong case for peaceful and virtuous coexistence between systems</u>*. That is to say, GNSS is strongly aligned with global governance principles as articulated by Global Development goals. GNSS can be argued to serve directly at least eight of the seventeen SGDs, namely:

- *SDG 8 – work and economic growth*
- *SDG 9 – innovation and infrastructure*
- *SDG 10 – reducing inequality*
- *SDG 11 – sustainable cities and communities*
- *SDG 13 – fighting climate change*
- *SDG 14 – Oceans and marine resources*
- *SGG 16 – Peace and justice*
- *SDG 17 – partnerships for development*

It is significant that there is *<u>no notice of issues related to GNSS having been so far politicized in international bodies</u>*, namely at the ITU (International Telecommunications Union), CEPT (European Conference of Postal and Telecommunications Administrations) or ESA (European Space Agency).

In this regard it is worth noting that in the case of the Russia-Ukraine war (2022-…) there were major disruptions of network industries. Europe was cut off from energy supplies (namely through the blow-up of the Northstream2 gas pipeline) and Russia was cut from the western-dominated finance system (its banks were de-linked from the swift system). With regard to spectrum-based electronic communications indeed Russia was "indefinitely suspended" from CEPT (leading to major spectral noise on the Finnish border, for instance) and subject to novel technical of GNSS jamming related to drone warfare (maneuvers circumscribed to the conflict's theater of operations). Nevertheless, **throughout this period the Glonass still operates and *no European civilian receiver is impeded* from tuning to its signals, *including critical services users* (police, emergency services, etc.).**

However, GNSS services can be degraded (less resolution) or even blocked (via encryption) and these gives them **"club goods"** features (excludability for external parties, but non-rivalry inside the system). Because of the risk of dependence and the need to ensure autonomy in the military sphere significant international powers have established their own system by committing vast resources under a **sovereignty** rationale.

In GNSS systems geopolitical considerations were always present. To emphasize, the emergence of GNSS was as *security-related to the core and from the outset*. The US and the Russian systems arose during the Cold War. It was only a decade since the crumbling of the URSS-led block that the US turned off the feature known as "selective availability" from its GPS system (quality gains from signal scrambling or induced noise elimination). This happened at the height of globalization, i.e. the US-led "liberal international order". The reasons for doing so seem explainable from a perspective of country centrality management and soft power investment. The White House statement of 1 May 2000 (see also news coverage) is worth retrieving:

> "This is a significant step toward furthering the worldwide utility of GPS for peaceful civil, commercial, and scientific pursuits. However, should an occasion arise in which it's in our interests to block GPS on a regional basis, we will have the ability to do so."

“This announcement is another step in this Administration's strategic vision for the evolution of GPS. This vision included a goal of encouraging the acceptance and integration of GPS for peaceful purposes, encouraging private sector investment, and promoting safety and efficiencies in transportation and other fields.”

It is after this turning point that other systems eventually come online. GNSS-assisted markets grew markedly ever since. The latest assessment by EU Agency for the Space program (EUSPA), published on 23 January 2024, states:

“In an era where innovative solutions are essential to progress, Earth Observation (EO) and Global Navigation Satellite System (GNSS) technologies emerge as linchpins for addressing societal challenges and boosting business processes. As of 2023, global revenues from GNSS and EO stood at approximately €260 billion and €3.4 billion, respectively. Projections for 2033 signal significant growth, with GNSS expected to reach €580 billion and EO nearly €6 billion.”

ANTECIPATORY ANALYSIS

It is possible to formulate an estimate of global market potential for insurgents (like BeiDu) as alternative or competing navigation satellite systems: it is very good/large (but not great/excellent) and will grow (although subject to increasing risk) with the size of the market.

Upside: the potential for global commercialisation

- Provides **more reliability** as usage expands continuously.
- As **diplomatic value** as it serves global challenges.
- Gives more options to the **rising "global south"** countries.

Downside: the barriers for global commercialisation

- One reason for the downside of our expectations has to do with quality parameters. The coverage is wide and satellite availability is rich but **resolution is much worse** than alternatives.

System	**Beidu**	**Galileo**	**Glonass**	**GPS**	**NavIC**	**QZSS**
Accuracy	3.6	0.2	2-4	0.35	1	1

Source: Banerjee (2003), which is chapter 20 of Asnal et al. (2023)

- Another hurdle as to do with the uncertainty created by the **intensification of geopolitical strategies** by big powers. As many experts and decision-makers of the field know, they are "unwritten rules" (a term we heard while researching for this note) that will constrain the ability of innovators and companies to cooperate from countries that are "politically distant" (a term that is used in think tanks) from the West (namely, China; Russia is already out).
- In particular, some **foundational technologies are increasingly subject higher and higher scrutiny**. These technologies include "space technologies and systems", as the

latest White House list of key technologies show (published recently, 12 February 2024, as can be seen here below).

THE WHITE HOUSE   Administration   Priorities

The critical and emerging technology areas in the 2024 update are:

- Advanced Computing
- Advanced Engineering Materials
- Advanced Gas Turbine Engine Technologies
- Advanced and Networked Sensing and Signature Management
- Advanced Manufacturing
- Artificial Intelligence
- Biotechnologies
- Clean Energy Generation and Storage
- Data Privacy, Data Security, and Cybersecurity Technologies
- Directed Energy
- Highly Automated, Autonomous, and Uncrewed Systems, and Robotics
- Human-Machine Interfaces
- Hypersonics
- Integrated Communication and Networking Technologies
- Positioning, Navigation, and Timing Technologies
- Quantum Information and Enabling Technologies
- Semiconductors and Microelectronics
- Space Technologies and Systems

More on this update: The *National Security Strategy* notes that technology is central to today's geopolitical competition and to the future of our national security, economy and democracy.

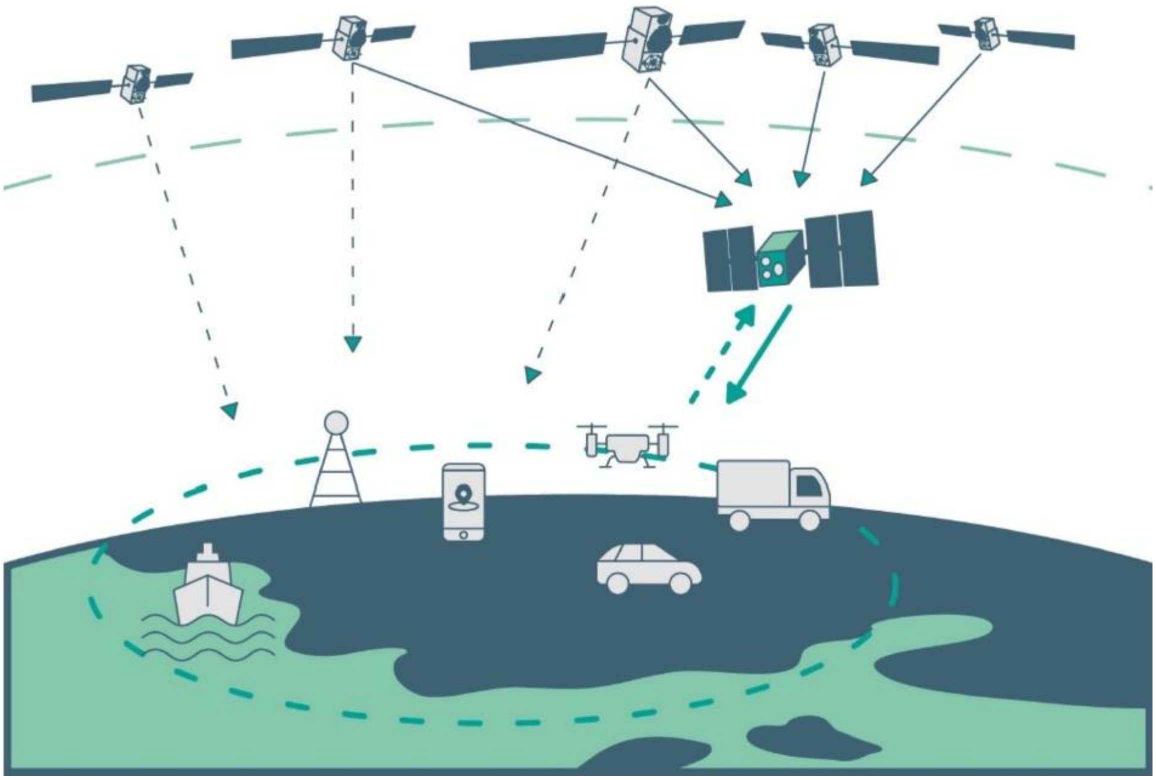
It is also possible to formulate a sketch foreseeable responses:

Constellation level: at the source of GNSS signals

- **Jamming of the satellites**. This is a dangerous initiative, which can be taken by satellite owners to mean an attack on sovereign assets. New techniques may notwithstanding disguise the origin of aggression and the media can be prompted to shift the blame of causality away from perpetrators.

- **Incumbent systems may increase the quality**. Namely, higher resolution and more added-value services.

- **Agile "New Space" approaches.** Conventional navigation satellites fly high, slow and deliver metre-level accuracy. But Position, Navigation, and Timing (PNT) through Low Earth Orbit (LEO) satellites are now a prospect (see picture below). This alternative can supplement existing constellations and allow new business models that demand i) faster position fixes, ii) rapid two-way authentication checks, iii) indoor-penetration, and iv) greater signal availability, especially in high-latitude and polar regions. In Europe, is a flagship program since November 2022. In the US, efforts have been developing, hardening and evaluating PNT for some time to ensure leadership in LEO.



Source:
https://www.esa.int/ESA_Multimedia/Images/2022/07/LEO_PNT

Receiver level: at the user end of GNSS signals

- **The potential to relate GNSS to cybersecurity threats cannot be downplayed. There are plenty of examples in the field of telecommunications to serve as template (see the case of the so-called "high-risk vendors" like Huawei). Note also the role of Qualcomm in being behind the technology of receiver as it could be subject to "export restrictions".** Places in which this topic may be part of the strategic menu is at the table of the G7 and also at the US-EU Trade and Technology Council.

- Moreover, the discourse regarding "decoupling" and "di-risking" may be stepped up to include GNSS services. This may lead to measures to **reap out the capability to get the signals from the hardware (the terminals), software (the modules) and applications (that apps are stopped from using data from "no-go" GNSS services)**.

- In particular, in Europe this movement toward a heightened "trade war" may **occur discretely and incrementally at very basic layers (like technical standards through institutions like ETSI or CEPT) or through more abruptly and explicitly through regulation and competition policy (by evoking clauses buried in rulebooks like the DSA or the DMA)**

SOURCES EVALUATION

The literature that is out there and can useful for this source of assessment is rather limited. The launch year and total population of GNSS satellites are not easy to ascertain. No reports were found regarding the market share of needs addressed by the different GNSS providers.

Besides secondary sources this assessment was also built from primary sources, namely app data and personal testimonies.

A total of 11 experts were approached. The experts consulted for this note come from a variety of countries (five), a variety of backgrounds (space engineers, spectrum supervisors, regulation economies), and a variety of occupations (professionals in international organisations, independent consultants, new space entrepreneurs).

This assessment was built by **amassing and cross-checking the disparate inputs and by integrating them in a coherent picture** with the best of our ability and knowledge of the field.