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ESA Engagement with PNT Sectors: The NAVISP Programme, a Key Enabler for Innovation

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The main goal of this paper is to present the rationale of the new ESA programme in the Navigation domain (i.e. NAVISP). It will support European industry in succeeding in the highly competitive and rapidly-evolving global market for Satellite Navigation, and more broadly PNT technologies and services, while supporting Member States in enhancing their national objectives and capabilities in the sector.

1 Introduction

GNSS and more broadly Positioning, Navigation and Timing (PNT) capabilities are truly a global utility that positively affect the daily lives of many people around the world. GNSS services provide economic benefits, transportation and security efficiencies that were previously unattainable. Today's construction, farming, mining, shipping, surveying, smart phones, car navigation, and traffic management systems have become dependent on GNSS (namely GPS) technology. GNSS enhances public safety by preventing transportation accidents and by reducing the response times of ambulances, firefighters, and other emergency services. GNSS also furthers scientific aims such as weather forecasting, earthquake prediction, and environmental protection. Furthermore, the precise time signal is embedded in critical economic activities such as synchronising communication networks, managing power grids, and authenticating electronic transactions. As in the rest of the world, the European society, and many sectors of the European economy are increasingly reliant on satellite navigation services.

2 A proliferation of satellite systems

The satellite navigation scene has changed vastly since 1983, when the American GPS (Global Positioning System) signal first became available for civilian use on an open and free-of-charge basis. Its Russian equivalent, GLONASS (GLObal Navigation Satellite System), is once again in full operational capacity since 2010, after a period of degraded performance. The Chinese system, BeiDou, is expected to achieve completion for worldwide service in 2020, although a limited version of its signal has already been available since December 2012. The Japanese regional system, QZSS, is already providing a limited service in the form of an augmented signal for GPS, but should be gradually upgraded and achieve full independence in 2023. The Indian regional system IRNSS (Indian Regional Navigation Satellite System), finally, is on its operational way as well. Not to mention, obviously, the European Galileo system expected to achieve full operational capability in 2020.

The same spacefaring nations are developing their own Satellite-Based Augmentation System (SBAS), primarily intended for the aviation sector but with increasingly widespread penetration in other sectors. There are today 8 SBAS systems in the world either in operations like the American WAAS (Wide Area Augmentation System), the European EGNOS (European Geostationary Navigation Overlay Service), the Russian SDCM (System for Differential Correction and Monitoring), the Indian GAGAN (GPS Aided GEO Augmented Navigation), and the Japanese MSAS (Multifunctional Satellite Augmentation System) or in definition and development (like the Chinese Beidou SBAS, the South Korean KASS and the African SBAS).

In parallel, these international players, and the USA in primis, are already thinking beyond GNSS, studying and developing novel approaches like miniaturised inertial sensors, pulsed lasers and tracked lightning strikes to provide precise location-based insights in GNSS-denied areas, driven by the evolving highly demanding military requirements (e.g. see DARPA programme).

More and more in the future, satellite navigation will be seen as one source of PNT information complemented/integrated with other terrestrial and/or space-based sensors.

3 Macro trends in the PNT sectors

One of the driving forces for such a proliferation of positioning systems is an important change in rationale which goes beyond the initial military driver for GPS, or the independence from other GNSS systems for Galileo.

Indeed it is now based on several key factors:

First, satellite navigation infrastructures constitute an asset of great value, embedded in the essence of our modern society through the increasing support that they bring to other infrastructures/sectors such as rail and road networks, air and maritime transportation, power grids, etc., as well as the critical support they provide in Search and Rescue applications (e.g. ability of QZSS to send messages to all smartphones within a certain area in case of emergency, the Search and Rescue cooperation conjointly supported by GLONASS, GPS, and Galileo, etc.);

Second, they have the potential to drive a highly innovative technological industry with repercussions in many sectors of the economy. As an illustration, a recent American study estimated the range of economic benefit of GPS to be somewhere between $37.1 and $74.5 billion for 2013, thus about 0.4% of U.S. GDP. The creation of value is thus substantial;

Third, in addressing societal and political challenges, powerful states have had to lead and provide the direction towards new "techno-economic paradigms", which do not come about spontaneously out of market forces. Historically the most impactful technological breakthroughs came from a public (often military-driven) funded investment. For instance, every technology that makes the iPhone "smart" (i.e. Internet, touch-screen display, Siri, and of course GPS) was publicly funded directly by the US government.

Thinking beyond GNSS, there are different important technology trends that will potentially disrupt the way industries will operate in the future. These include:

- Geo intelligence – Spatial elements will allow unprecedented visualization and augmentation, and predictive analysis for business, consumer and institutional applications.
- Autonomous driving and motion – Unmanned driving, operation and surveillance will increase efficiency, safety and security.
- Ubiquitous connectivity, positioning, and synchronization:
    - Not only people, vehicles and things, but entire supply chains will become connected, tracked and synchronized to improve efficiency, scheduling and automation;
    - Seamless communication, connectivity and positioning will be required to master the world's content challenge, the Internet of Things and critical infrastructure applications;
    - Eventually any infrastructure will require its level of robustness to increase constantly.

  Ubiquitous connectivity and positioning will require more and more hybrid solutions that will increase availability exponentially.

The World Economic Forum forecasts that more than 1 trillion sensors (deployed across every facet of our work, lives and, increasingly, bodies) will be connected to the Internet by 2022, taking the Internet of Things to the next level. It will impact and change the way businesses, governments and individuals interact with the world. Everything will become connected from the ground we walk on, to ourselves, to the homes we live in. Both consumers and businesses are going to take advantage of advancing technology to demand hyper-local and personalized products, services and experiences, instantly, seamlessly, and through new channels such as virtual reality. Connectivity as well as positioning will become of paramount importance. The increasing reliance of critical applications on PNT infrastructures will drive the requirements of more and more secure and resilient systems.

Looking at the market potential, currently there are about 4 bn GNSS devices used worldwide, expected by 2023 to reach 9 bn units, and to generate €112 bn in core revenues and about €300 bn in enabled revenues. The bulk of the traditional GNSS core revenues is and will be driven by LBS and road applications, which are expected to generate over 90% of the cumulative global market size in the 2013-2023 period.

Together with the opportunity presented by new emerging markets, the scale of the competition is widening beyond the typical market players and embracing companies from different industry sectors (e.g. tech giants like Google are already active in both promising upstream 'New Space', and downstream fields i.e. 'autonomous cars', etc.). This means that the industry boundaries that have traditionally divided companies according to what they make, what they do, and how they approach their business, are collapsing. The competition is going to increasingly take place across industry sectors, not only within them.

Today, no industry, business or organisation is safe from disruption and, when the disruptors show up, decision-makers should know that it is time to act because these disruptors do not just challenge traditional companies, they challenge whole sectors of the economy and society to reinvent themselves (e.g. Google entering the car manufacturing sector with its 'Google self-driving car' project). Often, this implies opening up firm boundaries to embrace partners (including customers and even competitors), build broader ecosystems and move to open platforms as well as radically reinventing business models. Indeed, mindsets in business are changing. Closed system, in-house innovations are no longer seen as advantageous to lead success. Instead, open innovation and open source movements are gaining ground. Space players and institutional stakeholders should keep this in mind when thinking about the evolution of GNSS and more generally space-based infrastructures and services.

4 Rising challenges for Europe

Within this changing and evolving world, the Galileo programme was conceived with a twofold primary objective:

- Achieve independence/autonomy with regard to other GNSS;
- Maximize the socio-economic benefits, therefore catching a significant share of the worldwide GNSS market.

The long-term sustainability of Galileo is intrinsically linked to the ability to demonstrate its pivotal role in the main relevant market sectors in which, today, GPS is de facto the primary enabling satellite positioning technology, and where the Russians and the Chinese are implementing bold measures to foster the use of their own systems in their respective captive markets. Galileo will be the third or the fourth GNSS to reach full operational capability (FOC). The size of the challenge for the European industrial sector is enormous. In order to support Galileo to become an enabler for the European economy growth and an opportunity for European industry to flourish, a structured link between the market owner industries and the relevant Galileo stakeholders should be built. This relationship should be designed in such a way as to foster the increasing competitiveness and penetration of European industry in the global market as well as to enhance the market-driven nature of the European satellite navigation infrastructure evolution within a broader PNT context, recognizing the fundamental disruptions the industries are facing in these days.

It is therefore necessary to support European industry to invest in and develop competitive and innovative enabling GNSS products along the whole value chain. Facilitating the emergence of a competitive European satellite navigation echo-system cannot be delayed until Galileo becomes operational, as it cannot be delayed to think beyond GNSS towards a broader PNT/ multi sensor / multi industry scene from upstream to downstream.

In fact, to make matters even more complex, often the space-based component of a service is not the prevalent element in the end-user service (for instance in in-car navigation, the GNSS element is only one of the three main elements of the services, the other two being for example a digital map and a route guidance function) and it is not necessarily perceived by the user as an enabling component (indeed in-car navigation is often perceived as similar to a mobile phone).

A key factor in increasing the end value of GNSS-based services is to bundle them with complementary ground-based system infrastructure/services to provide the end-user with a satisfactory quality of service over the whole range of needs effectively exploiting the benefits of the different available technologies. Anytime, anywhere positioning must deliver often against an operational backdrop of environmental interference both intentional and unintentional. Jamming and spoofing threats demand ever more robust, always-available solutions to ensure that mission-critical and safety-of-life applications deliver the results for which they are intended. Ubiquitous connectivity and positioning will require more and more multi-sensor fusion that can increase availability exponentially. Therefore, satellite navigation itself will no longer be enough.

Although many new navigation and positioning methods have been developed in recent years to address GNSS shortcomings in terms of signal penetration and interference vulnerability, much still has to be done to bring them together into a robust, reliable, and cost-effective integrated system. Several GNSS techniques as of today essentially exploited in professional domains (e.g. surveying, agriculture, aviation, maritime, rail, etc.) will become of increasing interest in the consumer domain, opening a plethora of commercial opportunities for new products along the value chain. Multi-constellation/multi-frequency GNSS receivers, complemented with regional information, promise dramatically improved positioning solutions and improved accuracy and enhanced integrity (similar to what SBAS systems like EGNOS are providing today) at the expense of posing a number of challenges to the navigation engineering community. Topics such as accuracy, precision, robustness, reliability, integrity of the position fix, interoperability with other systems, shorter time to first fix, satellite selection, and coverage will be tackled from novel points of view, enabling unexplored business models and applications only limited by the imagination.

In the future, a kind of **"**universal" PNT system might be expected to provide an accurate and reliable position anywhere and anytime. No single positioning technology is and will be capable of meeting the most demanding application requirements. A multi-sensor solution will be thus even more required. Developing innovative products/services will require expertise in all of the subsystems, which rarely exist in a single organisation.

Different stakeholders in the value chain (whether product developers, system integrators, service providers, etc.) will therefore be exposed to a very complex and diversified set of technological challenges that need to be mastered to deliver a competitive product. A good example is the case of a typical smartphone where at least six companies are involved in the navigation subsystem, namely: the GNSS chip supplier, the Wi-Fi positioning service, the mapping provider, the network operator for the cellular signal positioning, the inertial and magnetic sensor supplier and finally the provider of the operating system.

Another element of concern is the different innovation dynamic between the upstream and the downstream sectors of the satellite navigation value chain. Currently, the 'traditional' upstream sector tends to decide on investments in new technology when the downstream sector is developing technology based on earlier generations of upstream systems. The need to bridge the gap between upstream and downstream and thus help upstream companies make informed long-term R&D investment decisions is often only marginally satisfied, raising a considerable concern as to the rationale of space infrastructure evolution and its relevant requirements.

The above elements were also identified during the 2014 & 2015 ESA High Level Forum (HLF), where representatives of the European GNSS sector unambiguously expressed their views on the need for institutional action to support European industry to capture a significant share of the worldwide market.

Specifically, the following issues were highlighted:

- **Public funding instruments** (i.e. contractual relationship) need to be adapted to the conditions in the downstream sector/ application development sector (SME vulnerability, IPR policy, readiness to set up appropriate programmatic actions, and continuity with respect to early operational stages);
- For service development, a particular challenge relates to the lack of **development and deployment infrastructures for industry** e.g. to provide test & demonstration capabilities;

- **R&D** should focus on supporting applications where Europe can lead (close to European market owners), thinking beyond 'Space' and closer to the digital world;
- R&D topics that will not deliver immediate financial returns but pave the way for technological **breakthroughs** should be considered(e.g. technology/system evolution and exploratory studies**);**
- Continuity in the **preparation of future services**, beyond technological demonstration, should be systematically considered, i.e. there is a clear need for support in pre-operational phases, and R&D instruments to bring actual products/solutions to the market.

5 NAVISP: a key enabler for innovation

In this context several key institutional actions have been and are being undertaken by the relevant stakeholders. Essentially, the continuity of European GNSS programmes evolution and preparatory activities is now encompassed within the recently established GNSS part of H2020 (HSNAV), delegated to ESA under the Delegation Agreement signed in December 2015. In a wider perspective, the deployment, operation and evolution of the European Union's Galileo and EGNOS programmes (EGNSS) are now funded from the EU budget and the EU political support secures the long-term future of these important programmes.

The above funding and programmatic scenarios provide an important opportunity to implement the new ESA programme (i.e. **NAVISP**) leveraging ESA expertise in Galileo, EGNOS, navigation and other space fields to undertake innovative work on satellite navigation (in a broader PNT perspective) and to support ESA MS's specific national objectives in the field. NAVISP could act along the entire PNT value chain, including:

- **Infrastructure**: maintain and develop technological edge with forward-looking R&D beyond H2020 activities;
- **Downstream**: fostering space application development closer to the digital world and in partnership with European non-space industry players and market owners.

ESA is well positioned to implement such a programme due to its system architect role in the European GNSS, its undisputable capacity in fostering European Space R&D, its competence in translating user needs into technical and mission requirements, and its heritage in driving innovation inside the space sector and from the space sector to other industries (spin-in/spin-off).

Ultimately, the objective of such an action by ESA is to contribute, together with the EU, to an igniting and broadening of the virtuous circle of the space economy that thanks to the advancement and improvement of the European GNSS infrastructure will generate competitive products and services, and consequently greater economic benefits for Member States.

The main objective of **NAVISP** is to facilitate the generation of Satellite Navigation/PNT innovative propositions with Member States and their industry, in coordination with EU and its institutions to address the challenges previously described.

It will support European industry in succeeding in the highly competitive and rapidly-evolving global market for Satellite Navigation, and more broadly PNT technologies and services, while supporting Member States in enhancing their national objectives and capabilities in the sector, by:

1. Addressing the end-to-end PNT value chain with a view to enhancing MS industrial capabilities in Satellite Navigation while stimulating jobs and growth in the space sector;
2. Supporting national industry to strengthen the technology readiness of the relevant product portfolio and the emergence of new entrants onto the PNT market.

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