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Executive Summary

The rise of the European Union (EU) as a main European space actor is reshuffling the cards in the European architectural organization of space activities. While, until recently, space activities were managed by the Member States through their national agencies or within the European Space Agency (ESA), the emergence of the EU in this field has introduced a third institutional actor. They are all ultimately emanations of the European states, but their purposes, their competencies, the principles they are based on, and the rules they follow, are different. This brings about a need for new governance schemes, able to coordinate space activities appropriately to get the best outcomes from their joint initiatives in the space field.

So far, this new ambition of the European Union has translated into the development of programmes in two areas: Earth environment and security monitoring with Copernicus, and satellite navigation with EGNOS and Galileo. However, there is a difference between those two domains: the European States and ESA have carried out Earth monitoring activities for decades, but EGNOS and Galileo are the first European satellite navigation programmes and the choices made for their governance reflect this new leadership. Unlike Copernicus, where the EU still strongly relies on ESA, EUMETSAT and national capabilities for operations, the EU has fully taken over programme management for, and exploitation of, EGNOS and Galileo, through its executive arm, the European Commission. In order to deal efficiently with those new kinds of missions, it has also created a dedicated entity, the European GNSS Agency (GSA).

But EGNOS and Galileo should also be distinguished from each other. EGNOS, as a Satellite Based Augmentation System (SBAS), has been created to complement a GNSS – initially the GPS – and thus does not resolve the issue of dependency on the U.S.. Galileo is a far more complex and ambitious project, aimed at endowing the EU and its Member States with their own GNSS-type Positioning, Navigation and Timing (PNT) system, providing worldwide services. It is the largest infrastructure project ever undertaken by the EU, a major sovereignty tool and a great opportunity for Europeans to access the promising markets of GNSS, which cover a broad range of areas. Unfortunately, the Galileo programme has faced important problems and this has resulted in significant delays – upcoming exploitation is 13 years behind the original schedule – and the final cost of the programme – 9.9 billion € (under current economic conditions) by 2020 – has tripled. These tribulations have led to successive evolutions in its governance scheme, until the most recent changes in 2013, which are based on a triangular configuration of the Commission, ESA and the GSA. Since then, the deployment of the constellation has taken place at a steady rate, with initial services having started in December 2016.

In this report, we undertake an analysis of the current European governance of the European GNSS, focusing on Galileo, which is seen as a potential laboratory for the governance schemes of the next European space initiatives. The state of play in the exploitation phase that has just started is reviewed, in order to identify potential improvements in the current setting. In particular, this study will pay close attention to the positioning of the GSA, a new actor called upon to play a critical role in the programme.

The focus on the GSA is motivated by the central role this agency will now play in two key areas:

1. Security. Due to the pervasiveness of GNSS in our daily lives, Galileo/EGNOS must ensure service reliability and continuity to remain credible.
2. International relations since it would be legitimate after 2020, in our view, for the GSA role to be at par with other GNSS/RNSS providers to foster global governance "rules of the road" for maintaining a harmonious coexistence between these different PNT systems.

Regarding methodology, the information gathered to prepare this report is based on two kinds of inputs:

1. Interviews with different actors involved in Galileo's governance, and stakeholders in its environment (users of Galileo, other European entities etc.), conducted under Chatham House rules;
2. Analysis of the currently applicable regulations and other documents that define

the governance framework, as well as a literature review.

This report first identifies the political, economic and technical challenges associated with the governance of Galileo, to determine the generic features necessary to ensure the success of the programme.

The second chapter describes the governance scheme set up for the period 2017-2020, defined by the current Galileo-specific regulations and the general regulatory framework applying to EU programmes. In particular, the distribution of prerogatives between the Commission, the GSA and ESA, and their relations, are analysed.

Given the challenges to be overcome, and the internal organisation of the programme, the third chapter points out specific issues that will likely be faced by the current governance scheme in the exploitation phase. These include: a complex and sometimes non-optimal distribution of prerogatives, the interference of political considerations in programme management, some potential conflicts of interest, the problem of insufficient means in the GSA, and the resulting absence of an entity fully responsible for system exploitation.

The final chapter proposes three scenarios for maximizing the impact and reach of the programme. The first is based on the assumption that the current framework is maintained, and adjustments are made within it. The second envisages the creation of a single roof entity, with a bespoke legal status, that brings together the GSA and part of the ESA Navigation Directorate, as owners of most of the technical competences, to be in charge of exploitation. The last scenario is based on the transformation of the GSA into a mainly administrative agency, with most technical tasks entrusted to the private sector.

These scenarios have different strengths and weaknesses and are diversely tailored to the various objectives of the programme. The choice of the most relevant one will depend on a preliminary and definitive identification of technical, political and strategic priorities. But this is outside the scope of this report: it must be left to policy decision makers and should be decided, in our view, before 2020.

1. Introduction

1.1 Purposes, Principle and Current State of Global Navigation Satellite Systems (GNSS)

GNSS mainly provide two kinds of services on a worldwide basis: positioning and navigation on one hand, and precise timing on the other. Thanks to their outstanding features – in particular their accuracy and global nature, they have found their way into various markets in different fields: transportation (road, aviation, maritime etc.), science (surveying, geodesy etc.), military (troop positioning, missile guidance etc.), but also banking services and energy networks management (precise time stamping and synchronization) and mass-market location based services (smartphone and tablet applications).

The principle of these systems is straightforward: receivers carried by users receive radio signals (using specific frequencies within the L band, from 1 to 2 GHz) continuously broadcasted by GNSS satellites. The data sent contain the time of their broadcasting, as provided by an atomic clock on board each satellite, these clocks all being synchronized. Knowing at any time the positions of the satellites (ephemeris), the receivers then compute their 3D position from the time of arrival of the satellite-emitted signals[1]. The timing function follows the same principle, delivering accurate time from space-based atomic clocks worldwide. The features of these systems (accuracy, integrity and availability) can be improved locally by Satellite-Based or Ground-Based Augmentation Systems that integrate additional external information into the calculus process, together with the satellite signal.

As of January 2017, four GNSS have been deployed or under deployment: the U.S. GPS and the Russian GLONASS reached full capacity as early as 1995, while the European Galileo and the Chinese BeiDou are being deployed and expected to be fully operational by 2020. The U.S with WAAS and WAGE (for military), the Europeans with EGNOS, the Indians with GAGAN and the Japanese with MSAS, already own and operate a Satellite-Based Augmentation System (SBAS) completing GPS. China and Russia are developing their own systems with SNAS and SDCM respectively. In addition, some commercial SBAS, such as StarFire, are being developed and owned by private companies. Lastly, two other systems, the Indian IRNSS (fully deployed) and the Japanese QZSS (under deployment) provide GNSS services on a regional scale (see Annex A.1).

1.2 Description of Galileo

Galileo, like the other GNSS, is based on three segments: a space segment, a ground segment and a user segment.

The space segment is the constellation of satellites. For Galileo, at the end of deployment, this constellation will be composed of 30 Medium Earth Orbit satellites following circular orbits at an altitude of 23,222 km with an orbital period of 14 hours. They will be located in three different, equally spaced, planes with an inclination of 56° to the equator. Eight satellites plus two spares (also transmitting signals) are positioned in each plan. The lifetime of the current satellites (IOV and FOC) is theoretically more than 12 years[2]. Each satellite uses two hydrogen maser atomic clocks – one active, one as passive redundancy – and two rubidium atomic clocks – one as active redundancy, the other as passive redundancy[3].

The core ground segment is composed of two sub-segments: the Galileo Mission Segment (GMS) and the Galileo Control Segment (GCS). The main functions of the GMS are orbit determination, clock synchronization, evaluation of signals' integrity and uplink to the Galileo fleet of the data needed for the Galileo downlink. The GCS monitors and controls satellite platforms and payloads as well as the constellation as a whole. There is also a third

[1] A minimum of four satellites is needed to get a position fix.

[2] "Satellite facts and figures." 21 August 2015. European Space Agency 19 December 2016 <http://www.esa.int/Our_Activities/Navigation/Galileo/Launching_Galileo/Satellite_facts_and_figures>.

[3] "Galileo Space Segment." 6 April 2015. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/Galileo_Space_Segment>.

sub-segment, the Galileo Data Dissemination Network (GDDN), which securely interconnects the centres of the core facilities – between each other and with other facilities. Lastly, complementing those core facilities, the exploitation and service provision of Galileo relies on other ground based centres performing specific functions mainly related to security or services: the Galileo Security Monitoring Centre (GSMC), Time and Geodetic Reference Service Providers (TSP, GRSP), the Galileo Reference Centre (GRC), the European GNSS Service Centre (GSC), the SAR Mission Control and Rescue Control Centres, and the Galileo Integrated Logistics Centre (see 3.2.5.5). The number of those facilities and their interactions is one of the main sources of complexity in the programme (see Annex A.4).

The user segment consists of the receivers that are carried by users, and which solve the navigation equations in order to compute navigation coordinates and to provide accurate timing[4].

Galileo, as a second generation GNSS, includes all the advanced features of modern GNSS and is expected to provide high performances as compared to the current constellations. In particular, thanks to the higher altitude of the satellites, their more accurate clocks and the use of double frequencies signals, Galileo should be especially accurate (space ranging accuracy minimum performances level <2m for the Initial Open Service)[5]. Another main difference is its civilian nature, while the three other GNSS are operated by the respective Ministries of Defence. In line with those specificities, by 2020 Galileo will offer several different services:

- The Open Service (OS) is the standard service of Galileo. Similar to the open services offered by other GNSS, this service provides free of charge positioning, navigation and timing information worldwide. The OS uses E1, E5a and E5bfrequencies, and will be comparable to the service delivered by GPS on L1C/A, L2C and L5frequencies.
- The Public Regulated Service (PRS) is the most complex service delivered by Galileo. Like the OS, it provides positioning and timing information worldwide, but its access is restricted to users authorized by governments and some European Union bodies, following common rules[6]. The PRS, using encrypted and more robust signals, is mainly envisaged for sensitive applications requiring continuity of service and integrity. The extension of this service to other users is possible, eventually on a fee basis. The PRS, accessible through secure PRS compatible receivers, will be provided in the E1 and E6 frequencies and will be analogous to the P(Y) and L2-M GPS signals on L1 and L2 frequencies.
- The Commercial Service (CS) is a service without equivalent in the other GNSS, corresponding to the specific income generating ambition of Galileo, since the use of this service, professional or commercial, will be charged. It is intended to deliver added value data by comparison to the Open Service, especially through authentication services and improved accuracy, allowing new kinds of applications[7]. Nevertheless, the content of such added value seems not to be fully defined yet. Together with the OS signals, the CS will use two signals in the E6 frequency[8].
- The Search and Rescue Service (SAR) is the Galileo contribution to the COSPAS-SARSAT system for search and rescue operations, detecting emergency signals emitted by beacons and able to return confirmation that help is on the way. The signal broadcasted by Galileo as part of this service uses the L6 frequency.

In addition, Galileo will offer an integrity monitoring service complementing OS, or even open signals coming from another GNSS, to provide additional integrity information needed for life-critical applications. This integrity monitoring service is derived from the abandoned "Safety of Life service", and its implementation has been postponed for the time being. More information about the aforementioned frequencies are given in Annex A.6.

[4] "Galileo User Segment." 21 October 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/GALILEO_User_Segment>.
[5] European GNSS Agency. Galileo Initial Services - Open Service Definition Document. Prague: European Union. 24.
[6] European Parliament and Council. Decision N° 1104/2011/EU of the European Parliament and of the Council of 25 October 2011 on the rules for access to the public regulated service provided by the global navigation satellite system established under the Galileo programme. Brussels: European Union.
[7] "Galileo, the European Satellite Navigation system, opens up business opportunities and makes life easier for citizens." 25 July 2013. European GNSS Agency 19 December 2016 <https://www.gsa.europa.eu/news/galileo-european-satellite-navigation-system-opens-business-opportunities-and-makes-life-easier>.
[8] "Galileo Commercial Service." 18 September 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/Galileo_Commercial_Service_(CS)>.

1.3 A Brief History of Galileo and Its Governance

The history of Galileo is tumultuous and the governance scheme has changed over time before being provisionally stabilized in the current configuration. Nevertheless, numerous choices made in the past still have an influence on the current situation.

It is considered that the programme was initiated after the famous speech of the Transport Commissioner Lord Neil Kinnock (1995-1999) in 1998[9]. While the tripartite agreement had formally launched EGNOS earlier the same year, Lord Kinnock argued for the development of a European civilian GNSS, emphasizing the related economic perspectives, but also the need for Europeans to develop such a project for security and sovereignty purposes. In 2000 and 2001, ESA and the EU equally funded the definition of such a system. Convinced by the Commission, the EU Council approved the launch of Galileo in April 2001, with three subsequent phases: development, deployment and exploitation, the latter foreseen as occurring in 2008[10].

The model initially retained for programme funding was a Public-Private Partnership (PPP): while the development was to be funded by the public sector (ESA and the EC), the deployment and exploitation phases were supposed to be implemented by a concession, and financed by both public and private sectors. In accordance with this PPP model, in May 2002 the Council established the Galileo Joint Undertaking (GJU)[11] to implement the activities related to the development of Galileo within a unique legal entity, and in July 2004, a Community Agency, the European GNSS Supervisory Authority (GSA), to ensure respect of public interests related to European GNSS programmes. To that end, the GSA was the GNSS regulatory agency contracting with the concessionaire and in charge of the implementation of the contract. Its prerogatives also included the preparation of the Commission proposals regarding GNSS, the modernization of the system, and all aspects related to security, in particular security accreditation for the GNSS programmes[12].

The GJU launched a concession call in October 2003 and received four offers. In 2005, the GJU, unable to select one of them, asked for the merger of the two remaining submitting consortia, leaving the GJU with a single candidate[13]. This unforeseen evolution of the process, as well as the parallel delays of the programmes, had numerous causes. Among them, disagreements among member states regarding public procurement (the ESA "geographical-return principle"[14] being *de facto* reintroduced by some member states), the location of major ground installations, the potential military uses of PRS, an underestimate of the technological complexity of Galileo and of its risks, and on top of these, a progressive decrease in political support to the programme[15]. In January 2007, the GJU was dissolved and the GSA officially took over all its tasks. Negotiations stopped at the beginning of 2007, the merged Consortium refusing the risks incurred by the prevailing set up. In March, the Commission's Vice President Jacques Barrot sent a letter to Member State Transport Ministers, listing the problems faced in the negotiations and setting an ultimatum to the merged consortium on the establishment of the operating company. Following one of the scenarios proposed by the Commission, the Transport Council decided to abandon the PPP model[16,17].

It nevertheless renewed its support to the project and endorsed a full-public funding scheme, from the Community budget. This scheme was supported by most Member States, as well as by the Commission and the Parliament. As a consequence, the governance scheme evolved in 2008 and 2010 with two

[9] Kinnock, Neil. European Strategy for GNSS. SPEECH/98/210 of 20 Oct. 1998. Toulouse. <http://europa.eu/rapid/press-release_SPEECH-98-210_en.htm>.

[10] Council of the European Union. Council Resolution of 5 April 2001 on Galileo. Brussels: European Union.1.

[11] Council of the European Union. Council Regulation (EC) N° 876/2002 of 21 May 2002 setting up the Galileo Joint Undertaking. Brussels: European Union.

[12] Council of the European Union. Council Regulation (EC) N° 1321/2004 of 12 July 2004 on the establishment of structures for the management of the European satellite radio-navigation programmes. Brussels: European Union. 3-4.

[13] Plattard, Serge. "What's the problem with Europe's flagships Galileo and GMES?" Yearbook on Space Policy 2006/2007: New Impetus for Europe. Eds. Kai-Uwe Schrogl, Charlotte Mathieu, and Nicolas Peter. Vienna: SpringerWienNewYork, 2008. 156.

[14] The fair return principle ensures that the ESA countries taking part to an ESA project are rewarded with a share of the total value of the contracts corresponding to the contribution paid to the Agency. This is a procurement scheme totally different from the one used in the EU, based on free competition. For more information, see <http://www.esa.int/About_Us/Business_with_ESA/How_to_do/Industrial_policy_and_geographical_distribution>.

[15] Plattard, Serge. *Ibid.*,156-158.

[16] European Commission. Communication from the Commission to the Council and the European Parliament: Galileo at a Cross-Road: the Implementation of the European GNSS Programmes. COM (2007) 261 final of 16 May 2007. Brussels: European Union.

[17] Council of the European Union. Council resolution: Global Navigation Satellite System (Galileo): State of play and future options. 10126/07 of 8 June 2007. Brussels: European Union. 2.

new regulations that gave the Commission management of the programme and considerably diminished the role of the GSA (renamed as the European GNSS Agency), keeping only prerogatives in security accreditation, security monitoring and market uptake actions while bringing it under Commission control[18,19]. The initial project for the 2010 regulation proposed by the Commission provided for tight control of the Commission through the chair of the Security Accreditation Board and a number of equal votes for all Member States on the GSA Administrative Board[20]. Nonetheless, the Commission kept a veto right on some decisions. Based on this firmer ground, the programme finally managed to launch the first four In-Orbit Validation (IOV) satellites in 2011 and 2012, initiating the deployment of the satellites constellation and securing the allocation of frequencies. In 2013, in line with the new Multiannual Financial Framework providing the budget for the 2014-2020 period and the general progress of the programme, a new regulation driven from the perspective of the upcoming exploitation redefined again the governance structure, introducing a tripartite configuration based on the Commission, ESA and the GSA[21]. This regulation restored the importance of the GSA, becoming the entity intended to progressively take over responsibility for the exploitation of Galileo, the operations of which are outsourced. In 2014, a new regulation complemented those changes, focusing on the internal organization of the GSA[22]. Those two last regulations set the current governance scheme, as described in 3.2.

1.4 Current State and Next Steps

Currently, with the launch of four additional satellites on 17 November 2016**,** 18 satellites are in orbit, although two of them were initially launched into incorrect orbits (in August 2014), and required moving to usable orbits, while one IOV satellite lost some of its transmission capabilities[23,24]. According to the European GNSS Service Centre[25,26], as of 20 December 2016, 11 satellites were usable and worked well, while four additional ones were under commissioning. Two batches (14+8) of FOC satellites have been contracted in the past years and the contract for the last batch (8 satellites) should be awarded soon. On 15 December 2016, the programme decided to privilege stability, awarding the Galileo Service Operator (GSOp, see 3.2.5.5) contract to Spaceopal, which was already exploiting the constellation under deployment. On the same day, an important working arrangement defining the relation between ESA and the GSA for the exploitation phase was signed.

Most of the ground segment has been or is close to being deployed: the first version of the core ground segment was expected to be fully deployed by mid-2017[27,28]. The GSC was established in May 2013, the GRC in May 2016[29,30]. Two GSMC were created in Saint-Germain-en-Laye (France) and in Swanwick (UK), but the fate of the second – which is a

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[18] European Parliament and Council. Regulation (EC) N° 683/2008 of the European Parliament and the Council of 9 July 2008 on the further implementation of the European satellite navigation programmes (EGNOS and Galileo). Brussels: European Union.

[19] European Parliament and Council. Regulation (EU) N° 912/2010 of the European Parliament and of the Council of 22 September 2010 setting up the European GNSS Agency, repealing Council Regulation (EC) N° 1321/2004 on the establishment of structures for the management of the European satellite radio navigation programmes and amending Regulation (EC) N° 683/2008 of the European Parliament and of the Council. Brussels: European Union.

[20] Inside GNSS. "EC Proposes Big Changes for GSA within Galileo Program." Inside GNSS 20 April 2009.

[21] European Parliament and Council. Regulation (EU) N° 1285/2013 of the European Parliament and of the Council of 11 December 2013 on the implementation and exploitation of European satellite navigation systems and repealing Council Regulation (EC) N° 876/2002 and Regulation (EC) N° 683/2008 of the European Parliament and of the Council. Brussels: European Union.

[22] European Parliament and Council Regulation (EU) N° 512/2014 of the European Parliament and of the Council of 16 April 2014 amending Regulation (EU) N° 912/2010 setting up the European GNSS Agency. Brussels: European Union.

[23] "Sixth Galileo satellite reaches corrected orbit." 13 March 2015. European Space Agency 19 December 2016 <http://www.esa.int/Our_Activities/Navigation/Galileo/Launching_Galileo/Sixth_Galileo_satellite_reaches_corrected_orbit>.

[24] "Notice Advisory to Galileo Users (NAGU) 2014014." European GNSS Service Centre 19 December 2016 <https://www.gsc-europa.eu/notice-advisory-to-galileo-users-nagu-2014014>.

[25] "Constellation Information." European GNSS Service Centre 19 December 2016 <https://www.gsc-europa.eu/system-status/Constellation-Information>.

[26] In general, the satellites seem to provide very satisfying results, but there could be some issues with some rubidium atomic clocks, and more recently also on a couple of maser hydrogen atomic clocks. See, for instance, Cabirol, Michel. "Ça cloche pour une horloge d'un satellite". La Tribune. 14 November 2016 (in French).

[27] European Space Agency. GALILEO FOC2 WP2-X - Galileo Ground Mission Segment and Galileo Security Facility. Appendix 1 - High Level Statement of Work. 11 May 2016. Noordwijk: European Space Agency. 4.

[28] European Space Agency. FOC2 WP3x - Galileo Ground Control Segment High Level Statement of Work. 4 May 2016. Noordwijk: European Space Agency. 4.

[29] "The European GNSS Service Centre is open to help users." 17 May 2013. European GNSS Agency 19 December 2016 <https://www.gsa.europa.eu/news/european-gnss-service-centre-open-help-users>.

[30] "GSA establishes Galileo Reference Centre." 31 May 2016. European GNSS Agency 19 December 2016 <https://www.gsa.europa.eu/newsroom/news/gsa-establishes-galileo-reference-centre>.

back-up facility – may, or may not, be compromised by the *Brexit* procedure[31]. In 2015, signals usable for testing were produced, paving the way for a service validation campaign carried out in 2016. Thanks to this progress, the initial services (OS, SAR and pilot PRS for tests) were declared on 15 December 2016 offering good ranging performances, but limited continuity and availability since the constellation is still under deployment.

This acceleration of the programme will go on and even intensify in the coming months. Two Ariane launches are planned, adding 8 satellites to the constellation by the end 2018. While exploitation was supervised by ESA over the past years, it will be the role of the GSA as of 1 July 2017. Indeed, since 1 January 2017, the programme has entered into a six months handover process devoted to the development of GSA know-how. This is thus a major transition phase, since within six months time the initial services will have been declared, the entity in charge of the exploitation will have changed, numerous industrial contacts will be awarded and the global governance scheme will be evolving. This is also a challenging period. As a matter of fact, the declaration of services is the opportunity to test the competencies, interfaces and organization of the programme, but also carries a strong political meaning, aimed at establishing the credibility of the programme in order to stimulate the market, re-engage member states, secure funding in the next MFF, and demonstrate the relevance of the current governance.

This scheme should go on until 2020, with the progressive step up of the GSA, in line with the deployment of the system towards Full Operational Capability. The following phase, Full Operational Capability II, will be framed by a new regulation whose elaboration will begin in 2017. In parallel, the programme will prepare the next generation of Galileo, for deployment expected to start by 2025.

[31] Amos, Jonathan. "Tim Peak, Brexit and the UK Space Sector." BBC News 16 July of 2016.

2. The Challenges of Galileo Governance

Governance can be defined as the combination of norms, rules, adjudication procedures, and enforcement mechanisms set up in order to frame the interaction and decision-making processes among the different stakeholders involved in a collective problem. Thus, there is a need for governance when there are different actors, with potentially different broader objectives, that need to be coordinated in a proper way to achieve to the best extent their common goals. Depending on the context, the chosen criteria to assess governance are diverse, from ethics to performance. In a technical and industrial context, the governance of a programme emphasizes its results: those processes are above all chosen in order to ensure the achievement of the programme's objectives. In the case of Galileo, the question of governance is fundamental, given that this programme involves the European Union, ESA, and their Member States, all three different actors that must be associated in order to ensure the success of the programme.

This question raises a preliminary interrogation: what are the challenges faced by the programme that governance is aimed at taking up? This chapter intends to list and classify these challenges in three categories – political, economic and technical. In practice though, one should keep in mind that they are all interrelated and influence each other.

2.1 Political Challenges

2.1.1 Giving to the EU and Its Member States an Effective Instrument of Sovereignty

Securing European independence in the field of GNSS has been one of the main incentives in development of the Galileo project since its beginnings[32]. This concept has passive and active components. The first concerns the mitigation of European vulnerability to denial of access to a GPS and/or GLONASS. This vulnerability is constantly increasing, as GNSS tend to be used for critical applications in more and more fields. But for the same reasons, Galileo can also become an active instrument of sovereignty, as the widespread use of Galileo could provide for the same lever of influence over other countries massively using it. Depending on the scope of uses of Galileo, especially for security applications, it could also give the Europeans more leverage within NATO, or support autonomous intervention of European forces, independently from the U.S., by being assured of having a reliable GNSS[33].

It should also be noted that developing such a common infrastructure fully owned by the EU and having strong security implications is a new step for the EU. As such, Galileo is also a symbolic project for the EU, whose success could pave the way for other similar EU projects, with a strong security dimension, and in strategic fields such as space. The project is thus also building sovereignty at the European level.

2.1.2 Providing Effective Interaction between the European Stakeholders

There is a complexity inherent in the governance of Galileo in the space field that arises from the various natures of the stakeholders within the European organizational architecture. While all other GNSS programmes involve a single country, and are under the control of one military institution, Galileo intends to be the GNSS of the EU as well as of its 28 Member States, and associated third countries[34], and to rely on the European Space Agency, an institutionally distinct, intergovernmental agency. Yet, the involved stakeholders have different interests. For instance, Member States are interested in the project in various ways: some are especially motivated by the industrial benefits of the programme; others wish to be directly involved in programme oversight. Due to their own geostrategic concerns or priorities, they also have different views on the purposes of Galileo (possibility of military uses, services usable for commercial purposes, etc.). In addition, they have different cultures: the European Commission, as a supranational regulatory institution, has specific views and procedures that

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[32] Kinnock, Neil. European Strategy for GNSS. SPEECH/98/210 of 20 Oct. 1998. Toulouse <http://europa.eu/rapid/press-release_SPEECH-98-210_en.htm>

[33] Lindström, Gustav and Gasparini, Giovanni. "The Galileo satellite system and its security implications." The European Union Institute for Security Studies, occasional papers n°44 (2003). 21-24.

[34] The EU is the owner of the programme, but gives the possibility to some countries to be associated through bilateral agreements. Through this way, Switzerland and Norway take part to the programme.

are different from the ones of the ESA, the latter being an intergovernmental research and development agency, while Member States also have their own organisations, skills and knowledge.

On top of this, the articulation between all the actors, as well as setting up all the governance structures, must be done in accordance with EU general rules and regulations (financial rules, comitology[35] principles etc.), creating additional constraints.

2.1.3 Dealing with Security Issues Related to Galileo

Even as a civilian programme, security issues are central to Galileo. On the one hand, there is an increasing number of GNSS-dependent activities (in 2011, 6-7% of Europe's GDP went through GNSS[36]). On the other hand, safety-critical applications are developing at a steady rate and throughout various fields – from autonomous cars to aviation and various governmental activities – making GNSS into a *de facto* critical infrastructure. Hence, this growing criticality induces a new vulnerability, and GNSS are becoming first priority targets for hostile third parties. This development inevitably poses a range of security issues to be dealt with in order to ensure the reliability of Galileo. Indeed, there are risks related to the satellite signals (spoofing, jamming etc.), to specific processes (security key distribution for instance), to the physical protection of the system (satellites and ground installations), and to cyber attacks. In particular, the increasing number of incidents and full-scale demonstrations of jamming and spoofing gives rise to growing concerns about the reliability of GNSS. Such a strategic and complex programme can also be exposed to the risk of sensitive information leaks that could increase vulnerabilities.

Addressing these issues requires an appropriate organization and a security culture to effectively anticipate, detect, and protect against such threats, and react properly to stop or mitigate their effects. Security is an inherently complex issue, since hostile players trying to attack the system are, by essence, always one step ahead. This makes illusory any definitive planning to secure the system, and justifies the need to set up a management structure rigid enough to ensure the application of security measures, and flexible enough to adapt to new threats to be able to react quickly to constantly evolving security challenges. In the case of Galileo, security issues are significantly complicated by the distribution of associated prerogatives between the governance stakeholders. Security traditionally pertains to Member States, which also have different views and requirements on the matter. The involvement of other EU institutions, like the European External Action Service (EEAS) or even non-EU actors, such as NATO, is a further factor of complication.

It should be noted that ensuring security is not only important *per se*, since it is an also important component of the trust that can be placed in the system. Security is thus a major enabler for the other political and economic objectives of the programme – in particular, international relations (see 2.1.4) and market development (see 2.2.2). Therefore, security is indeed a major challenge for Galileo, as it has to compete in this area with systems under military control.

Should military use of Galileo be developed, all those issues will become especially pressing, while other governance questions, such as the implementation of a relevant interface with the military, will be a rising concern.

2.1.4 Ensuring a Strong Presence on the International Scene

The environment of Galileo is composed of other satellite navigation providers: three other GNSS (GPS, GLONASS and BeiDou) and two RNSS (IRNSS and QZSS). The existence of "common aversions" and "common interests" between them makes interactions inevitable. These interactions are likely to transform this set of coexisting systems into a "system of systems", whose components are described in Annex A.1. As one of the four global PNT systems, Galileo has a number of obligations to fulfil in order to take part in the general governance of such a system of systems.

Firstly, the EU and its Member States need to continue to protect the radio frequency spectrum and more specifically the L band, a scarce and fragile resource shared by the global providers. This is achieved by taking strong and

[35] The comitology is the set of procedures constraining the Commission decision-making process that has been created in order to ensure the control of the Member States over the Commission implementation of EU laws and, in this context, of the programme. For more information see Regulation (EU) N° 182/2011 of the European Parliament and of the Council of 16 February 2011 laying down the rules and general principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers.

[36] European Commission. Fact Sheet: Frequently asked questions - Galileo, the EU's satellite navigation programme. 28 March 2015. Brussels: European Union <http://europa.eu/rapid/press-release_MEMO-15-4711_fr.htm>.

aligned positions at the World Radio-communication Conferences, and being part of the regular exchanges that take place within the annual meeting of the International Committee on GNSS and its working groups. Frequency allocation related issues are not addressed as such in this report.

Second, it has to ensure the full compatibility of Galileo with the other constellations, meaning that the emission of Galileo signals will not interfere with signals produced by others. It will also be interoperable with the other systems, which implies the requirement for Galileo signals to be processed together with signals coming from other constellations so as to achieve, for instance, a positioning fix.

Third, Galileo will participate in discussions and negotiations with its partners to set up common measures to mitigate intentional and unintentional jamming and spoofing. In addition, it will also be participate in reaching common performance standards, a coordination process that is currently underway.

Last, owning a GNSS involves a responsibility toward the international community, and especially to our allies. Indeed, as a passive system available to anybody, GNSS could be used by entities hostile to the interests of our partners. The governance of Galileo must be able to react effectively in case of international crisis, which requires the ability to take quick decisions regarding the system, for instance to deny local access to it.

2.2 Economic Challenges

2.2.1 Setting up a Cost-Effective Organization

Whatever the programme, cost effectiveness is one of the main objectives of its governance. This is even truer for a costly, long-term programme such as Galileo. In addition, the partially commercial nature of Galileo, especially with its commercial service, raises considerations such as profitability and return on investment, which are extraneous to other public, military-oriented GNSS. Accordingly, optimization of resources in programme management will be a main objective of governance, which implies the elimination of useless redundancies and the best use of the competencies of each involved actor.

2.2.2 Fostering the Development of a Downstream Market Associated with Galileo

One of the main economic benefits expected from Galileo is the growth of downstream markets, including the fostering of receivers and chipsets industries, and above all the development of new GNSS applications.

But maximizing this positive economic impact firstly requires ensuring widespread utilization of Galileo. Reciprocally, the development of Galileo-compatible applications and receivers will encourage its use, with all the associated economic and political benefits. While the stakes are high, Galileo comes in an especially competitive environment, as GPS is already considered today as the "golden" standard, GLONASS is operational, and BeiDou is deploying now at a steady rate (see Annex A.1). In a multi-constellations approach, processing signals from more than one constellation provides better performance to some extent. Above three, the positive effects related to the number of available satellites are, in most of the cases, negligible. With four GNSS, numerous applications markets are expected to become significantly competitive.

Yet, all the GNSS provide a free and non-discriminatory service, competing mainly on the reliability and availability of the systems and their providers. To build such credibility and stand out in this competitive environment, Galileo must prove itself to be a secure system that provides high technical performances. The programme must also demonstrate a real, long-term commitment and sufficient stability of the system and its objectives. It is also important to act quickly regarding the most important decisions – declarations of services, deployment of satellites, modifications of the system as well as its future development. This last point implies not only building strong understanding of the market to be able to act wisely, but also to take on a pro-active role, with an effective market communication strategy and stimulating the market through incentives. This intimate relation with the markets must also fuel thinking about further system evolution, in order to appropriately plan the technological trade-offs.

In all these considerations, it should be noted that GNSS applications cover different fields, involving different communities of users, each having its own specificities and requirements. These communities are composed of professionals or individual customers, sometimes coexisting in the same field. Among professional applications, depending on their degree of maturity and criticality, some applications are highly regulated, framed by well-established standards and certification processes. On the other hand, less critical or developed GNSS-based professional applications are mainly unregulated. Moreover, one of the main trends of the last decade is the explosion of individual applications and the spread of personal GNSS receivers for various uses.

The achievement of this priority goal for Galileo, that is market development, thus requires setting up relevant interfaces with the different communities in order to understand their needs and requirements, to be flexible enough to adapt accordingly and, taking into account their specific features, to find the appropriate level in the value chain and the appropriate tools to stimulate demand and maximise the adoption of Galileo. The specifics of each field of applications, related communities and the Galileo services targeting them, are presented in Annex A.2.

Another dimension triggered by this commercial ambition, and thus specific to Galileo, is the liability issue. The spread of Galileo uses, and especially of its commercial service, necessitates a clear, effective chain of responsibility covering cases of failure, in order to build up user confidence regarding the added value of Galileo. For regulated applications, these liability issues strongly depend on the ability of the programme to ensure that the system is appropriately certified.

2.2.3 Fostering Indirect Benefits

Beside these benefits, more indirect returns can be expected from Galileo. The new possibilities provided by Galileo, as a commercial, high performance GNSS, could lead to a number of new applications that themselves bring productivity gains and other benefits for European economies.

Such new applications could also lead to the removal of current, costly redundant systems, e.g. positioning marine beacons or aviation ground navigation systems. For this purpose, Galileo must deliver better performances and reliability than those provided by the current redundant systems.

Fostering these kinds of indirect benefits requires defining a clear policy regarding GNSS, as part of a broader strategy that is properly coordinated with other sectorial policies in order to get the best outcomes from the system.

2.3 Technical Challenges

As a complex, cutting-edge technological programme, Galileo is necessarily faced with technical challenges that its governance scheme should help to solve. In particular, the diversity of technical tasks and the distribution of relevant competencies among the different actors necessitate defining appropriate resources and allocating prerogatives to ensure that relevant interfaces are established between them.

2.3.1 Successfully Exploiting the System

The first technical challenge is to make the system fully operational, ensuring continuous satisfactory functioning, i.e. meeting the defined performance requirements. Continuity of service is an absolute priority: a signal degradation lasting only seconds or minutes can have major consequences, and such vulnerability could dramatically worsen with the spread of critical GNSS-dependent applications and processes. For similar reasons, the system should not be operated in a way that is misleading to users. Other features of the system should also be ensured to meet the political and economic objectives of the programme: sufficient robustness and availability, high-level accuracy, capacity to react to the requests of users, etc. And of course, security can only be guaranteed through the application of appropriate technical solutions and processes.

This means continuously providing a global signal while the number of active satellites constantly changes and repositioning manoeuvres are frequent, as well as conducting ground and in-orbit tests, together with satellite recalibrations, and testing changes in operational modes. This also implies constantly monitoring the system in order to be able to appropriately react in case of emergencies while disturbing its functioning to the least possible extent. Last but not least, satellite lifespan requires regular replenishment – and the associated launch – and reconfiguration, while the ground segment as well as the space segment are subject to upgrades. All these activities need proper planning to efficiently allocate resources.

Exploitation therefore necessitates gathering diverse competencies and setting up the appropriate structure and communications to ensure effective coordination. GNSS satellites are quite simple, but the ground segment is a large information system covering complex activities that require diverse and specific skills (satellite control, encryption, cyber security, telecommunication, signal dissemination, user interface, maintenance etc.) while the user segment presents specific, additional constraints.

These issues will be especially burning during the upcoming period, from 2017 to 2020, as both the deployment and the exploitation phases will overlap. Setting up and modifying the constellation will have to take into account the constraints of exploitation of the system and service provision. This will result in constant trade-offs between exploitation and deployment.

2.3.2 Ensuring the Evolution of the System

The other highly technical task that must be tackled parallel to exploitation is to plan and prepare for the future development of Galileo.

Indeed, though the exploitation of Galileo has just begun, the pressure of the competitive environment compels the programme management to already think about its evolution. It is indeed a positive signal that needs to be sent to economic stakeholders, showing a long-term commitment to the programme. Moreover, by 2020 the GPS performances should be highly improved with the first operational GPS III satellites, while the BeiDou constellation should be fully deployed. Thus, even if Galileo's Full Operational Capability is expected to deliver performances at least equal to those of its current competitors, if not better, it will be necessary to start deploying a new generation by 2025 to maintain a technological edge, enabling the achievement of the economic objectives of the programme as well as accounting for obsolescence, which will require progressive replenishment of the orbital plans.

Parallel to those economic considerations, the evolution of the system serves another purpose of the programme: developing and keeping high level competencies associated with GNSS technologies in Europe, and more generally, fostering innovation in the GNSS area as well as in related fields.

Logically, this activity requires very high-level technical skills, and this has deep implications for programme management since gathering such competencies necessitates the involvement of different actors: ESA, the GSA, industry, GSOp etc. Furthermore, future development should be user-driven, requiring a constant and intimate link with market stakeholders to ensure proper integration of their requirements and needs in the Galileo next generation design.

In short, the evolution of Galileo necessitates the implementation of a structure able to channel relevant information flows between governance stakeholders and users.

2.3.3 Technically Enabling "GNSS Diplomacy"

Ensuring state-of-the-art performances of the system through effective exploitation and timely and relevant evolution is not the only technical challenge faced by Galileo. As mentioned above, to be fully effective Galileo must ensure compatibility, and eventually interoperability, with other constellations. This means that technical solutions must be found to concretize the cooperation schemes agreed with other systems[37].

[37] One example of this kind of "technical enablement of diplomacy objectives" is the development of MBOC modulation, following the provision of the 2004 agreement to ensure a high interoperability between GPS and Galileo signals.

3. The Exercise of Galileo Governance within the European Framework

3.1 Framework of the European Space Programmes

3.1.1 The Space Ambitions of the European Union

Historically, space activities in Europe have been handled by the Member States both through their national space agencies and within the European Space Agency (ESA). Recently, the European Union has been increasingly involved in the space field, considering that it could bring diverse kinds of benefits: economic (increased competitiveness, innovation stimulation etc.), social (environmental protection, civil protection etc.) and strategic (consolidation of political, technological and economic independence, security applications). This conception of space activities highlights their political and economic dimensions and is thus fully in line with the Europe 2020 strategy.

In line with these ambitions, space became a shared competence between the EU and the Member States in 2009, when the Lisbon Treaty gave a legal basis to EU space activities. Indeed, Article 189 of the Treaty on the Functioning of the European Union provides for the definition of a European space policy and proposes the development of an EU Space Programme. It also explicitly mentions the European Space Agency as a partner in this field[38]. In accordance with these legal provisions, the European Commission has produced various communications since then. In 2013, the Commission outlined a space industrial policy strongly insisting on the necessity of creating a European competitive space industrial basis[39]. The last communication, released in October 2016, defines a Space Strategy for Europe[40], which elaborates on previous goals, since this strategy is based along five lines: the maximization of the benefits of space for EU society and the economy, enhancement of the competitiveness and innovativeness of the European space sector; reinforcement of European autonomy in space; strengthening Europe's role as a global actor and the promotion of international cooperation; as well as the practical delivery of space activities through the establishment of appropriate partnership with all the stakeholders.

3.1.2 The EU-ESA Framework

Prior to these developments, the EU and ESA had already signed a framework agreement in 2003 to take advantage of their complementary competencies and be able to develop ambitious space projects under a coherent general approach that also reduced ineffective redundancies.

This agreement covered different fields, including navigation and space-related spectrum policy. It paved the way for the progressive definition of a coherent, articulated European space policy, set up a "Space Council" bringing together the Council of the EU and the ESA Council at Ministerial level, and mentioned practical arrangements for cooperation between ESA and EU in future joint projects. Concretely, different kinds of cooperation models were evoked, including coordinated co-funded activities, EU participation in ESA optional programmes, and ESA management of EU space-related activities in accordance with EU rules[41].

Though the signature of this agreement was a major step forward, the agreement remained very general and did not resolve many of the concrete negative effects arising from the cultural and organizational differences between the two institutions. Furthermore, this agreement did not take into account the evolution of the role of the EU in the space field as defined by the Treaty of Lisbon three years later. Those persisting cooperation issues convinced both institutions that this framework could not be definitive and should be improved. In 2014 the Commission released a communication

[38] Treaty on the Functioning of the European Union. Article 189 <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN>.

[39] European Commission. EU Space Industrial Policy: Releasing the potential for economic growth in the space sector. COM (2013) 108 final of 28 February 2013. Brussels: European Union. 4.

[40] European Commission. Space Strategy for Europe. COM (2016) 705 final of 26 October 2016. Brussels: European Union.

[41] Agreement between the European Community and the European Space Agency, done 25 November 2003, entered into force 6 April 2004.

stating its views on some of the remaining difficulties, especially pointing out the disparities in financial rules, the asymmetric membership (which would become especially significant with *Brexit*), the lack of policy coordination mechanisms and the lack of political accountability of ESA. It also considered different scenarios across the board to solve those issues, from keeping the *status quo* to ESA becoming an EU agency[42].

In the meantime, relations between ESA and the EU institutions and organs are mainly defined through delegation agreements and working arrangements related to the specific phases of each programme.

3.1.3 The Galileo Programme in the EU Space Policy

The communications of the Commission, as well as the resources allocated through the multiannual financial frameworks, have regularly confirmed that, together with Copernicus, Galileo is one of the two flagship space projects of the European Union. The total cost for Galileo and EGNOS, from 1994 to 2020 was around € 13 billion. For the 2014-2020 period, the EU allocated € 7,071 million for the two GNSS programmes, of which € 4,930 million are dedicated to Galileo. This significant amount, in a period of severe EU budget pressure, demonstrates a strong commitment from EU institutions to the programme so far.

The launch of the Galileo programme preceded the legal formalization of the EU's ambitions in space through the Treaty of Lisbon and the following communications of the European institutions, as well as the framework agreement between ESA and the EU. Nevertheless, as the programme has changed over time, its evolution has been taken into account in the current arrangements. In particular, Galileo in its current phase can be seen as a project fully funded by the EU, parts of its execution being delegated to ESA, as defined in the 2004 framework agreement; hence EU ownership of Galileo.

As one of the pillars of the European Space Strategy, full deployment and exploitation as well as the market uptake of Galileo have been set as priorities in the communications of the Commission detailing the EU strategy in this field, and are seen as an engine for European space initiatives that could lead to further developments, such as a European launchers policy[43]. The latest Commission communication, "A Space Strategy for Europe" confirmed the importance of the programme within the EU space policy, as a major element of the five axes mentioned in 3.1.1. The next concrete commitment in the near term lies within the upcoming negotiations for the next Multiannual Financial Framework (MFF, see 3.2.1) for the period from 2021 to at least 2026[44].

3.2 Galileo Governance Scheme, Actors and Prerogatives

3.2.1 Definition of the Governance Scheme

Fully funded and owned by the European Union, the definition of a Galileo governance scheme follows the rules established within the primary treaties of the Union: the Treaty on European Union and the Treaty on the Functioning of the European Union. As a consequence, the structures of Galileo governance and the prerogatives of the involved actors are defined by regulations produced through the ordinary legislative procedure, involving the European Commission, the European Parliament and the Council of the European Union (see 3.2.5.2). Those regulations are completed by decisions produced either through the same procedure, or by the Commission, in accordance with comitology rules[45]. Last, given the security dimension of the programme, the Council and the High Representative of the Union for Foreign Affairs and Security Policy (HR) make decisions related to Galileo as part of their responsibilities in the Common Foreign and Security Policy.

The budget of the programme is established in the Multiannual Financial Framework, which is defined for a duration of at least 5 years, usually 7 years (see 3.2.5.2). Because of the many intricacies the programme has gone through, different regulations have been passed, while several have been amended or repealed. Furthermore, the main regulation known as the "GNSS Regulation" (see below), which defines the modalities of the programme implementation, is expected to be revised with the evolution of the programme and

[42] European Commission. Progress report on establishing appropriate relations between the European Union and the European Space Agency (ESA). COM (2014) 56 final of 6 February 2014. Brussels: European Union.

[43] European Commission. EU Space Industrial Policy: Releasing the potential for economic growth in the space sector. COM (2013) 108 final of 28 February 2013. Brussels: European Union. 20.

[44] "Multiannual Financial Framework: shaping EU expenditure." 12 April 2016. European Council and Council of the European Union 19 December 2016 <http://www.consilium.europa.eu/en/policies/multiannual-financial-framework/>.

[45] See note 35.

the definition of the MFFs. Currently, the framework of this governance is determined by five regulations regarding the programme, the structure of management, and particularly the GSA, the PRS and some specific security aspects. These include:

For programme implementation

- 2013 - *Regulation (EU) N°1285/2013* of the European Parliament and of the Council on the implementation & exploitation of European Satellite Navigation Systems (hereafter referred to as "GNSS Regulation").

For the setting up of the structures for the management of EGNOS and Galileo:

- 2010 - *Regulation (EU) N° 912/2010* of the European Parliament and of the Council of 22 September 2010 setting up the European GNSS Agency, repealing Council Regulation (EC) N° 1321/2004 on the establishment of structures for the management of the European satellite radio navigation programmes and amending Regulation (EC) N° 683/2008 of the European Parliament and the Council.
- 2014 - *Regulation (EU) N° 512/2014* of the European Parliament and of the Council of 16 April 2014 amending Regulation (EU) N° 912/2010 setting up the European GNSS Agency (hereafter referred to as "GSA Regulation").

For the definition of the rule of access to public regulated service:

- 2011 **-** *Decision N° 1104/2011/EU* of the European Parliament and of the Council of 25 October 2011 on the rules for access to the public regulated service provided by the global navigation satellite system established under the Galileo programme.

On the security aspects:

- 2014 - *Council Decision N° 2014/496/CFSP* of 22 July 2014 on aspects of the deployment, operation and use of the European Global Navigation Satellite System affecting the security of the European Union (hereafter referred to as "Joint Action").

It should also be noted that a new GNSS regulation is expected to be defined in 2019 to cover the years beyond 2021, in parallel with the preparation by the Commission of the next MFF. Other than these framework legal provisions, relations between different actors are clarified through delegation and working agreements detailing the concrete processes of cooperation for the different phases of the programme.

3.2.2 Phases of the Programme

According to the current GNSS regulation, the Galileo programme is divided into four phases, each having its own budgetary line: definition; development and validation; deployment; and exploitation[46]. The effective governance scheme depends on the specific phase. It is worth mentioning that from 2017 to 2020, two phases will be overlapping, since deployment will be achieved in 2020 while the exploitation phase started on the 15 December 2016.

The *definition phase,* ending in 2001, corresponds to the system structure design and the determination of its elements. It was equally funded by ESA and the EU, for a total cost of € 133 million and managed by ESA[47].

The *development and validation phase*, ending in 2014, included the construction and launch of two experimental and four In-orbit validation operational satellites, the setting up of the first ground infrastructures and the validation of the system based on this mini-constellation. It was almost equally funded by the EU and ESA, and was carried out by ESA.

The *deployment phase* started in August 2014 with the launch of the first Full Operational Capability (FOC) satellite. The deployment of the space segment consists of the construction, setting up and protection of the FOC satellites completing the constellation – with at the end of the deployment, 24 active satellites and 6 spares - and of scalable maintenance or other necessary operations. For the ground segment, this phase consists in the setting up and protection of all necessary ground-based infrastructures including control centres, service centres and radio-navigation data-processing infrastructures. It also includes all preparations needed to start the last phase. This phase, fully funded and managed by the EU, should lead to the provision of enhanced services by mid-2018, ending up with the full deployment of the system (FOC 2) before 31 December 2020.

[46] European Commission. Regulation (EU) N° 1285/2013 of the European Parliament and of the Council of 11 December 2013 on the implementation and exploitation of European satellite navigation systems and repealing Council Regulation (EC) N° 876/2002 and Regulation (EC) N° 683/2008 of the European Parliament and of the Council. Brussels: European Union. 9-10.

[47] House of Commons – Transport Committee. Galileo: Recent Developments HC 53, First Report of Session 2007-08 (Incorporating HC 1055, Session 2006-07) – Report, Together with Formal Minutes, Oral and Written Evidence. 4.

The *exploitation phase* started in December 2016 with the provision of initial services, including the Open Service (OS), the Search & Rescue Service (SAR) and the Public Regulated Service (PRS) for pilot tests. It comprises the management, maintenance, continuous improvement, evolution, protection and replenishment of the space-based and ground-based infrastructures, as well as any other activities aimed at smoothly running the programme. It also includes certification and standardization activities, service provision and associated marketing, and cooperation with other GNSS. The development of the next generation of the system and the evolution of the provided services are also part of this stage[48]. The handover of exploitation management, from ESA to the GSA, will take place at the beginning of this phase. This phase is fully funded by the EU (€ 3 billion for 2014-2020) and managed by the EC.

3.2.3 Main Actors

3.2.3.1 The Commission

Prerogatives

The role of the European Commission (EC) in the European GNSS programmes is mainly defined by the GNSS Regulation, and further specified by particular regulations and implementing decisions.

The Commission has overall responsibility for the Galileo programme, and is in charge of the management of the funding allocated through the MFF. This includes taking the major programmatic decisions, defining the associated objectives and priorities, establishing the programme's legal and policy frameworks as well as the missions, service and security requirements while ensuring the coherence of those decisions with other EU funding programmes, notably H2020. In particular, the EC defines the operational and technical specifications of the services and takes into account the future evolution of the system. The last component of this overall responsibility is that the Commission supervises other actors, oversees the implementation of the programme, ensures a clear division of tasks between the GSA and ESA and mitigates cost, schedule and performance risks. The Commission also provides member states and the European Parliament with all relevant information.

In addition to these aspects of its general responsibility over the programme, the Commission manages, on behalf of the EU, the assets produced under the programme and relations with other countries and international organizations. Since those negotiations can be complex, the EC is supported by the Member States (especially on security subjects) and ESA (for technical expertise) through a dedicated coordination process before and after negotiations. The EEAS also provides support and takes part in negotiations. Regarding marketing development, the Commission has high level powers in the promotion of Galileo's uses. It also assesses the impact of Galileo on EU competitiveness for the upstream & downstream markets, services provision and end users.

Last but not least, the Commission has responsibility for the security of the programme, in accordance with the requirements of member states. It thus supervises the implementation of those requirements, trying to ensure that they have minimal delay and cost impact on the programme. It also plays a coordination role for the entities involved in security, and provides advice for the Joint Action (see 3.2.5.3). Concerning the PRS, the Commission updates and amends the Common Minimal Standards to take into account developments in the Galileo programme.

Internal organization regarding the Galileo programme

In order to fulfil its tasks concerning Galileo and EGNOS programmes, the Commission has set up a specific directorate for the EU Satellite Navigation Programme, under the authority of the DG GROW (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs). This directorate consists of three units, with a total staff of 75 evenly split between the Programme Management unit, the Legal and Institutional Aspects unit, and the Applications, Security, International Cooperation (including market uptake) unit.

In addition, the Commission has set up two expert groups for specific subjects, gathering EC representatives, member states and experts. The first one is the Security Board for the European GNSS, which advises the Commission on security related matters[49]. This is where member states present their security requirements, which are discussed in order to reach a consensus that will enable decisions to be implemented by the GSA and ESA in their industrial contracts. The GSA, ESA and EEAS can only be associated as observers, providing non-binding inputs to the EC. This expert group has six working groups: National Expert Team (WG-NET), Public Regulated Service

[48] This is also funded by the programme H2020 from the Union and by the programme NAVISP on the ESA side. The new satellites should begin to replace the current generation around 2025.

[49] European Commission. Commission Decision of 20 April 2009 establishing an expert group on the security of the European GNSS systems. Brussels: European Union.

(WG-PRS), Protection of Classified Information (WG-PCI and COMSEC), PRS User Segment Standards (WG-PUSS), Incident Response Coordination Working Group (WG-IRC) and PRS User Segment Standards (WG-CDA). The second expert group is the Search and Rescue Galileo Operations Advisory Board. It deals with the SAR Service, defining its operational and exploitation model so as to facilitate its integration into the Cospas-Sarsat system.

Though the DG GROW is in charge of programme management, it is not the only DG related to Galileo, since DG MOVE, DG CONNECT, DG HOME and DG AGRI are customers of Galileo for their own programmes. An inter-service group, meeting on an ad-hoc basis at the DG, Directorate and experts level, allows the concerned DGs to anticipate programme developments, identify concrete actions for their own programmes and inform the DG GROW of their requirements.

Following the rules of comitology, Member States scrutinize EC programme implementation and exploitation through a European GNSS Programmes Committee (see 3.2.5.4).

3.2.3.2 The GSA

GSA status

The GSA is a decentralized (or regulatory) agency of the EU and a key element of European GNSS governance. Such agencies are intended to improve the functioning of EU institutions, and are tailored for the completion of specific administrative, technical or scientific tasks. They are created through secondary legislation (usually a Council regulation), without a predetermined life span, and endowed with legal personality. In its current form, the GSA was set up by the Parliament and the Council through Regulation (EU) N° 912/2010, amended by the Regulation (EU) N° 512/2014 (GSA Regulation).

The activities of decentralized agencies are supervised by an Administrative Board comprised of EU Member States as well as the Commission. They enjoy fewer constraints in their functioning as compared to the Commission since they have greater flexibility on budget matters, better reactivity and the capacity to hire highly specialized staff – especially through the recruitment of external consultants. They should be less influenced by general political issues than European institutions, and benefit from an increased visibility among both public and international partners[50].

However, this status is also constrained by regulations and rules regarding, in particular, resources management: the framework of the GSA is not only delineated by the five regulations aforementioned (3.2.1), but also by general provisions and their interpretations through internal decisions. Those complementary regulations and decisions are:

- *Regulation (EU, Euratom) N° 966/2012* of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union;
- *Commission Delegated Regulation (EU) N° 1268/2012* of 29 October 2012 on the rules of application of Regulation N° 966/2012;
- *Decision of the Administrative Board* of 25 April 2014 adopting the GSA Financial Regulation 2014;
- *Decision of the Administrative Board* of 25 April 2014 adopting the GSA Financial Regulation Implementing Rules 2014.

It should be noted that, in 2012, the problem of the multiplication of agencies, their heterogeneity and lack of accountability to the European institutions led them to engage in reflections that resulted in the endorsement of a legally non-binding common approach. This approach, which is still in effect, aims at specifying further the place of the agencies within the EU, their modalities of creation and dissolution, their funding rules, their budget management, their structure and the control over them exerted by the Commission and the other European institutions. The GSA, with its current organization is regarded as a role model concerning the implementation of those recommendations[51].

Prerogatives of the GSA

As mentioned in the introduction, the role of the GSA, its prerogatives and its internal organization, has changed several times since the beginning of the Galileo programme. The Agency was created in 2004 to protect the public interest within the former Galileo PPP model, and given with an important core of related prerogatives (concession contract implementation, security management, PRS related activities, Member States coordination etc.). After a drastic reduction of its role, the last regulation gave an important role back to the

[50] Ramboll-Euréval-Matrix. Evaluation of the EU decentralised agencies in 2009, Final Report Vol. 1: i.

[51] European Commission. Progress report on the implementation of the Common Approach on EU decentralized agencies. COM (2015) 179 final of 24 April 2015. Brussels: European Union. 7.

GSA as the entity that should progressively take charge of system exploitation.

The current prerogatives of the GSA are now mainly defined by the GNSS Regulation, completed by the GSA Regulation. They are of two kinds: some prerogatives are fully owned by the GSA ("core prerogatives"), whereas others are delegated by the Commission through a delegation agreement.

Core prerogatives

The GSA is responsible for the security of the system in the fields not covered by the Commission (as defined by the GNSS Regulation), the Council and the HR (as defined by the Council decision N° 2014/496/CFSP). In practice, it plays a key role in this area through:

1. Monitoring of system security and executing instructions from the Council or the HR in case of security threats;
2. Responsibility over programme security accreditation, through implementation and monitoring of security procedures and security audits.

The GSA also has specific responsibilities regarding the PRS: it manages access at system level, supports and coordinates the national Competent PRS Authorities (CPA), assists the EC in the respect of CMS (see 3.2.5.1), provides PRS related security analysis and is proposed to be the CPA for EU PRS participants (Council, Commission, EAAS, agencies) and international organizations[52].

The last core prerogatives of the GSA regard market development, in coordination with the Commission. It provides market analysis for Galileo services, and establishes an action plan to foster their uptake by user communities. This includes certification and standardization actions, as well as the establishment of contacts with relevant stakeholders to promote the uses of Galileo services and understand their needs.

Prerogatives delegated by the Commission:

Nevertheless, the main prerogatives are delegated by the Commission. The most important one is the management of exploitation, whose operational activities are outsourced to GSOp. The GSA thus manages all the related contracts, including with the operator, but also associated with the other service facilities (GRC, GSC, GSMC, Time and Geodesy facilities, SAR Ground Segment and Validation Test Bench). Those prerogatives include system infrastructure management, upgradeable maintenance of the systems, certification and standardization operations and service provision, and activities relative to the evolution and development of the system and its services. The GSA is also expected to provide the Commission with technical expertise and contribute to the definition of mission, service and system evolution.

Other delegated tasks are marketing development prerogatives with the promotion of services, applications and fundamental elements such as Galileo-compatible receivers and chipsets, research and development prerogatives (with tasks related to Horizon 2020 and FP7) and tasks associated with the PRS.

Internal organization of the Galileo programme

General

The internal organization of the GSA in its current form is essentially defined by the GSA Regulation. But this is also strongly influenced by the progress of the programme itself. Indeed, as the GSA will take over the exploitation in 2017, its organization is currently not stable, as well as its size. From a staff of 112 in 2013, the GSA numbered 153 staff in 2016. That year was the peak of the ramp-up since only 6 additional staff are expected by 2020. However, this headcount is also increasingly completed by external consultants and the overall staff could continue to increase – there were 15 in 2015 and 35 in 2016. Those figures do not include the operations for the exploitation of the system outsourced to GSOp. The detailed GSA headcount and its evolution are given in Annex A.5.

The structure of the Agency is divided into three organs:

- The Administrative Board
- The Executive Director
- The Security Accreditation Board (SAB)

The Administrative Board

The Administrative Board is composed of a representative per Member State, four representatives from the EC and a representative without voting power from the Parliament. The SAB, the HR and ESA are also invited as observers. A decision is taken by an absolute majority of the members.

The Administrative Board has authority over the core activities of the GSA, overseeing them and the associated expenses, except those carried out by the SAB and those delegated to

[52] The PRS chain is very specific, and particularly decentralised. Each Member State has to establish a CPA, which defines for its country the PRS users and their access to the service, following the Common Minimum Standards on which the Member States agreed. The CPAs receive requests from their users and directly transmit them to the GSMC, which orders GSOp to implement. GSOp only implements the request and is not "aware" of its origin.

the GSA by the Commission. Those delegated activities represent more than 90% of the current expenses of the GSA and for those tasks, the Executive Director is directly accountable to the Commission and indirectly to the programme Committee to which the EC reports[53]. The Administrative Board adopts annual and multi-annual programmes for the GSA that need to be accepted by the Commission. It is not clear at the moment to what extent this board will oversee Galileo operations, but one can expect than its responsibility will increase later[54].

The Executive Director

The Executive Director implements the tasks defined as part of the annual and multiannual work plans agreed within the Administrative Board or delegated by the Commission. The only exception is related to tasks under the responsibility of the SAB. These include marketing development, management of the exploitation, the implementation of security requirements, and security monitoring etc.

Nine entities are under the responsibility of the Executive Director:

- Security department
- Market Development department
- Project Control and Quality management department
- Galileo Security Monitoring Centres
- Galileo Programme Management
- EGNOS Programme Management
- Internal Audit
- Communication
- Administration

Though the GSA headquarter is located in Prague, the GSA has set up centres in different parts of Europe. Most of them are dedicated to exploitation (Ground Segment), or to service provision to users (Galileo Services Facilities). Their locations are listed in Annex A.3 and the scheme of their interactions is given in Annex A.4. The main Galileo centres are described below.

Galileo Control Centres (GCC) and associated elements

The Ground Segment is made up of two control centres and a global network of transmitting and receiving stations. Those two centres, located at Fucino (Italy) and Oberpfaffenhofen (Germany) are redundant: they both manage the core control functions (spacecraft housekeeping and constellation maintenance) and mission functions (determination and uplink of navigation data messages to provide the navigation and timing services)[55].

Control functions are supported by a Galileo Control Segment (GCS), of which the other elements are five globally distributed Telemetry Tracking and Control stations (TTC) communicating with the satellites for regular contacts, contingency contacts and long-term test campaigns.

Mission functions are supported by a Galileo Mission Segment (GMS) global network of Galileo Sensor Stations (GSS) continuously monitoring navigation signals from satellites. The GMS communicates through a global network of Mission Up-Link Stations (ULS) located in five sites: Svalbard in Norway, Kourou in French Guyana, Papeete in French Polynesia, Sainte-Marie on Reunion Island, and Noumea in New Caledonia[56].

Remote stations (TTC, GSS and ULS) are connected to the GCCs by a hybrid communication network including special radio, wired data and voice communication links.

Galileo Security Monitoring Centre (GSMC)

The Galileo Security Monitoring Centre is composed of two facilities, one in charge in Saint-Germain-en-Laye (France) and a back up in Swanwick (United Kingdom). They are the only GSA major operational centres where most of the staff are insourced. They are involved in three areas:

- Security: Monitoring security threats and the operational status of systems components;
- PRS: Ensuring the security of PRS information dissemination and the interface with governmental entities and Galileo core components;
- Emergency: Implementation of "Joint Action" instructions following a Council or HR decision in case of emergency (see 3.2.5.3).

Galileo Reference Centre (GRC)

[53] European GNSS Agency. Multi-Annual Work programme 2014-2020. 2013. Prague: European Union. 29.

[54] So far, the tasks and responsibilities currently delegated by the European Commission are included in the annexes of the annual and multi-annual programmes for information only.

[55] "Galileo Ground Segment." 18 September 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/Galileo_Ground_Segment>.

[56] European Space Agency. GALILEO FOC2 WP2-X - Galileo Ground Mission Segment and Galileo Security Facility. Appendix 1 - High Level Statement of Work. 11 May 2016. 8.

Together with the use of Key Performance Indicators (KPI), the GRC, located in *Noordwijk*, is one of the two parallel ways set up by the GSA to monitor the performance of the operator. This centre provides the GSA with an independent system to evaluate the quality of the signals and the operational performance of GSOp both through specific campaign-based analysis and daily monitoring. The operations in the GRC are outsourced (and independent from GSOp), but the centre can also use expertise available in member states and the data they collect. Its operations started progressively with the declaration of initial services.

European GNSS Service Centre (GSC)

The GSC is the gateway for users and will be operated by GSOp. This is intended to be the single user interface for the Open and Commercial Services, providing constant information about the health status of the system, communications in case of system outage (equivalent to the civil aviation "NOTAM") and an interface with all the information needed for chip or receiver manufacturers as well as market information.

When the Commercial Service is delivered, it will be hosted by the GSC: the outputs and inputs will be channelled to the CS Service provider through this centre.

Security Accreditation Board (SAB)

The Security Accreditation Board is a hierarchically independent structure within the GSA, in a way parallel to the Administrative Board/Executive Director couple. The independence of the SAB decision-making process is thus ensured, though the resources are still provided by the Agency. In order to prevent its technical isolation, SAB staff are also part of the Security department. It is composed of one representative of each member state, of the Commission and of the HR.

The SAB is situated at the end of the security-ensuring chain. It accredits the systems and major operations of the programme (launches, early services, Joint Action implementation for instance), assessing the remaining risk and risk mitigation plan of the systems through an iterative process, and then sensitizes the Commission before it takes a decision. Additionally, the SAB briefs to EC on specific security-related subjects, if necessary, and sits on the European GNSS Programme Committee.

To fulfil its missions, the SAB has set up two technical bodies: the Galileo Security Accreditation Panel (GSAP) and the Crypto Distribution Authority (CDA). The GSAP plays a main role, preparing the technical aspects of SAB decisions through analysis, reviews and tests. It is potentially open to any state, but in practice, a limited number of experienced member states attends it. The CDA deals with the management of EU cryptographic materials necessary for the functioning of the system.

3.2.3.3 ESA

Prerogatives

The GNSS Regulation provides ESA with different prerogatives during the deployment and the exploitation phases. However, those two phases are likely to overlap until 2020, and this evolution will take place progressively.

During the deployment phase, the Commission delegates to ESA system design and development, as well as the associated procurement. Concretely, the ESA/GSA interface will become the main ESA interface for the programme and ESA will only procure and launch the satellites for the Commission. This interaction is framed by a convention of delegation and validated by the GNSS Committee. Furthermore, ESA continues to supervise the exploitation of the constellation under deployment operated by a private operator until mid-2017, the first months of 2017 being dedicated to the handover to the GSA.

The precise role of ESA during the exploitation phase is mainly defined through a working arrangement with the GSA (see 3.2.4.3). ESA is the system architect of Galileo, in interface with the GSA. Procurement and integration of the components of the ground segment and services are done directly for the GSA. In parallel, ESA fosters the know-how transfer associated with the handover of responsibility for exploitation. It will then continue to provide technical support related to exploitation and maintenance, carrying out laboratory tests and providing technical solutions for detailed maintenance cases and complex technical issues in the current system. ESA will also prepare the evolution of future generations of the system (design, elaboration, follow-up, procurement and validation).

During these phases, ESA also provides technical expertise to the Commission. In particular, the space agency is involved in the international negotiations regarding Galileo, where it delivers inputs and processes the technical outputs of the negotiations. ESA also carries out research activities regarding the first phases of the system's next generation and Galileo's infrastructures, which are funded as part of the EU Horizon 2020 programme.

Internal organisation regarding the Galileo programme

On the ESA side, the Galileo programme is carried out within the Directorate of Navigation, supervised by a Programme Board gathering ESA Member States.

At the beginning of 2017, the Directorate was made up of 254 full time equivalent staff, with more than 80% involved in the Galileo programme. Among them, 20 staff are supervising the system operator until the full handover to the GSA.

In accordance with the evolution of prerogatives of ESA, the Agency is going through a staff reorganization. By the end of the process, the total number should be the same, but most operational activities will be discontinued and system design activities will restart for the development of the Galileo next generation.

3.2.4 Relations between the Main Actors

Given the entanglement of their prerogatives, the three actors of the governance triangle are in regular interface on different aspects of the programme management. In particular, they all take part in the Programme Change Control Board, a trilateral board where any modification of the technical configuration of the programme is discussed. Yet, this board meets occasionally in today's programme. In addition to those trilateral relations, they have also bilateral interfaces between them, which are detailed below.

3.2.4.1 Commission-ESA

Relations between the European Commission and ESA are complex by nature. The two institutions have different histories, different purposes and different organisational cultures. The Commission is a political institution that has been created within the frame of the EU construct, while ESA is an independent intergovernmental organisation created for scientific and research purposes.

The current relation is mainly a vertical one: the Commission, as programme manager, delegates tasks to ESA, and exerts tight scrutiny over the activities of the agency, including systematic information from the EC and the submission of costs estimates from ESA. The delegation agreement stipulates, *inter alia*, the conditions for the use of the allocated funds, the actions to be implemented for system design and development, management procedures as well as follow-up and control measures. The current GNSS regulation also specifies that the degree of control of the EC over ESA should be analogous to that of the EC over an EU agency. The intensity of such interactions is nevertheless on the decreasing since the next phase involves an increase in ESA/GSA interaction.

3.2.4.2 GSA-Commission

The relationship between the GSA and the Commission takes place through different channels, corresponding to the different kind of prerogatives entrusted to the GSA. The Commission is represented on the Administrative Board of the SAB – with no voting power – and directly delegates a number of tasks to the GSA. This kind of interaction is clearly framed by the regulations regarding the organisms of the EU. The delegation interface largely predominates given the nature of, and the budget for activities which are not delegated[57], with which the Administrative Board is marginally associated, meaning that it receives updates on progress at each Board meeting but has no decision-making power on the delegated tasks. As the Regulation imposes tight conditions on the related delegation agreements, it gives the Commission strong control over the GSA. This means limited responsibility, compared to the status first given to the GSA and to the other EU agencies, which are mainly supervised by member states.

This provision, in line with the GNSS regulation, is justified by the fact that the Commission has *de jure* responsibility for the programme. Since the GSA in its current form is a young organization, the member states and the Commission considered that it was necessary to stabilize the GSA before entrusting it with greater responsibilities, and the GSA seems to share this view. One can expect a progressive increase in the autonomy of the GSA, in line with the consolidation of its competencies, to be finally suitable for the full handling of exploitation by 2020. This will be decided in the next GNSS regulation and though the best option is an autonomous GSA, fully in charge of exploitation, other scenarios are possible. It will of course depend on the results during the next two years, but such considerations are also included in more general thinking about the roles of all the stakeholders of governance.

This is not the case for the SAB which, because of its hierarchical independence from the Executive Directorate, and its composition, may be seen as a tool in the hands of the member states to balance the power of the Commission, *de facto* able to block important decisions.

[57] European GNSS Agency. Multi-Annual Work Programme 2014-2020. 2013. 29.

3.2.4.3 GSA-ESA

Though the GNSS regulation requests the Commission to clearly divide the tasks between the GSA and ESA, this aspect as well as most of the modalities of their interaction during the exploitation phase are defined in a bilateral way, through the working arrangement signed in December 2016. This arrangement is a contract, as the EU financial regulation pertaining to the agencies only allows them to have contractual agreements, including with public entities. It is divided into three specific contracts, defining a relation with multiple components. The main one, contained in the two first specific contracts is vertical: the GSA is the customer of ESA, which provides the ground segment and implements the system to reach FOC 2.0. The GSA thus pilots ESA activities as this binding working arrangement provides, with a juridical text supported by market, technical and management annexes. However, the working arrangement gives more autonomy to ESA in the management of its procurement in comparison to the 2014 agreement.

In parallel to this interface, another component of the GSA-ESA relation, defined by the third specific contract, corresponds to a horizontal interaction and addresses two issues. First, ESA provides the technical support to the GSA that this agency needs for exploitation and for specific tasks, with a defined amount of resources. Second, the arrangement provides coordination mechanisms and board decisions in order to harmoniously manage the deployment of the constellation by ESA and its exploitation by the GSA. ESA also supports the GSA for the evolution of the system during exploitation by proposing relevant technical solutions.

3.2.5 Other Actors in Governance

3.2.5.1 Member States and Associated Third States

Though Galileo is a fully funded EU programme, member states potentially have strong influence over the programme since they are involved from all sides: within the Council, the SAB, the GSA Administrative Board, the ESA Ministerial Council and ESA Navigation Programme Board, and in the European GNSS Programme Committee. The GNSS Regulation also allows member states, with the approval of the Commission, to directly fund specific elements of the programme.

The main role of member states concerns the security of the programme, more specifically regarding security accreditation and the PRS. This service works in a highly decentralized way, based on national Competent PRS Authorities (CPA), which is the interface with the PRS authorized users that member states designate. For this, in November 2015 common minimal security requirements – the Common Minimum Standards (CMS)[58] – were agreed. The Commission also needs member states' expertise regarding security for negotiation on the use of PRS by a third state. They are also involved in the Joint Action through the Council.

Besides these general prerogatives, several Member States have specific responsibilities in the programme. Some have Galileo infrastructures on their territory and are responsible for their protection. Member States' agencies are supposed to provide technical support to the Commission, and some of them are significantly involved in specific tasks: CNES will operate the SAR service, and the DLR owns 50% of the current GSOp, Spaceopal.

It should be noted that though Galileo is owned by the EU, Switzerland and Norway, as associated countries, play an important role, each in a different way: A Swiss Company provided the atomic clocks used in the payload, while Oslo accepted the deployment of two important Galileo ground bases on its territory.

3.2.5.2 The Council and the European Parliament

The Council and the European Parliament are, together with the Commission, the main actors of the "Meta-governance" of the programme, i.e. the definition of the Galileo governance scheme and resources.

Regulations defining the structure of the programme management are produced through the ordinary legislative procedure: proposed by the Commission and adopted by the Parliament and the Council. The Council also plays a specific role in producing decisions for the Common Foreign and Security Policy related aspects of the programme.

The two institutions also exert a major influence on the programme through the definition of the multiannual budget of the EU as well as the annual appropriations. Both are defined

[58] Cameron, Alan. "System of Systems: Galileo turns 12 — or 9." GPS World 7 January 2016.

through a special legislative procedure[59]: they are adopted by the Council after approbation of the Parliament. In practice, the European Council also plays a main role in orientating the Council of the EU.

The Council and the European Parliament are informed about the evolution of the programme (costs, risks, calendar, results but also working arrangements, delegation agreements, industrial contracts and decisions taken after accreditation) by the Commission. In particular, the Galileo Interinstitutional Panel (GIP) has been set up for this purpose, but this structure has proved hard to remain active. It has not been used over the last two years. The European Parliament and the Council also can revoke delegated acts regarding security. Lastly, the GSA Administrative Board also reports to them, and the Parliament has a representative without vote at the GSA Administrative Board.

The Council has two additional prerogatives. First, it plays a major role in international relations, mandating the Commission for international negotiations[60]. In the case of Galileo, it specifically approves the PRS access negotiated by the Commission with third states and international organizations. Second, it decides, together with the HR, upon the emergency decisions raised by international risks to be taken as part of the Joint Action[61].

Thus, concretely speaking, those two institutions have a limited role within the programme, but a major, though occasional, role on the programme ambitions and governance, especially through the development of GNSS regulations and the multiannual financial framework.

3.2.5.3 European External Action Service

The European External Action Service (EEAS) and especially its Head, the High Representative for Foreign Affairs and Security Policy (HR), are not involved *per se* in the Galileo programme governance but the service is provided with major responsibilities in the management of emergency cases according to the Joint Action defined by Regulation 2014/496.

This Joint Action covers cases of threats to the EU or member state security or essential interests, for instance linked to international crisis and related to the exploitation of Galileo, requiring the giving of instructions to the GSA (in practice, to the GSMC). Though the normal procedure envisages decisions to be made by the Council, if the HR decides that the situation requires an emergency decision, she/he will be endowed with this responsibility.

The EEAS has organized itself for these purposes, notably setting up a GNSS Threat Response Architecture (GTRA).

3.2.5.4 European GNSS Programme Committee

The European GNSS Programme Committee was created following the rules of comitology. It monitors and supports the activities of the Commission and is also a space for dialogue with member states, though there are also redundancies with the ESA Navigation Programme Board and the GSA Administrative Board. It has, *de facto*, an advisory function. This programme Committee has four working groups:

- Galileo Commercial Service (CS WG)
- Compatibility, Signal and Interoperability Working Group (CSI WG)
- Galileo Reference Centre Working Group (GRC WG)
- European GNSS Evolution Working Group (EE WG)

The last working group also includes ESA and GSA representatives in addition to member state representatives.

3.2.5.5 GSOp

As mentioned above, exploitation operations are outsourced by the GSA to a private company, GSOp. The corresponding bid solicitation conducted by the GSA was finalised at the end of 2016, extending the mission of Spaceopal that had already been operating the building constellation under a contract with ESA. The contract value is €1.5 billion.

GSOp operates the two Galileo Control Centres, the Galileo Service Centre and the other relevant exploitation infrastructures provided by the programme, requiring around 200 staff. It is in charge of the space and ground segments operations for the Open Service and the Commercial Service. This includes launches, routine maintenance (the detailed/special maintenance is carried out by ESA), satellite

[59] "Multiannual Financial Framework." September 2016. European Parliament 19 December 2016 <http://www.europarl.europa.eu/atyourservice/en/displayFtu.html?ftuId=FTU_1.5.3.html>.
[60] "The role of the Council in international agreements." 18 May 2015. European Council and Council of the European Union 19 December 2016 <http://www.consilium.europa.eu/en/council-eu/international-agreements/>.
[61] Council of the European Union. Council decision N° 2014/496/CFSP of 22 July 2014 on aspects of the deployment, operation and use of the European Global Navigation Satellite System affecting the security of the European Union. Brussels: European Union.

station-keeping, signal dissemination and user interface provision.

GSOp is responsible for ensuring that the programme complies with the Galileo Services performance requirements. It is expected to have relative autonomy thanks to procurement procedures allowing it to autonomously settle minor issues and realise minor developments. The GSA supervises its activities through Key Performance Indicators (documentation update, reactivity, availability, coverage, etc.) and direct monitoring of GSOp performance through the GRC. GSOp also reports through an escalation process depending on the seriousness of the problems encountered. Concerning liability, the GSOp contract should provide the operator with a liability limited to specific contractual ceilings, since the tender documents define the GSA as the service provider, in principle liable vis-à-vis users[62]. The GSA is liable up to a second ceiling, while the final liability is to be borne by the Commission.

Since the GSA is the customer of GSOp, there is a less formal relationship with ESA. However, the GSA-ESA working arrangement provides that the space agency supports the GSA in the management of the GSOp contract with a dedicated team, and interfaces with GSOp for coordination purposes during the exploitation and deployment activities overlap.

[62] Baumann, Ingo. "State of Play in the European Union" Inside GNSS December 2015.

4. Current Issues in the Galileo Governance Scheme

Since the entry into force of the 2013 GNSS regulation and the 2014 GSA regulation, the Galileo programme has made dramatic progress. On the institutional side, those new regulations continued the work started in 2008 in order to set up relevant structures of governance to ensure fully public management of Galileo. The GNSS regulation clarified the provision of each actor, and outlined the effective mechanisms to be implemented for the next phases of the programme. With the re-consolidation of the GSA, triangular governance, that is expected to continue until 2020, was instituted and will be then revised in the next GNSS regulation. The GSA regulation accordingly established a clear organisation structure for the GSA and its internal mechanisms. Together, they created an effective institutional framework for the deployment phase, and prepared the stage for the upcoming exploitation phase.

As a consequence, very good operational results have been obtained since then. The deployment of the space segment, in particular, strongly accelerated with the launches of 14 FOC satellites between August 2014 and November 2016. The last one, on 17 November 2016, sending four satellites into orbit, also demonstrated the possibility of using the European launcher Ariane, rather than the Russian Soyuz, for the next launches of Galileo, ensuring European independence in this programme. In parallel, most of the ground segment facilities have been deployed, and on the user side, the initial services were declared on 15 December 2016. The performances observed and announced on this occasion seem to be remarkably good[63]. Clearly, the programme has taken off, leading to a current situation significantly different from 2013.

However, those good operational results do not guarantee that the governance scheme provided by the current GNSS regulation is optimal, nor that it is fully adapted to the next step of the programme: the exploitation of the system. While this phase has just begun, and on the eve of the preparation of the next regulation, the intention here is to identify a number of potential issues, and in the next chapters propose recommendations to overcome some difficulties that may jeopardize healthy governance.

4.1 Transversal Aspects

4.1.1 The Necessarily Complex Governance of the Programme

One of the features of the current governance of Galileo, as described in Chapter II, is its complexity, which originates from different sources, and their interactions with each other: the current European institutional configuration in the space field, the general EU framework, and the history of the programme.

First, as described in (3.1.2), the organisational architecture in the space area at the European level rests on three pillars: the European Union, the European Space Agency and the Member States, the latter holding back for the Galileo programme. The EU is increasingly the political driving force in this field, proposing, funding and now managing two new programmes in the space sector. In parallel, most of the technical competencies in this domain are within the European Space Agency. For its part, the GSA has increasing weight on security and market development, and is developing rapidly in exploitation expertise thanks to the knowledge gained from the EGNOS exploitation. While ESA is an unavoidable partner for European Union space programmes, there is no standard or reference institutional scheme of cooperation between the two organizations and this hampers the overall efficiency of the management of the programme[64,65]. Without an up-to-date and stable framework, accepted by all stakeholders, the current unachieved structure of governance may give way to the

[63] With in particular the following figures: Ranging accuracy: ~0.8 m; UTS dissemination accuracy: ~ 9,5 ns; GPS-Galileo time offset: ~6.8 ns. More information at <http://www.insidegnss.com/node/5260>.

[64] ESA Council at Ministerial Level. “Political declaration towards the European Space Agency that best serves Europe.” ESA/C-M/CCXXXIV/Res. 4 (final) of 20 November 2012. Naples.

[65] European Commission. Report from the Commission. Progress report on establishing appropriate relations between the European Union and the European Space Agency (ESA). COM (2014) 56 final of 6 February 2014. Brussels: European Union.

expression of conflicting views, in particular regarding the rules of programme management but also concerning the institutional evolution of the European approach to space. This necessarily leads to the development of complex, sub-optimal cooperation processes since the chosen schemes are also the outcome of *ad-hoc* compromises between ESA and EU bodies.

Second, the European Union is a complex structure in itself, and this feature reflects on its programme management. Unlike the other GNSS programmes, where the governance is easier because of military control, the Union involves twenty-eight member states with diverging interests, as well as its own institutions. While those institutions differ in nature (intergovernmental or community for instance) the executive and legislative powers are distributed among them, through complex procedures. Hence a heavy machine, the functioning of which is subject to inertia and lack of flexibility that may weigh on the governance of an operational programme.

The third source of complexity is at the programme level and is related to the choices made in the past about the project and its successive evolutions (see 1.3). The current configuration is indeed partially the consequence of the decisions made to address issues the programme faced earlier on, and not only the result of a concerted thought to create from scratch an optimal governance scheme taking advantage of the status and competencies of each actor. In particular, the EC, the GSA and the ESA had different roles in the first configuration, and the prerogatives they progressively got in 2008 and 2014 through the successive regulations evolved in the current situation because of the needs of the moment.

As a consequence, all the actors of the governance triangle have been endowed with tasks which have never before been part of their core business: initially, in 2004, the GSA was not created to be in charge of the exploitation of the system, which was supposed to be operated by a private company through a PPP model; ESA plays the role of a procurement agency while it is a structure dedicated to research and development; and the Commission is for the first time responsible for the overall management of a large space programme[66]. This hitherto unseen distribution of prerogatives and its sometimes blurred delineations potentially exacerbates the issues related to differences of cultures, functioning and purposes.

Another important resulting problem is the separation, within this complex structure, of control of programme management key parameters – cost, calendar and performance. The distribution of prerogatives and competencies prevents those key parameters to be managed by a single entity, impeding the establishment of the leadership necessary to move the programme efficiently forward. Though the governance scheme was different, this dilution of responsibility and its negative impacts on governance was already pointed out by the Court of Auditors in 2009[67]. That being said, significant progress has been made recently to converge to a more effective network structure of governance. In particular, the delegation arrangements and the recent working arrangement between the GSA and ESA have provided a sound base to clarify those interactions.

4.1.2 The Constraining Framework of the European Union

The framework of the European Union constrains programme management especially because of the nature of the institutional instruments available for its implementation. Indeed, the necessity to quickly put back on track the project after the failure of the PPP prevented the development of institutional and legal tools (organs, processes, rules etc.) corresponding to the new ambitions of the EU in the space field. The governance schemes retained in 2008 and 2014 were based on actors and processes that preceded the programme's quantum change from a PPP to a fully public funded model, bound by general regulations and thus not tailored to the specific needs of the management of large space operational systems.

Thus, after the failure of the PPP, the only legal basis to fund the programme was the Trans-European Transport Networks Frame (TEN-T), which involved specific rules regarding the governance of Galileo. In particular, the TEN-T was developed for civil applications usually without strong security components, and assumes a shared competence of the MS and the Commission. Currently, the general regulatory requirements bind the actors of the programme in their internal functioning. The comitology rules apply to programme implementation and thus constrain the actions of

[66] Council of the European Union. Council Regulation (EC) N° 1321/2004 of 12 July 2004 on the establishment of structures for the management of the European satellite radio-navigation programmes. Brussels: European Union. 3-4.

[67] European Court of Auditors. The management of the Galileo programme's development and validation phase. Special Report N° 7/2009. Brussels: European Union. 34.

the Commission regarding the management of Galileo. Furthermore, the EU financial regulation released in 2012 also firmly binds the execution of the budgets attributed to the Commission, providing in particular limited room to manoeuvre in its recruitment procedures, its authorized manpower, and corresponding salaries of its workforce[68]. To a lesser extent, the actions of EU bodies under Commission control, such as the GSA, are framed by a specific "Framework Financial Regulation" – a delegated regulation of the Commission – and its declination through the GSA Financial Regulation of 2014. Those regulations *a priori* enable more flexibility in resource management[69,70,71].

Furthermore, European Union rules also constrain relations between Galileo governance actors and the way they interact, since the legal form of the delegation and working agreements as well as the possibilities they offer are also specified by the aforementioned regulations. In particular, the delegation agreements are framed by the Framework Financial Regulation, mainly through its Article 8[72]. They also impose a contractual form for the relations of EU agencies with bodies external to the EU, adapted from relations with private actors. The resulting contractual nature of the working arrangement between ESA and the GSA has deep implications: it may dissociate the interests of the Agency and those of the programme. Indeed, it tends to redefine the role of ESA from steering industrial management and risk mitigation to a more "industrial" role, delivering specific services on the request of the programme management and thus having an interest in defending the limits of its commitments regarding them.

Here as well, endeavours have been made by the three actors to improve those institutional relations. For instance, the delegation agreement from the Commission to ESA and the working arrangement between the two agencies provide ESA with more flexibility in its procurement and, on paper, has significantly clarified the relations between the two agencies for the coming years. But some constraints remain unavoidable as long as new instruments, more adapted to this kind of programme, are not developed.

4.1.3 Issues Caused by the Programme Management at the Political Level

The evolution of the role of the Commission is probably the main consequence of the failure of the PPP model. The Commission saved the programme through its will, pushing for a fully public funded model and proposing itself as overall manager of Galileo. This salutary solution was probably the only option at that time but as was identified by the Court of Auditors in 2009, it also presented some risks, in particular as a result of the limited experience of the Commission in the management of this kind of programmes at that time[73]. As a matter of fact, the management of operational programmes is not a classic function for a political and regulatory institution like the Commission. This requires a way of functioning, the setting up of specific processes and an appropriate, result-oriented culture that the Commission had to develop at that time. Furthermore, the political nature of the Commission may also have an influence on the programme management. Indeed, this institution is particularly sensitive to the broader political context of the European Union. While the political momentum of Galileo has largely worn down, it is difficult to protect the programme from reallocations of human resources to issues considered more pressing (Brexit, migrant crisis, etc.). So far, the European Commission has managed to preserve the staff resources granted to the programme, but has not significantly increased them for the exploitation phase (see Annex A.5). The Commission is also more exposed to public opinion and to the risk image carried by the programme and this can slow down or misdirect the decision making process. On the one hand, it can lead to an exaggerated aversion to the most publicly perceived risks – legal and budgetary. On the other hand, some decisions that should be based on purely technical considerations – for instance, the launch of satellites or the location of the GSA facilities – might be also influenced by political considerations.

The dilution of responsibilities within the EU framework, the competing views of some member states, and the focus on the most immediate issues due to limited staff resources, until recently has hampered the development

[68] European Parliament and Council of the European Union. Regulation (EU, Euratom) N° 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union and repealing Council Regulation N° 1605/2002. Brussels: European Union.
[69] European Commission. Commission delegated regulation (EU) N° 1271/2013 of 30 September 2013 on the framework financial regulation for the bodies referred to in Article 208 of Regulation (EU, Euratom) N° 966/2012 of the European Parliament and of the Council. Brussels: European Union.
[70] European GNSS Agency. Decision of the Administrative Board adopting the GSA Financial Regulation 2014 of 25 April 2014.
[71] European GNSS Agency. Decision of the Administrative Board adopting the GSA Financial Regulation Implementing rules 2014 of 25 April 2014.
[72] European Commission. *Ibid.* 3-4.
[73] European Court of Auditors. The management of the Galileo programme's development and validation phase. Special Report N° 7/2009. Brussels: European Union. 40.

of a long term programmatic vision. The Court of Auditors identified this issue in 2009, both for EGNOS and Galileo programmes[74,75]. There is a persistent difficulty in clearly defining the features of Galileo services fifteen years after the end of the definition phase: the Commission has not yet adjudicated the disagreement between member states on the applications of the PRS (see 4.3.4), the Safety of Life service has been abandoned because of the lack of interest from the targeted users, and the Commercial Service is suffering from delays (see 4.5.2). This difficulty points out insufficient preliminary thought about the nature and the objectives of the programme. The remaining ambiguity concerning the division of prerogatives between GSOp and the GSA also suggests that the question of the model of exploitation has not fully been settled (see 4.2.3). Last but not least, the late taking of important decisions regarding the exploitation phase, only some weeks before the declaration of initial services (choice for GSOp, working arrangement etc.), and the complexity of the associated transition phase (see 1.4), composed of a superposition of difficult tasks in an unusual sequence (the service provider could change six months after the beginning of the service provision), also reveals a lack of anticipation and planning.

Nevertheless, the Commission, with the degree of latitude it disposes, seems willing to increasingly address these issues as shown in its announcement in the recent Space Strategy for Europe of the release of a radio navigation plan in order to facilitate the introduction of GNSS applications in different sectors[76]. It could multiply the positive economic fallouts expected from Galileo (see 4.5.3). The Commission has also clearly identified the need to start work now on the evolution of the programme. Those decisions show a commitment to the future, which is central for the other stakeholders of Galileo, including the users.

4.1.4 Issues Relevant to the Current Status of the GSA

Given the limitations emanating from the political dimension of the Commission and the rules applying to this institution, the progressive transfer of some of its responsibilities to the GSA, as foreseen by the current GNSS regulation, seems beneficial. Indeed, the GSA, as a distinct agency involved only in the GNSS field, is in theory less subject to broader political pressures. The different contractual structure of agencies also enables hiring staff in more cost-effective ways, facilitating the acquisition of specific competencies. In practice, these expected positive effects need to be confirmed.

First, the mentioned advantages of an agency for such a programme might be hampered by the *de facto* insufficient independence of the GSA. Indeed, the Commission keeps a tight control over the Agency, which limits its autonomy, except for the SAB. Within the Administrative Board, the Commission is the most important player thanks to its right of veto on the main decisions[77]. But its control is even more important through the delegation of prerogatives (see 3.2.3.2), for which the Executive Director of the GSA reports directly to the Commission, rather than to the Administrative Board. It is worth noting that this practice is somehow a drift from the initial provisions, which mention the exceptional character of delegation[78]. While an agency should take advantage of its relative autonomy, competences and awareness of the risks faced by the programme, far from any political influence, the GSA is currently, more than most other decentralized agencies, dependent on the Commission. The need to increase the responsibilities of the GSA is a shared opinion. Therefore, the sequence should ensure that the GSA elaborates its proper awareness of the priorities and risks in order to gain maturity before taking on higher responsibilities. In this respect, the example of EGNOS is enlightening since the Administrative Board is still secondary in this programme: all the issues are primarily discussed within the GNSS Programmes Committee. However, a positive signal in June 2016 was the nomination of Jean-Yves Le Gall a heavyweight in the European space landscape, also France's inter-ministerial coordinator for European satellite navigation programmes, as the chair of the Administrative Board.

In addition, the GSA faces difficulties in acquiring the expertise necessary to successfully carry out its mission, and in particular to manage the exploitation of the system (see 4.2.1). These difficulties have multiple causes, one of them being the geographical location of the

[74] European Court of Auditors. The management of the Galileo programme's development and validation phase. Special Report N° 7/2009. Brussels: European Union. 36.
[75] *Ibid.* 46.
[76] European Commission. Space Strategy for Europe. COM (2016) 705 final of 26 October 2016. Brussels: European Union. 3.
[77] In particular, the approbation of the annual and multiannual work plans of the GSA requires the vote of the Commission representatives. See article 5 paragraph 7 of the GSA regulation for more information.
[78] See Article 8 of the Decision of the Administrative Board adopting the GSA Financial Regulation 2014 of 25 April 2014.

GSA headquarters in Prague[79]. Another one is the steep slope in the building up of the required staff and competencies: exploiting an infrastructure like Galileo is a new activity for both the Commission and the GSA. The headcount of the GSA for the period 2014-2020, planned in accordance with the current GNSS regulation, was made following an external consultancy for the Commission in 2013, but what was found to be necessary has not been granted to the GSA finally. The workforce plan has not been significantly updated to meet actual needs. As a consequence, in order to meet its responsibilities, the Agency substantially relies on outsourcing, which already amounts to more than 30% of the staff, and eventually costs far more (this point is developed in 4.2.1). Partially because of the difficulty of gathering competencies, the ESA must support GSA for the next years, as part of the working arrangement (see 3.2.4.3). Aware of these risks, the GSA should ask the Parliament and the Council for more resources at the beginning of 2017.

Last, the GSA has not yet settled into a stabilized mode of functioning conducive to the management of operations. This task is particularly challenging given the evolving and heterogeneous portfolio of prerogatives of the GSA, with tasks as different as exploitation management, market development and security accreditation. Therefore, immediate attention should be paid to the capacity of the GSA to acquire quickly the expertise needed to successfully ensure the shift toward exploitation, while carrying out the full spectrum of its activities with all the necessary very different competencies[80]. Moreover, the late negotiation of the working arrangement and contract relating to the interfaces with ESA and GSOp (see in 4.2.3) might be a factor of instability. As a matter of fact, its content, the prerogatives demarcation with GSOp and the extent of the involvement of ESA in the activities of the GSA strongly condition its needs. At the same time, the accumulation of different delegation and working arrangements (for EGNOS, for the different phases of Galileo, etc.) may lead to further complexity.

4.1.5 The Uneven Interests of Member States

In theory, member states have a major influence on the programme (see 3.2.5.2). Yet, their effective influence is difficult to assess for different reasons.

First, the multiple channels indeed give them multiple entry points, but the positions they take are not necessarily consistent within the different institutions. Second, their interests, engagement and organization regarding the programme strongly differ: some member states are more interested in the industrial benefits of the programme, others in its management or in the security aspects. They do not share the same views on the perimeter of uses of Galileo services, especially regarding military uses as well as the definition of some services. Last, they have more or less held back from programme management since it is funded through the EU. In practice, they have made little use of the examining power they are provided by the regulations of the European GNSS Programme Committee. In particular, they have never challenged the current ratio of power between the institutions, and in particular the dependency of the GSA. One of the main roles remaining in their hands through the Council of the European Union is the definition of the MFF, which provides Galileo with funding for a five-year period. However, the associated trade offs involve dramatic amounts of money, and Galileo is just a very small part of them: therefore, this framework is not appropriate for detailed discussions regarding the programme.

Finally, the area where the member states are still strongly influential is security, since they still have not formally entrusted the European institutions in this matter, keeping with them most of the associated prerogatives. Here as well though, progress is being made, especially regarding the GSA.

The Member States may re-engage on the renewal of the political momentum for Galileo associated with the declaration of initial services.

4.2 Exploitation

The transversal issues discussed in Chapter 4.1 – particularly those concerning the GSA that will undertake the exploitation of the system – have specific impacts on the exploitation of Galileo.

[79] Indeed, most of the European specialists in the GNSS field come from Western Europe, and it is thus necessary to bring this expertise in Czech Republic. Yet, the European regulation provides for the application of a correction coefficient to the remuneration of European expatriate officials, based on the local prices (see <http://ec.europa.eu/eurostat/web/civil-servants-remuneration/correction-coefficients> for more information). The resulting wages are relatively low and thus non-competitive in comparison with the ones in ESA or in the industry.

[80] The GSA has been entrusted with the exploitation in 2013, with the GNSS regulation. The GSA Work Programme 2016 mentions explicitly the difficulty for operational departments to acquire new and specific competencies.

4.2.1 Influence of Resources Limitations on Exploitation

As compared to the resources granted in the GPS programme, the GSA works on a tight budget. Indeed, for the 2014-2020 period, Galileo deployment and exploitation is funded with around € 5 billion. In comparison, the budget granted to the GPS during the 2014-2017 period amounts to about US$ 4 billion[81].

This issue is even more burning when it comes to human resources: the difficulty that the GSA has in gathering the expertise as described in 4.1.4 is of special concern regarding exploitation. Indeed, there is no doubt that the Agency shows good will to meet this imminent responsibility, and has learned a lot from the exploitation of EGNOS. However, Galileo is a far more complex system and its exploitation requires significantly higher technical and organisational skills. Indeed, the GSA, being in charge of the exploitation of an operational space system on a 24/7 basis, will carry out activities of a very different nature than any other decentralised agency.

Furthermore, the total headcount of the Agency needs to be considered from a quantitative standpoint. As described in 4.1.4, the headcount has not been tailored to meet the requirements for each task and especially for exploitation. The date of its beginning has slipped since 2013, but the yearly authorised GSA manpower has not been significantly updated (see Annex A.5). As a consequence, while exploitation started to be transferred to the GSA in January 2017, the total staff has already mainly been consolidated, and should not significantly increase to support this new activity. This gap between the progress of the programme and the resources granted, which is pointed out in the GSA Work Programme for the year 2016[82], may exert a strong pressure on the current staff, leading to further risks.

To bridge this shortage of manpower, GSA is contracting with external consultants and internally redeploying in-house staff from administrative tasks to operational activities[83]. However, this large resort to outsourcing – 35 consultants and 4 seconded national experts, while the exploitation of Galileo involves 43 in-house agents – entails three main issues: it is not adapted to steering the large contract with GSOp, it is far more costly, and it prevents the GSA from building and keeping the internal expertise needed to fulfil its tasks in the long run and consolidate its position within the GNSS governance.

4.2.2 Complexity of the Exploitation Scheme

Like the programme as a whole, the organisational structure set up to undertake the exploitation of Galileo is based on a complex scheme involving many actors. As described above, the GSA is still under the tight control of the Commission, and the latter is *de facto* involved in system exploitation. The outsourcing of exploitation introduces another actor[84], while the Galileo Reference Centre, which monitors the system's performances in parallel to the KPI supervision, is also outsourced and adds a further layer. Last, ESA is also involved in exploitation since it provides important technical support to the GSA for this mission (see 3.2.4.3).

In the longer term, the provision of more services will bring additional actors. Indeed, the SAR is provided by the CNES, and the Commercial Service should also introduce a specific service provider. The PRS will be based on a decentralised model, including national authorities providing the service to their users. Though related activities will be channelled through the GSA, all those actors will add further complexity to the exploitation of the system.

Similar to programme management at large, this succession of layers is likely to dilute the responsibility for exploitation and might be detrimental to the quality of the services delivered. In particular, a failure could lead to aggravated damages if vigorous and quick actions cannot solve the issue. Even before the declaration of initial services, while operations-related issues and the exploitation scheme were far simpler (only ESA and a private operator involved, no services provided) there were some difficulties in identifying the causes of problems and solving them by contracting with industry. Moreover, this blurred scheme hinders confidence building in the system.

4.2.3 Issues Related to the Relationship with ESA and GSOp

Until 2020, the GSA will have to manage both the deployment of the system and its exploitation, two tasks that will be carried out by two actors: ESA is entrusted with the deployment of Galileo, and GSOp will operate the system.

[81] "Program Funding." Global Positioning System 19 December 2016 <http://www.gps.gov/policy/funding/>.

[82] European GNSS Agency. 44th meeting of the Administrative Board - Annual Work Programme 2016 of 10 March 2016. 63.

[83] *Ibid*. 64.

[84] It should be noted that given the resources provided to the GSA, outsourcing was the only way to carry out the exploitation.

Those two activities – and thus the associated entities – might conflict. While ESA intends to update the system and realise the related tests, the operator favours its stability. The GSA will thus require a deep understanding of the system from a technical point of view in order to make the appropriate arbitration between two entities endowed with strong technical competences. Besides this issue, the separate, complex interfaces with each actor also raise specific questions.

The relationship between the GSA and ESA is going through an important evolution as part of the change in the governance scheme occurring with the beginning of the exploitation phase. This new relationship is defined by a working agreement that was signed on 15 December 2016 (see 3.2.4.3). This important agreement was announced for 2015, but the negotiations, especially complex and resource-consuming, lasted far longer than expected and were finalized only some days before the beginning of the handover. However, the two parties reached an agreement that seems to offer a satisfying base for the exploitation phase – though it still needs to be confirmed in practice. This interface is indeed complex (see 3.2.4.3) and the agencies will have to develop trustworthy collaboration to implement the arrangement in the best manner.

There are also some lingering uncertainties regarding the interface between the GSA and GSOp. To begin with, contract ambiguities seem to remain about the delineation of their respective prerogatives, especially regarding services provisions. Indeed, the tender states that GSOp will operate the GSC – which is the user interface, but assigns the service provision to the GSA. Therefore, there may not be a clear role separation between the operator dealing with the "back office" – the operations – and the GSA in charge of the front office – the user interface. This complex delineation of tasks also concerns the decision making process: for instance, the responsibility for taking an important decision, such as using a spare satellite, seems unclear. The management of operations through Key Performance Indicators (KPI), though complemented by direct monitoring within the GRC, may also be a source of questioning. Those indicators are not yet stable since it is difficult for the moment to define reference values. Since the KPI are not defined in the unclassified tender documentation, one can also wonder whether their nature is definite and, in particular, if they help in fully defining the "make or buy" limit between the GSA and GSOp[85]. This could mean that this border will be clarified following a "bottom-up approach" by the skills and the initiatives of the operator, while it should be decided by the programme management. Here as well, the unclear demarcation of prerogatives may reflect an incomplete programmatic vision and/or insufficient resources within the Agency.

In the current situation, it seems challenging to entrust an entity with the full responsibility for service provision and the exploitation of the system. GSOp operates, but all the facilities and the constellation are provided by the GSA. The latter has the mandate to be in charge of exploitation, but has not the technical competencies to alone assume end-to-end responsibility. Such expertise is partially present in ESA, which is expected to hold back from programme management. The Commission has an overall responsibility, but is far from the day-to-day exploitation. Therefore, it is difficult to identify, at this time, an undisputed, fully competent entity assuming the role of "Mr Performance" for Galileo. The absence of such an incarnation, as well as of any other means for guaranteeing the systems' performances could compromise the achievement of the programme objectives, especially regarding the spread of its uses (see 4.5.1).

4.3 Security

4.3.1 Influence of the Complexity of the Governance Scheme on Security Management

As described in Chapter 4.1.1, the number of involved actors is a clear factor of complexity. But in the field of security, insufficient trust between them makes the issue even thornier. In particular, member states are not yet ready to fully entrust the Commission when it comes to this subject – and do not necessarily trust each other. Unlike other aspects of the programme, they keep for themselves a number of prerogatives in security, as evidenced by the functioning of the Security Accreditation Board for instance. The positioning of the member states, their differences of opinion, and sometimes, their lack of consistence and constancy in the different institutions they are involved in, make governance of the security aspects especially complex.

In the absence of an appropriate pre-existing structure within the EU in charge of security, the prerogatives have been distributed between different actors: the Commission, the GSA, ESA, EEAS, etc. (see 3.2.3 and 3.2.5).

[85] European GNSS Agency. "Galileo Service Operator" Tender Information Package. GSA/CD/14/14 of 24 December 2014. Prague: European Union.

Beside the potential redundancies this induces, it might be counterproductive to have so many actors in this domain (leaks, responsibility dilution etc.). Actually, the programme should ideally be supported by central management of security related issues. Currently, the GNSS regulation provides the Commission with the overall responsibility for security; however, it has neither the culture nor the competencies to deal with those issues in detail. And even if the Commission can gather such expertise within working groups (see 3.2.3.1) that support its actions, potential conflicts of interests remain: leaving the command of security to the political level is not compatible with effectiveness of operations. In the same way, ESA also does not have strong security culture since none of its programmes can compare to Galileo in this matter. The GSA does not seem ready to assume such a responsibility for the moment: though clear progress has been observed recently, it still requires more competencies, independence and staff to consolidate its position in this field (see 4.3.3).

This complexity leads to confusion on various specific issues. One of the most significant is the status of the validation chain– where upgrades are tested before their implementation in the system. Indeed, though the status of the operational chain is clear – it is owned by the Commission, and has been accredited by the SAB, the ownership of the validation chain is still subject to debate, and not accredited. This function should be clarified, since all security is to be moved to the operational chain, later in the programme.

4.3.2 A Misperception of Security Issues

For Galileo, the security-related issues arise in a very different way from other GNSS. This comes from the civilian nature of the programme, but also from the essence of the EU, since security still mainly pertains to the member states. And within the EU, the Common Security and Defence Policy is the domain of the European Council and of the High Representative. The Commission and its agencies are thus purely civilian institutions, as well as ESA. Though the nature of those is consistent with the civilian purposes of the system, this has impacted on the security culture within the programme and thus has given way to a misperception of these issues for Galileo.

Indeed, security management has long been associated with the military, which is certainly an erroneous view (see 2.1.3). There is, on the contrary, a specific difficulty for Galileo: the programme has to ensure a level of security similar to military GNSS providers, while complying with civilian rules and procedures in a variety of domains (communication, procurement, etc.).

Thus, this dimension has been strongly underestimated since the beginning of the programme. The fact that Galileo will not be a R&D project anymore in early 2017 and that as soon as the operations start, it might be under attack, has long been neglected. An analogy can be made with the Internet: in its early years, nobody could imagine the potential for attacks while nowadays, cyber security is omnipresent[86]. The increasing criticality of GNSS should indicate that a similar phenomenon could happen for those systems, and in fact is happening today. This misperception explains why security was not included *ex ante* in the programme management. Thus, rather than a set of conditions to ensure from the outset in order to enable the programme, leading to cost-effective and proportionate decisions, security requirements have been perceived as undesirable, secondary constraints adding technical difficulties and thus often postponed, or lately introduced upon request of a member state. This untimely full awareness of security issues is also amplified by an exogenous cause, which is its inherent complexity (see 2.1.3): threats evolve very quickly, requiring the ability to deal with new risks during the development of the system[87]. The limited resources and the necessity of moving the programme forward to make up for wasted time has also prevented properly addressing these issues[88].

This is a concrete drawback on the programme: not being tackled fully and promptly, security entails sometimes dramatic cost overruns and delays: for instance, numerous security requirements now specified by the SSRS[89] were not foreseen when ESA contracted Galileo's elements, and those security requirements were simply not included. This current difficulty to promptly account for security has been present since the beginning of the programme, and was already mentioned by the Court of Auditors in 2009[90]. However, it would be unfair to consider that this problem is only

[86] Gutieriez, Peter."At ENC 2014: A GNSS Wake Up Call for Europe." Inside GNSS 16 April 2014.

[87] The change of opinion of the United States regarding Galileo illustrates this irreducible issue: while they initially opposed to its development, the U.S. later understood that a second GNSS was an opportunity to get an overall enhanced robustness when they became more aware of the security risks.

[88] Gutieriez, Peter."At ENC 2014: A GNSS Wake Up Call for Europe." Inside GNSS 16 April 2014.

[89] SRSS: System-specific Security Requirements Statement.

[90] European Court of Auditors. The management of the Galileo programme's development and validation phase. Special Report N° 7/2009. Brussels: European Union. 27.

linked to the governance of Galileo: GPS is currently suffering the same kinds of issues with the deployment of the OCX[91], but it is for sure accentuated by the lack of anticipation mentioned in 4.1.3, and the inexperience of the involved institutions in comparison with those in charge of the other GNSS.

4.3.3 Some Innovative but Incomplete Solutions

Galileo is the first programme handled at the Community level with such a strong security dimension. It has required the establishment of new structures able to cope with those issues. This has led to innovative solutions – that could be reused in future programmes – but which could be improved in order to maximize their benefits.

Indeed, the GSA has managed to develop some know-how in security and it is a better fitted actor than the Commission in this matter. While this culture is not spread across the Agency, the GMSC has acquired key expertise in this field, with, in particular, a valuable understanding of the associated challenges. The scheme set up for the PRS (see 3.2.3.2) is also a notable compromise, given the initial difficulties. But here too, the problems related to staff consolidation identified in 4.1.4 appear as a limitation.

The Security Accreditation Board is also a new, innovative instrument aimed at tackling a new kind of issue within the European Union, allowing the member states to play a key role in security safeguards in programme management. Yet, the current configuration is somewhat flawed by its belonging to the GSA. This does not respect a wise principle of power separation: the accreditation should not be done by the operator. Admittedly, the GSA regulation provides for the clear independence of the SAB regarding the decision making process, but there are still concerns related to the *de facto* dependence of the SAB on the resources provided by the Executive Director. This is another example of the influence of programme history on the present configuration: the accreditation within the GSA was relevant when the Agency was the European GNSS Supervisory Authority, whose mission was to manage the public interests in the PPP. This also illustrates the risks potentially incurred from inadequate human resources: as a matter of fact, the SAB staff is part of the same security department as the rest of the GSA security teams in order to prevent knowledge isolation. So far, such a configuration has not led to significant issues. But until the end of 2016 the GSA had had no operational role, since the exploitation of the constellation was done by ESA. According to the working arrangement, after a transition period, the GSA will have to submit the accreditation application to the SAB during the exploitation phase. This decision may raise a risk of conflict of interests regarding security accreditation[92].

In its decision 2014/496, the Council also created specific procedures to react should issues caused by international events affect the exploitation of Galileo and necessitate the giving of orders to the GSA. This procedure is especially innovative as it allows the Council or the HR to direct orders to an agency under Commission control, and in general, endows the HR and the EEAS with large responsibilities in such a situation (see 3.2.5.3). It also confirms the anchoring of the security aspects at the intergovernmental level, since the appropriate decision is taken or confirmed by the Council, with the Commission having a minimal role. This illustrates the difficulty of tackling security issues in the current EU frame. This procedure is also delicate as in some cases – responding to the request of an ally to deny the use of Galileo to a hostile entity for instance – the decision ought to be taken quickly, and could imply a huge political risk, for the HR in particular. This is why everything should be done to simplify and automate the decision-making process with, especially, the establishment of all the relevant communications lines and the appropriate organization of all the actors (including the member states). It is noteworthy that such an important decision was made in 2014 (the 2004 Joint Action did not define a specific procedure) and that progress in implementing it has been relatively slow. In particular, some member states have shown little interest or even difficulty in organizing themselves appropriately and some important protected communication lines were not set up until recently.

4.3.4 The Specific Case of the PRS

Security issues are especially critical for the PRS, which is the most complex service provided by Galileo and the "crown jewel" of the system. Though interesting solutions have been found to manage this service while respecting the interests of each Member State with the setting up of CPA and the agreement on CMS (see 3.2.5.1), fundamental issues have still not been solved, especially the definitive purposes of this service. While some member states would like to allow military uses, others consider that this system has a

[91] Gutierrez, Peter. "GAO: New GPS Ground System, Not GPS III Engineering, Primary Cause for Delays." Inside GNSS 30 November 2016.

[92] This kind of conflicts of interests exists in some other programmes, like WAAS. However, Galileo is a far more complex and critical system.

commercial potential, and their positions are sometimes inconsistent or changing. This is a major concern because, should the system be used for military purposes – and in particular for missile guidance – it would introduce new, important security constraints. Furthermore, it is illusory to think that the PRS can be seen as standing on its own: the security issues it generates reverberate on other services. Thus, if such a decision were made, the programme would necessarily have to adapt. The fact that this issue has not been solved yet is critical and is a consequence of the difficulty of making definitive, strategic decisions at the beginning of the programme: such issues must be settled quickly, since Galileo needs stability now, with the declaration of initial services.

In any case, member states seem to be increasingly interested in this service, and they themselves recently broke the taboo of the military dimension of Galileo mandating the EDA to work on the definition of the future military needs for GNSS, especially Galileo. Accordingly, in mid-2016 the EDA created a dedicated European Military Satellite Navigation Policy working group. The use of Galileo is envisaged as part of the multi constellation solution, together with GPS. But here as well, if the decision to use this system for military purposes is taken, it should be as part of a larger defence plan in Europe, and not only as an interesting and powerful technical system. The complex chain of command also concerns the military: there are fewer concerns with the clear, apparently more manageable chain of command of the GPS, while private exploitation could also raise other concerns. This complexity may not be sufficiently conducive for international cooperation: the U.S. seems not interested in using PRS for highly sensitive applications, for instance. Galileo should thus demonstrate its security reliability if such applications are intended to be tackled.

4.4 International Relations

As global systems, the GNSS exploitation necessarily compels international relations, above all with other GNSS providers (Annex A.1). Thus far, the efficiency of "Galileo diplomacy" has proven to be limited. The 2004 agreement with the U.S. was certainly an important move, as it provided Galileo with advantageous conditions to become the second most important GNSS, highly interoperable with GPS – a place that has since been challenged by BeiDou. But the Europeans did not manage to solve the issue of the PRS frequencies overlay with China, while the U.S. quickly settled their problems with Beijing, reaching an agreement in 2010 and formally beginning cooperation with a Joint Statement in 2014 setting up discussions in the fields of compatibility and interoperability notably[93]. Last, the issue raised by the "UK surprise patent"[94] on a key GPS/Galileo technology that could have limited the uses of the services coming from both signals, was quickly resolved by the U.S. as it came to an agreement with the UK in January 2013[95]. The European Union reacted less strongly and managed to resolve the issue only in April 2016[96].

This apparently less effective European "GNSS diplomacy" has different causes. The first is probably the lack of a "single desk" – another consequence of the complexity of the governance of Galileo within the EU framework – that makes difficult both the achievement of a common position and the clear expression of it. Indeed, several institutions have the legitimacy to play a role in this domain. The Commission is the programme manager, the Council is endowed with important prerogatives in this field (see 3.2.5.2), member states have important expertise, the EEAS is the "diplomacy service" of the EU, ESA has the technical competencies, and the GSA will be in charge of exploiting the system. In the current compromise, though the Commission is supposed to have leadership as mandated by the Council and supported by the other institutions, the European delegations appear to be less organized and efficient than their counterparts. As an example, the ICG includes representatives from some of the different European institutions mentioned above, totalling far fewer members than others and without real coordination between them.

Furthermore, the discussions taking place in those international relations can be highly technical: for instance, for compatibility issues, it is necessary to be able to demonstrate the effects of a specific position on the spectrum. But few ESA experts are present, and the GSA is not even associated with the inter-

[93] "Joint Statement U.S.–China Civil Global Navigation Satellite Systems (GNSS) Cooperation."19 May 2014. Global Positioning System 19 December 2016 <http://www.gps.gov/policy/cooperation/china/2014-joint-statement/>.

[94] In 2012, the British military claimed a patent that could harm Galileo and GPS marketing development, since the manufacturers could have been forced to pay royalties, and endangered the EU-U.S. agreement. For more information, see Davis, Dee Ann. "British Military Claims Patent on GPS, Galileo Civil Signal Structure" Inside GNSS 27 April 2012.

[95] Divis, Dee Ann. "UK/U.S. Deal on GPS Signal Patent Omits Galileo Version." Inside GNSS 31 January 2013.

[96] Inside GNSS. "EU, UK Resolve Galileo Signal Patent Dispute." Inside GNSS 15 April 2016.

national negotiations, weakening the European position. Security is also an important factor of credibility[97]. Additionally, the other GNSS providers, operating military systems, take advantage of the support of their ministry of defence. One can hardly identify such strong support on the European side. Besides, this lack of political weight is also illustrated by the difficulty of defend Galileo in European spectrum regulatory authorities – like the CEPT or ETSI, which also undermines the European position[98,99]. Both those technical competencies and this apparent lack of political support can give the impression to international partners that they do not have a credible and legitimate interlocutor facing them.

In fact, despite the repeated commitment of the Galileo stakeholders to develop the system globally, it seems that the international relations concerning Galileo are hindered by the lack of an ambitious long-term vision. The Europeans seem to focus mostly on the deployment and the exploitation of Galileo, taking the international outreach of the programme for granted, without really considering the progress made by other actors in this field. For instance, BeiDou has increasingly gained credibility on the international scene, China gives itself the means to fulfil its ambitions with important, highly coordinated and technically skilled delegations allowing them to talk on an equal footing with the U.S.

4.5 Commercial Development, Uses Spread and Innovation

Since the beginning, the economic and commercial dimensions of the programme, as well as its repercussions in terms of innovation and growth have been regarded as the main objective of Galileo, together with sovereignty and independence objectives[100]. In spite some of Galileo's competitive edges, the current governance also presents issues that mitigate these advantages, which seems to contradict the declared goals.

4.5.1 Lack of a Standardized Input Structure for Galileo Users

In terms of performance, for most applications, the main criterion that influences the choice to use a particular GNSS is trust in its continuity of service. From this point of view, guaranteeing satisfactory conditions of exploitation and security, as discussed above, is a necessary condition to ensure the spread of the uses of Galileo.

But it also depends on the capacity of the GNSS provider to clearly understand the specific technical needs of each community of users, including the difficulty arising from their diversity (see Annex A.2). Meeting all these requirements to a high degree thus necessitates a constant, long term connection with all those actors, in order to design the system and its services accordingly, and to adapt them during their exploitation. In other terms, the communities of users want to have the possibility to influence the technological trade-offs of the programme, which requires the programme to be organised accordingly. For the development of the first generation, this was not the case: the Court of Auditors estimated that the technical specifications of the system did not take sufficiently into account users' needs, and the recent Commission communication "Space Strategy for Europe", considers that the development of the second generation should be more user-driven[101,102]. The abandonment of the "Safety-of-Life Service", which did not meet aviation requirements even though it mainly targeted this community, demonstrates that, at least during the definition phase, the programme was weakened by its relative isolation from the GNSS community of users.

The current GNSS regulation still does not provide a clear solution to dealing with this issue; in particular, the prerogatives distribution remains somehow confusing. Indeed, on the one hand, the promotion of uses involves the Commission, in particular when there is a need to create a regulatory framework or when this activity implies international agreements. On the other hand, the GSA is the formal interface with users, accompanying member states as they develop applications and standards. Although the Agency has undertaken important

[97] De Selding, Peter B. "U.S., Norwegian Paths to Encrypted Galileo Service Open in 2016." Space News 18 December 2015.
[98] However, it should be noted that the U.S. GPS faces an analogous issue with the FCC.
[99] Davis, Dee Ann and Gutierrez, Peter. "Move to Allow GNSS-Interfering Pseudolites Emerges in Europe" Inside GNSS 15 September 2014.
[100] Kinnock, Neil. European Strategy for GNSS. SPEECH/98/210 of 20 Oct. 1998. Toulouse, France. <http://europa.eu/rapid/press-release_SPEECH-98-210_en.htm>.
[101] European Commission. Space Strategy for Europe. COM (2016) 705 final of 26 October 2016. Brussels: European Union. 5.
[102] European Court of Auditors. The management of the Galileo programme's development and validation phase. Special Report N° 7/2009. Brussels: European Union. 29.

endeavours in this field and has acquired a significant level of competency, resulting in a progressive increase in its role, it is currently not yet sufficiently geared for really proactive campaigns. Moreover, there is no formal and generic structure to allow the different European or national communities to provide inputs to the governance since countries organise themselves when they want. This means that communities of users are unevenly represented, depending in particular on the degree of organization of their country regarding Galileo. There is, for instance, inter-ministerial coordination in France aggregating the requirements of institutional users and providing them to the GSA: this scheme seems to satisfy the communities of users involved, but most of other countries do not have this kind of coordination. This lack of a formal structure providing an entry point to users encouraged ESA to create a forum for aviation in order to gather their specific requirements, the GSA being involved on its part too. A normal situation would be to have such prerogatives, as much as possible, in the hands of the GSA.

A further distinction should be made for the promotion of the uses of Galileo, since the approach strongly depends on whether this is an unregulated or a regulated application. In the first case, the most important feature is to be well connected to receivers' manufacturers and applications developers, especially sensitive to the need of consumers in competitive, non-regulated markets.

This is significantly different for regulated applications. Here, the main issue is to comply with the standards established as part of the regulation. There is thus necessarily a process of certification, which is complex, and the aim is not just to meet the user requirements, but most importantly to demonstrate that those requirements are met with a sufficient level of trust. On this point, the current governance scheme of Galileo does not envisage a single entity fully accountable for the performances of the system. Furthermore, no entity external to the chain of exploitation, technically competent and independent from the programme management, is entitled to assess and validate the performances delivered, as is the case for other critical operational systems: EASA for EGNOS or planes, safety authorities for nuclear power plants etc. The GRC monitors the performances of the system – which is one essential aspect of the issue – but is not independent. Actually, performance validation should have been undertaken since the definition of the system's technical specifications and the inception of the development phase. Failing such involvement, external entities certifying the system for specific applications would in the end mostly rely on the political commitment of the Commission on performance. Given the liability issue associated with such a certification (an entity certifying the system becomes partially liable), the potential use of Galileo for the highest safety critical applications remains to be seen.

4.5.2 Commercial Service and Liability Issues

The service that most embodies the commercial ambitions of Galileo is the Commercial service. Notwithstanding, this service has suffered from important delays: the CS was expected in 2015 but it was not part of the initial services and is now expected in its first version by 2018[103,104]. A vision shared by the member states of what it should be is emerging – a high accuracy and authenticated service (the latter by 2020), but its definition could change again, and this will have technical repercussions. The decision to provide such a service is a risky bet that no other GNSS providers have taken: they are all based on the dichotomy of free service/military encrypted service. Delivering such a service also removes from the private sector the possibility of providing added value to the open service. So far, it seems that the GSA has not yet found a service provider to deliver it. One may also wonder whether these features, on the eve of the rise of a multi-constellation world, will still offer undisputed competitive advantage.

One of the advantages of the Commercial service, together with a reason for its complexity, is the existence of multiple liability issues that arise from the contractual relations along the service chain. There is no international legal instrument governing liability, and the other GNSS providers seem to have avoided getting involved in such issues. At the European level, the need to establish a relevant framework has long been identified (the collapse of the PPP model is largely due to the lack of such a liability scheme) but the most recent GNSS regulation still does not provide for it. The liability of the Commission and the GSA is thus regulated under the general provisions of Article 340 and through the contract with GSOp. The regime of EGNOS seems well defined (the operator takes out insurance and is liable up to a certain ceiling, followed by the GSA and then the Commission) and would probably apply to Galileo. In any case, the success of the Com-

[103] Gutierrez, Peter. "Galileo Themes, Threads and Visions." Inside GNSS January 2016.

[104] Godet, Jérémie. "Galileo Initial Services." Presentation. GALILEO: Dawn of a New Age of GNSS Service. Webinar online. 19 December 2016.

mercial Service will partially depend on the implementation of a clear and specific liability framework.

4.5.3 Issues Related to the Indirect Benefits of Galileo

Lastly, indirect benefits expected from the programme, both regarding economic fallouts and innovation stimulation should not be underestimated. Chief among them is the potential withdrawal of ground-based stations for aviation and maritime beacons, which are costly and irreplaceable infrastructure at the moment. With the generalized use of Galileo, as part of a multi-constellation or not, one can expect that at some point, an only-GNSS-based-approach will ensure sufficient robustness and continuity of service to allow the removal of other redundant PNT systems for specific applications. This is a real potentiality that brings important economic benefits to the programme. However, this milestone does not seem to be currently in the scope of the programme management. This would require both an approach based on the extent of use of Galileo for the relevant applications, and the development of a broader European PNT policy identifying GNSS positioning within the general European and Member States radio navigation architecture, and taking full advantage of the redundancies and synergies with other GNSS. In that sense, the announced release of a radio navigation plan by the Commission in its last communication is an encouraging sign. The U.S. and Russia already have such instruments (respectively with the Federal Radio Navigation Plan and the GLONASS Federal Programme 2012-2020) and this broader view allows them to proactively foster the use of their GNSS in to maximize these kinds of direct or indirect benefits.

Among the other issues, a more transverse approach within the Commission between DG GROW and the other DGs (in particular DG MOVE) should be encouraged. A working group has been established for this purpose, which has not yet proven to provide fruitful coordination. Last, the IPR policy applicable to the programme, which consists in giving the intellectual property of the elements produced to the Commission – as is provided for in the current GNSS regulation – might not be the best way to stimulate innovation.

4.6 Evolution of the Programme

There is a clear awareness that the evolution of the programme should be prepared upstream, even if the first constellation is not yet fully deployed. As mentioned above, the Commission also considers that this evolution should follow a more user-based approach than in the first generation (see 4.5.1). The Commission has already set up a working group that strongly engages member states in the preparation of the next generation. However, the GSA, which developed a valuable knowledge of the market, acquired growing technical skills and is constantly in touch with GSOp, as well as ESA, which owns most of the related expertise, are only observers in this working group. The Commission is also preparing the revision of the GNSS regulation accordingly, together with a funding envelope for the next MFF.

The limited human resources have an influence on this question as well: the development of a new Galileo generation should be embedded in a programmatic vision that still has to be deepened (see 4.1.3). Currently, with all the short-term issues that still need to be addressed, the programme management has "its head to the grindstone", rending difficult the allocation of resources and competencies to longer-term issues. As in the case of market development, the setting up of an appropriate structure taking into account the needs of users will have a major impact on the effectiveness of the technical choices that will be made as part of evolution planning.

Last, some ambiguities remain. Concerning funding, the GNSS regulation provides that the future generation will be funded by the budgetary line of the exploitation phase. The same regulation also states that the Commission mandates ESA through the H2020 programme, but only for the preparatory phase. After that, this evolution should be the responsibility of the GSA: staying with the current regime seems to be somewhat contrary to the regulation, and the working arrangement will not clarify it since its priorities are rather focused on the end of the deployment and the implementation of FOC 2. Yet, the GSA currently seems undersized to take over such a responsibility, though this last consideration will also depend on the definitive scheme of interactions with GSOp and ESA (see 4.2.3) that is to be implemented.

5. Towards an Optimisation of the Governance Scheme for Galileo

The preparatory works for the next GNSS regulation will begin in 2017, and this gives the member states an opportunity to consider new governance schemes for the Galileo programme. In this perspective, but also in order to explore longer term possibilities, we make some propositions for concrete governance changes that could facilitate solving efficiently the issues identified in Chapter 4. Though many of them are related to, or are the consequences of, broader challenges regarding the European space sector and its actors, we intend to provide only programme-level proposals. For this purpose, three alternative governance schemes are considered, mainly based on the variation of the positioning of GSA within the organizational architecture. Scenario scheme 1 is the most conservative, while scenario schemes 2 and 3 would require more political will as they assume deeper changes in the governance structure, but they could also provide more significant improvements.

It should be noted that the possibility of having ESA exploiting the system – as was the case until the initiation of the handover to the GSA – has been ruled out. It was considered at the beginning of the programme – before the PPP model was chosen – and did have some merits. ESA, which defined, developed, and deployed Galileo and was provisionally in charge of its exploitation before the declaration of services, has thorough system expertise. Not being in charge of the exploitation, the GSA could have been brought back in the role of GNSS Supervisory Authority it was initially designed for. However, such a scheme is no longer politically viable considering today's state of play of the different European stakeholders involved in GNSS. In particular, exploitation and service provision are not part of ESA historical missions, and the evolution of the Agency demonstrates its desire to stick to its traditional research and development activities[105].

The sole criterion considered for the three scenario schemes is the improvements they can offer to the programme, without any kind of prejudice. However, the relevance of those models of governance also depends on the guidance the member states want to provide to the programme.

5.1 Scenario Scheme 1: Basically Keeping the Governance Scheme Provided by the GNSS Regulation

The first scenario scheme consists naturally in the extension after 2020 of the provisions stipulated in the current GNSS regulation and described in Chapter II of this report. This scheme is unavoidable in the short term, since it started to be implemented from the beginning of 2017. In the long run however, it would be profitable to make adjustments – while staying in the same general framework – to limit as much as possible the risks identified in Chapter 4. Noticeably, the Commission/GSA and ESA/GSA interfaces should be improved in order to ensure better functioning of the GSA.

Indeed, a number of issues identified in this scheme of governance are associated with the weakness of the GSA, both in terms of staffing and insufficient autonomy. As shown in Chapter V, these two questions are strongly interrelated, and mainly result from the fact that most GSA tasks are delegated by the Commission. Therefore, an important adjustment would be to entrust the GSA with those prerogatives as core tasks, enhancing its flexibility regarding human resources management, limiting its dependence on outsourcing, and improving its capacity to recruit the necessary specific expertise. This consolidation could also be supported by a reorganization of its internal means: market development activities could be outsourced in order to concentrate resources on operational activities. This long-term consolidation of in-house expertise would strongly help the Agency to fulfil its missions under the best conditions.

[105] When European states decided to entrust themselves with a satellite meteorology programme, ESA developed the space segment that was then put in the hands of EUMETSAT, an ad-hoc intergovernmental organisation in charge of the operations. In the field of telecommunication, ESA developed and launched the first satellites for Eutelsat, and currently keeps designing space systems for the company.

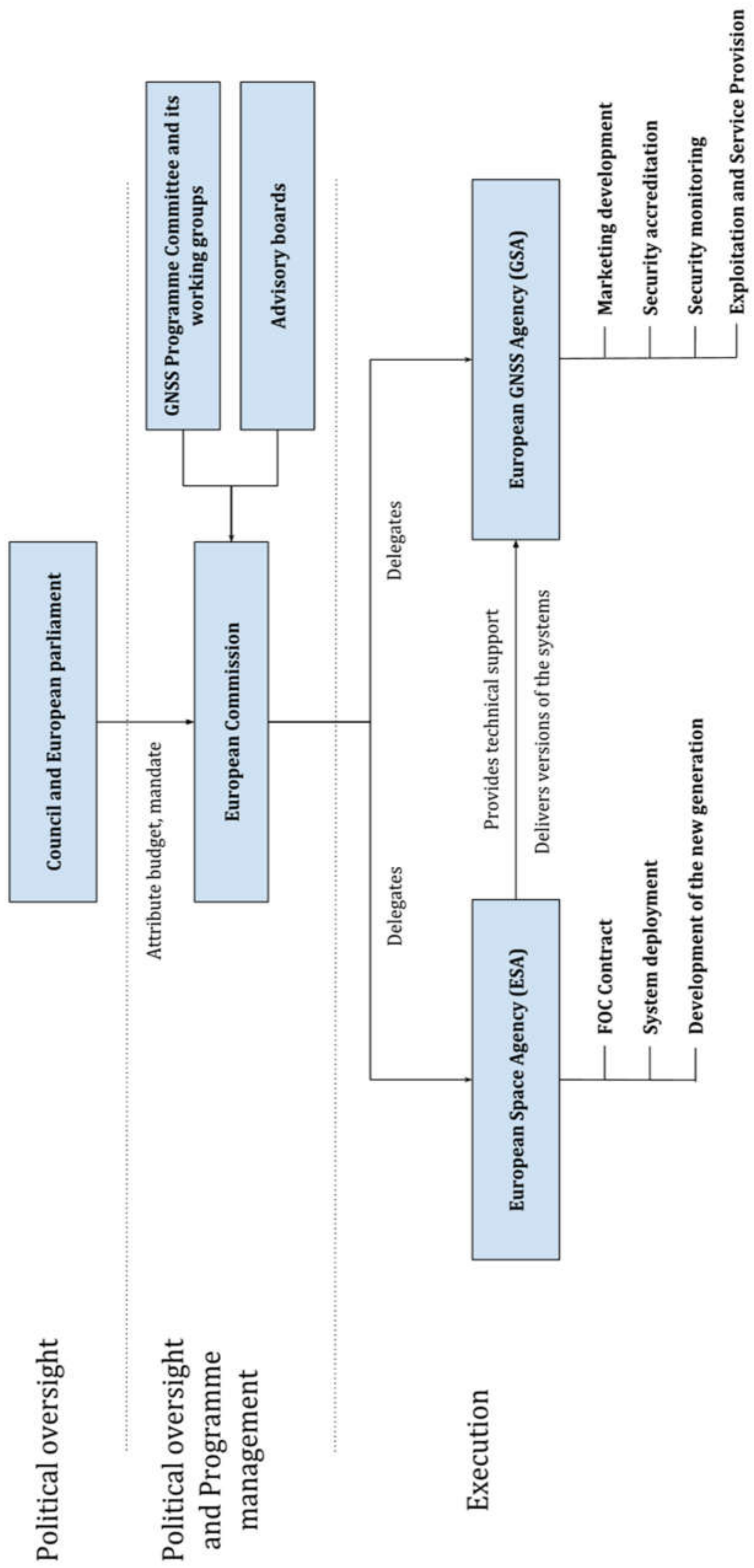

Figure 1: Scenario scheme 1 based on a "Standard GSA"

An indirect consequence would be the rise of the GSA Administrative Board as one of the main governance organs, and the main channel of control of programme management over the GSA. This would greatly simplify the chain-of-responsibility and, through the re-introduction of an intergovernmental dimension within programme governance, it could reinforce the re-engagement of the member states. In parallel, the Commission would keep an important influence on the GSA, thanks to an increase in its representatives and/or votes on this board. Last, increasing GSA autonomy would help protect the programme from the general political issues to which the Commission is sensitive. In addition, such a more relaxed control of the Commission over the GSA would allow the Commission to focus on the definition of high level requirements associated with the development of a strategic vision for the programme, and on the expansion of international activities, notably cooperation with the other GNSS providers.

In parallel, the ESA/GSA interface in the current state of play is widely regarded as resource-intensive and a source of further complexity. The working arrangement has brought solutions, but its effectiveness has to be proven in practice. In particular, a specific effort should be made to clarify the delineation of prerogatives between the two agencies since the remaining uncertainties, the sometimes insufficient trust, and the resulting potential overlaps of their actions remain major sources of both strain and of resources wastefulness. Therefore, the transfer of competences that will take place in the next years, through the handover and then as part of the working arrangement, is especially important. As a matter of fact, it would limit the dependence of the GSA and simplify the GSA/ESA interface by reducing it as much as possible to its vertical component.

This scenario scheme would therefore allow ESA to focus on its field of expertise: in particular through the development of the next Galileo generation, but also by being more closely associated with the international negotiations. However, such a result seems to require a significant increase in GSA resources.

Those adjustments can mitigate the effects of several identified issues, but this governance scheme remains intrinsically partially dysfunctional, as described in Chapter 4. The scheme is indeed especially complex, implying the division of key control parameters between the different actors and the multiplication of interfaces. It also hampers the international outreach of the programme and maintains potential conflicts of interest in security (both in the SAB and in the Commission) as well as in the guarantee of performance. These problems could be partially tackled by a significant increase in the means associated with the programme: for instance, the allocation of more own resources to the SAB, would limit the *de facto* dependence of this board on the rest of the GSA. But the scheme itself remains suboptimal, as similar results may be obtained with fewer resources.

5.2 Scenario Scheme 2: Creation of a Single Common roof GNSS Agency

The second scenario scheme is based on the reduction of the complex triangle of interactions to a more classical "users – operator – developer" chain. Given that the GSA in its current configuration is insufficiently tailored (both in terms of headcount and expertise) to assume the central role for operating such a complex system as Galileo, the best way to achieve optimal synergies would be the creation of a "common roof" GNSS agency, bringing together most ESA Galileo staff (those who are not involved in R&D for the programme) and the GSA staff.

Similar to EUMETSAT, the role of ESA would be secured since the Agency would be in charge of the development of the new generations of the system. Facing a unique, highly competent agency, the Commission could focus on the definition of programme political oversight and the definition of its high level requirements, as in the previous scenario scheme.

The most immediate benefit of such a configuration is the dramatic reduction in the complexity of governance, especially through the reduction of complex and resource-costly internal public interfaces (see 4.1.1). In this scenario scheme, the governance scheme is based on only two, far more manageable, interfaces: the complex, multi-dimension current GSA/ESA relation is replaced by a classic operator/developer interaction, while a unique Political level/Programme level interface substitutes for the current heavy and rigid Commission/GSA and Commission/ESA delegations. The additional resources and the enhanced flexibility provided by this simplification would thus significantly improve programme management.

Furthermore, this new "Super GSA" would be strong enough to ensure, as a core task, the exploitation of the constellation. As a consequence and unlike the current GSA, the status of this entity should be decided in accordance with its function: its legal form should be revised in order to ensure its successful establishment. Within the EU, it could probably be done using the possibility of departing from the financial framework regulation provided by the general rules of the EU[106]. Other possibilities include the creation of another kind of agency within the EU, more adapted to the specific constraints associated with the exploitation of an operational system delivering a 24/7 service, or the setting up of an international organization – like EUMETSAT – managing the exploitation of the system owned by the EU[107]. It seems indeed necessary to provide to such an agency sufficient room for manoeuvre, especially regarding human resources management. In particular, the headcount authorized for the agency should be more flexible – less dependent on the MFF, or even removed – and the recruitment process simplified to enhance the agency's adaptability. Wages should also be less dependent on the location of the agency, as under the current Financial Framework Regulation. Such improvements seem to constitute a preliminary condition for the significant increase of in-house expertise that would be required for the establishment of such an entity.

Such a scheme would also ensure important continuity in the programme since the single roof agency would take advantage of the experience and knowledge accumulated by ESA over the past years. Thanks to this expertise, the "super GSA" would be able to manage the contract of GSOp in the best conditions and with limited risks, or even eventually, directly operate the constellation, similar to EUMETSAT. As a technical pole within the programme, it could embody the role of "Mr. Performance" currently missing: an entity fully in charge of exploitation and controlling the key parameters of programme management. For its part, the SAB should be dissociated from this entity to become a separate body accrediting the system. Given the type of governance of the SAB (fully intergovernmental) and the nature of its activities, this new agency could be part of the CFSP and placed under Council authority. Going this way, conflicting interests in security would be dramatically reduced. In the same way, another agency, under council authority or even external to the EU, should be created to certify the performance of this system. Alternatively, an entity already existing, able to do this kind of certification service and having the relevant competencies (or the capacity to acquire it), independent from the programme could take up this responsibility.

This programme management would follow the orientations and high level requirements provided through the Administrative Board, both by the Commission and the Member States. Here as well, this steering role of the Commission could be enhanced through an increase of its representatives, or votes. Both the Commission and the member states should be there as users of the programme: concretely, they should be appropriately represented by delegates mandated to represent the interests of the community of users from their country or from the EU. This could be done by upstream inter-ministerial coordination at the national levels and inter-DG coordination within the Commission. By co-steering a consolidated single roof agency, the Commission could also concentrate its resources on the international relations, being supported in this area by the expertise of the single roof agency making available an end-to-end understanding of the technical issues, and the extended SAB for security questions. Such a strongly consolidated GSA could even be the single window entity that assumes responsibility over international relations.

ESA, keeping the R&D competencies, would remain the architect of the system, a task that fully corresponds to its core activities. Such a positioning would ensure the best use of its competencies and prevent issues related to the insufficient delineation of the competencies devoted to ESA, while aligning the interests of the Agency with those of the programme. This would optimise the use of available competencies.

This second scenario scheme is paradoxically the most classic if compared to the other similar European space programmes (EUMETSAT and formerly Eutelsat) and the most innovative in comparison with the scheme envisaged for Galileo so far. It presents many advantages (continuity, governance simplification, better use of the competencies within each entity, experience of comparable projects, etc.). In addition, the clear division of security prerogatives, the high degree of independence of the exploitation entity, and the way the Member States could control it, pave the way for defence applications, especially through the use of PRS. In parallel, the growing importance of the GSA for international relations would enable having a central actor for the future expected international agreements regarding this service. However, this scenario scheme also entails some uncertainties: in particular,

[106] The article 208 of the Regulation (EU, Euratom) N° 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union allows decentralised agencies to "depart from the framework financial regulation" if "their specific needs so require and with the Commission's prior consent".

[107] One can consider that the specificities of the tasks that such an entity would undertake – in comparison to the ones carried out by other EU agencies – provide an opportunity to create entities with a new status, endowing the EU with a more tailored instrument for the exploitation of operational systems, that could be reused in future projects.

the appropriate status to be given to this "super GSA". The biggest difficulty remains the political will needed to introduce those changes and significantly modify the bases of the programme one more time.

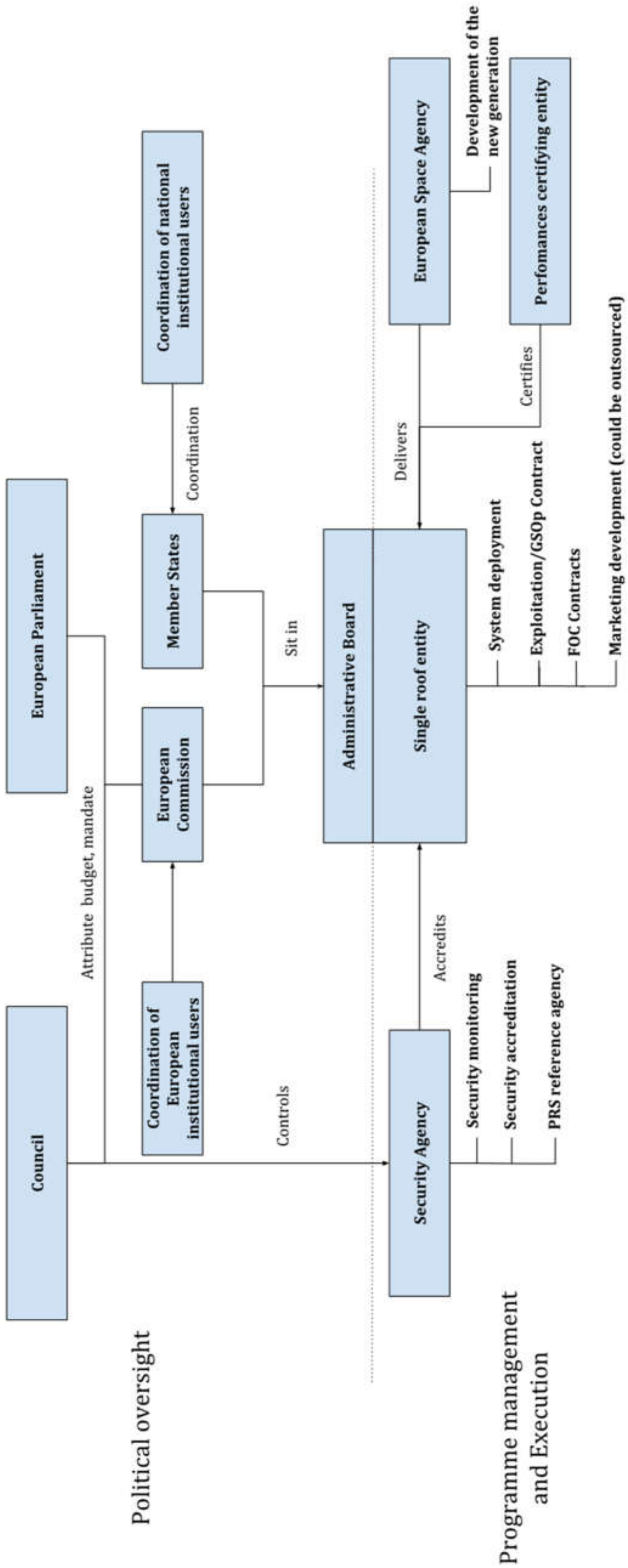

Figure 2: Scenario scheme 2 based on a "Super GSA"

5.3 Scenario Scheme 3: The GSA as a Coordinating Agency for a Galileo Steering Board

The third scenario scheme is based on the opposite paradigm that frames scenario scheme 2: rather than incorporating the GSA within an entity concentrating most of the technical competencies in order to simplify governance and limit the number of interfaces, the GSA could forsake most of its current technical prerogatives to become mainly an administrative agency, providing a unique interface with all the other stakeholders (actors of governance, GSOp and institutional users) in order to support a programme steering board that would take responsibility for the management of Galileo.

Transforming the GSA into such a mostly administrative agency involves transferring its security and technical prerogatives to other bodies. On the one hand, the exploitation and service provision could be fully outsourced to GSOp, bringing back the GSA to a role similar to that envisaged when the Agency was created, in the frame of the PPP model. On the other hand, the security related prerogatives (security monitoring and accreditation) would be assigned to a distinct agency under Council governance, similarly to what is described in the second scenario scheme. This way, this GSA as a "GNSS Administration" could concentrate its resources on becoming a structure receiving inputs from all the stakeholders of the programme, following an approach based on thematic working groups. In particular, all the European institutional actors (national ministries and the Commission DGs) should take part in boards overseeing specific fields of GNSS applications (aviation, LBS, etc.) in order to coordinate between themselves and provide common requirements for Galileo. This would provide the programme with a powerful structure aggregating the high level requirements of the different communities of users, following a supranational and sectoral approach. The GSA could also host other transversal working groups in order to deal with specific issues related to international cooperation, the evolution of the programme, or ad-hoc engineering issues. All inputs gathered by the GSA would feed the work of its Administrative Board, which could become the effective steering committee of the programme. Last, the GRC could become the performance certifying entity for the system, without conflict of interests given that responsibility for service provision is left to the private sector.

Under such a configuration, the transfer of workforce from the Commission to the GSA that is foreseen for the period 2014-2020 could be significantly amplified to leave to the Commission only the highest level tasks (definition of long term strategies, negotiation of high level international agreements etc.). Programme management would be left to the steering committee, where the weight of the member states and of the Commission could be balanced.

Given the essentially administrative nature of such a GSA, ESA would be mainly in interaction with GSOp, being mandated by the steering committee to produce for this entity the new versions of the system. At the same time, the space agency would be the only public technical pole within the governance, limiting wasteful redundancies and associated internal interfaces. Its knowledge of the system, as its developer, would allow the Agency to provide its technical expertise to the steering committee on demand, as well as for international negotiations. The technical management of the system having been left to the private sector, it would confirm ESA in its role of a research and development organisation.

This approach is the closest to the one envisaged at the beginning of the programme: it emphasizes its commercial dimension and removes most of the technical and operational tasks from the EU. This scheme redefines the governance as mainly user-driven, and probably fosters the development of efficient supranational GNSS related policies thanks to its sectoral coordination at the European level. It also addresses major security conflicts of interest, creating a specific entity to deal with the security-related issues. Since this scenario scheme, like the second one, assumes an important evolution of the governance scheme, it requires the taking of a strong decision regarding the main orientation the programme is aiming at.

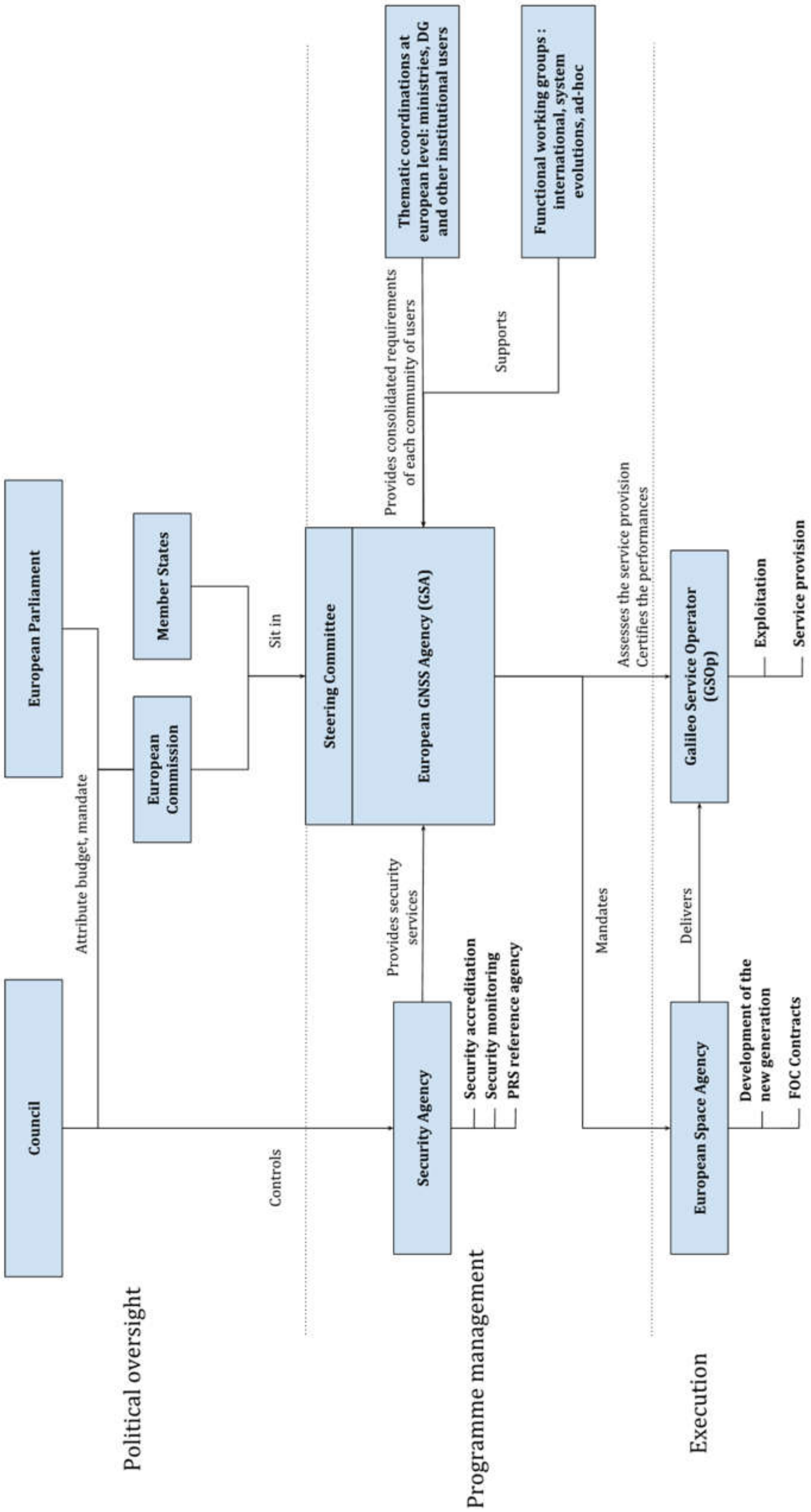

Figure 3: Scenario scheme 3 based on a "GNSS Administration"

6. Conclusion

Considering the challenges faced by Galileo and the complexity of its environment, in the coming years the governance of Galileo will continue to have a strong influence on the subsequent successes of the programme. As mentioned above, it is undisputed that the programme has made big progress over the last two years, and one might consider that the last GNSS regulation and its implementation allowed the deployment phase to reach a satisfying "cruising speed", illustrated by the latest successful launches. However, those accomplishments do not mean that the governance scheme it provides is optimal, nor that it is fully adapted to the next steps of the programme. As a matter of fact, in this report we have identified several issues, inherent to the organizational architecture provided by the currently applicable regulations and related to the different aspects of the governance, which could impede the achievement of the political, economic and technical objectives of the programme.

In order to limit these negative effects, this report provides recommendations, with three alternative schemes of governance. Bearing in mind the central role that is devoted from now on to the GSA in terms of security management and a privileged interface for international relations, especially with the other GNSS/RNSS providers, to ensure that global governance between these PNT systems is indeed sustainable. These scenario schemes have their own strengths and weaknesses, and they require diverse political will to be implemented. However, their relevance also significantly depends on the guidance the member states want to give to the programme. Indeed, while the initial services were declared on 15 December 2016, important decisions having major influence on the programme and thus on its appropriate governance are still pending. Should military uses of Galileo be authorized? To what extent should the commercial dimension of the programme be a driver as compared to the sovereignty and strategic independence aspects? What responsibilities do European public entities want to leave to the private sector? Answering those questions is thus a precondition to making the institutional choices necessary to establish efficient and definitive governance for the programme. Following the previous period that was mainly focused on the preparation of the declaration of initial services, the years to come with a 2020 deadline must be used to resolve those preliminary issues.

When taking this necessary step, the different scenario schemes can be considered. The first one is especially conservative, as it consists of keeping the scheme defined by the GNSS regulation, but making some corrections to limit the effects of the identified issues. It would thus require relatively little political will, but as it would not resolve the roots of the acknowledged problems, it remains a suboptimal governance scheme in our view. The second scenario scheme, dubbed "single common roof" is more innovative, though it relies on the examples of previous similar successful European programmes and in particular EUMETSAT. It consists of the simplification of the general governance by the creation of a single entity filling most of the tasks now attributed to the GSA and ESA, in order to limit the number of actors and the interfaces between them. This way, such a scheme could resolve many of the pinpointed issues of the current governance, but at the expense of a higher political cost. The last scenario scheme is the most pioneering – in particular in the field of GNSS – as it proposes a stronger role for the private sector, together with highly user-driven governance. It would be, in a way, a return to a strongly commercial oriented conception of the programme based on a concession, but being established later, after the deployment of the constellation.

All the proposed scenario schemes are primarily based on the redefinition of the role of the GSA within the governance, successively envisaged as a "standard GSA", a "Super GSA", or a "GNSS Administration". This agency is indeed a more recent institutional actor, and thus the most "malleable" of the stakeholders, which can still be significantly modified. For this reason, the choice of one of the scenario schemes should also take into account the future role that could be given to this agency outside of the Galileo programme, or the model of agency it could become for other space programmes managed by the EU. One of those long-term possibilities is to take advantage of the expertise the SAB has acquired in security accreditation to extend its prerogatives to other programmes. Should the SAB remain in the GSA (as suggested in scenario scheme 1), the GSA could become a "Global Security Agency", placed under Council governance and nonetheless accrediting Galileo, but also Copernicus or the future Govsatcom initiative as a start. Monitoring activities for Galileo and eventually for other programmes could also remain associated with this new GSA: the agency would play the role of "Devil's advocate" for the security of future European space programmes and be a pole of expertise in this field for the EU. An alternative corresponding to scenario schemes 2 or 3 could be to transform the SAB into a dedicated space security agency under the purview of the Council of the EU, providing such a service on request of the GSA. Those evolutions would be in line with the ambition announced in the Space Strategy for Europe to consider the extension of GSA security related responsibilities to other EU space activities[108].

[108] European Commission. Space Strategy for Europe. COM (2016) 705 final of 26 October 2016. Brussels: European Union. 12.

Annex

A.1 Other Components of the "System of Systems"

A.1.1 Other GNSS

GPS

GPS is the GNSS system owned by the United States, occupying the leading position in this field. It was the first GNSS programme, started in 1973[109] and it reached fully operational capability in 1995[110]. Together with the Russian GLONASS, GPS is currently one of the two fully operational GNSS, but it maintains a special status because of its performances and the incomparable spread of its uses and applications. Today, it is dubbed as the "golden standard" among the GNSS.

Like the other GNSS apart from Galileo, GPS is a national infrastructure under military control as it is operated by the U.S. Air Force. Nonetheless, GPS policy regarding civil users has evolved over time. In 1991, the U.S. formally committed to the provision of a Standard Positioning Service (SPS), free of charge and open to everybody, but intended to keep an edge for military uses through "Selective Availability", a voluntary degradation of the signal that limited the accuracy of SPS to 100 metres, while the Precise Positioning Service (PPS), which was only open to users authorized by the Department of Defense, provided an accuracy of 10m. In 1996, a Presidential Decision Directive defined a new strategy for U.S. GPS policy, promoting the peaceful civil use of GPS to establish it as an international standard and take advantage of the commercial and political fallout of this positioning. This dual dimension remains the reference for GNSS systems that Galileo intends to challenge with its commercial, *a priori* non-military nature. Under the new U.S. GPS Policy, the Department of Transportation was associated with management of the programme, though the DoD kept a privileged place as the main funder. Following this new orientation, selective availability was discontinued on 2 May 2000 on the direction of President Clinton. The current GPS policy is the U.S. Space-Based Positioning, Navigation, and Timing (PNT) Policy, established in 2004[111]. This policy consolidates the orientation provided by the U.S. GPS policy, emphasizing the primarily military nature of the system, but also the need to maintain the U.S. leadership in civilian uses of GNSS. It also points out the security dimension of such a programme and underlines that it belongs to the components of the "U.S. Critical Infrastructure", providing the programme with a special status, particularly regarding its funding under U.S. law. The Space-Based PNT Policy also introduced the institutional changes needed to take into account the new complexity of the programme associated with its larger objectives. In particular, a Space-based PNT Executive Committee, co-chaired by the DoD and the DoT (see Annex A.7), took over management responsibility and associated U.S. government Department and Agency customers of GPS in its governance. Last but not least, the Space-Based PNT Policy also embedded in the larger Federal Radionavigation Plan, a document providing a general strategy regarding radio navigation, which is updated on a regular basis – the last version was adopted in 2014[112].

From a technical point of view, the current GPS delivers different kinds of signals, each associated with specific purposes (see Annex A.6). Three signals are for civil uses: to the legacy C/A signal (on the L1 frequency), modernization programmes added the L2C signal (L2 frequency) designed to meet commercial needs, and the L5 code signal for safety of life applications[113], both in a pre-operational state. One signal is currently dedicated to military uses:

109 Misra, Pratap and Enge, Per. Global Positiong System - Signals, Measurements, and Performance. Revised Second
Edition. Ganga-Jamuna Press, 2011.

110 Zarchan, Paul. Global Positioning System: Theory and Applications Volume 1. American Institute of Aeronautics and Astronautics, Inc., 1996.

111 National Security Presidential Directive. U.S. Space-Based PNT Policy. NSPD-39 of December 15, 2004. Washington.

112 U.S. Department of Defense, Department of Homeland Security, and Department of Transportation. 2014 Federal Radionavigation Plan. Springfield, Virginia.

113 "New Civil Signals." Global Positioning System 19 December 2016 <http://www.gps.gov/systems/gps/modernization/civilsignals>.

P(Y) code (L1 and L2 frequencies). All these signals provide an equivalent accuracy but the last takes advantage of features that enhance its security (robustness, resistance to spoofing etc.).

The GPS programme is also on the eve of an important evolution based on two components: the imminent launch of third generation satellites (the first generation was experimental, and the system is now fully composed of second generation satellites), in parallel with the deployment of a modernized ground system segment (OCX). GPS III will provide two new signals: L1C (L1 frequency) for civilian purposes, and has been developed together with Europe to enable interoperability with Galileo, QZSS and BeiDou, and the M-code for military purposes (L1 and L2 frequencies)[114]. The M-code signal is more resistant to jamming than Y-code signals and takes advantage of its relative isolation (see Annex A.6), making possible the denial of civil signals without affecting the military). Selective Availability is absent in GPS III, making the May 2000 political decision technically definitive[115]. These new features, in particular the use of double frequencies, should allow GPS to deliver performances comparable to those expected from Galileo. GPS III first satellites should be launched from 2017, but ensuring those performances will require the full deployment of OCX, which is currently suffering technical delays[116].

The close cooperation between Galileo and GPS is based on an agreement signed in 2004 by the European Union and the United States. The agreement harmonized the technical features of the two GNSS in order to ensure their compatibility and foster their interoperability at non-military level[117]. For this purpose, one frequency and the related signals structure used by both constellations were decided jointly, while both parties agreed to bring closer their geodetic coordinate reference frames and to transmit continuously the time offset between the two constellations[118,119]. Another objective of the agreement was to maintain fair trade conditions in GNSS markets. To that end, the agreement created four working groups: Compatibility and Interoperability, Trade and Civil Applications, Cooperation for the next generation GNSS, and Security. In doing so, it avoided numerous potential legal claims and paved the way for further rapprochements, giving to both constellations a privileged place in the future GNSS "system of systems". The agreement also solved the issue raised by the European attempt to use for the PRS the same frequencies as the GPS M-code signal, strongly opposed by the U.S.[120,121]. After the placement of PRS on another part of the spectrum, the U.S. Department of Defense began to consider PRS as an interesting complement; negotiations for U.S. access to PRS is now the main topic of EU-US possible cooperation on GNSS[122]. Future negotiations could address the development of a dual mode PRS/M-code, but this will require demonstrating that the security level of PRS is comparable to GPS. A main concern for the U.S. is the coexistence of military and civil users for these services.

GLONASS

Together with GPS, GLONASS is the only fully deployed GNSS. It is also an old system, with respect to GNSS history: the Soviet Union started its deployment in 1982 and the system was brought into full operational capability in 1995, the same year as GPS[123]. Similar to the American GNSS, the system is under military control, also offering a free of charge, non-discriminatorily accessible worldwide service. While the system was at one point more attractive to civil users than a GPS still degraded by Selective availability (it was removed in 1999 for GLONASS), the lack of resources due to the economic difficulties in Russia led to its abrupt decline, down to only 6 fully operational satellites in 2001[124]. From 2006, the Russian GNSS was resurrected and, strongly supported by the government, it again reached full operational capability in 2011[125]. The programme is now implemented through the

[114] *Ibid.*
[115] "Selective Availability." Global Positioning System 19 December 2016 <http://www.gps.gov/systems/gps/modernization/sa/>.
[116] Divis, Dee Ann. "GAO: New GPS Ground System, Not GPS III Engineering, Primary Cause for Delays." Inside GNSS 30 November 2016.
[117] Especially with the development of the MBOC modulation getting closer the GPS L1C and the Galileo E1 OS signals.
[118] Agreement on the promotion, provision and use of Galileo and GPS satellite-based navigation systems and related applications, Dromoland, done 26 June, entered into force 12 December 2011.
[119] "MBOC Modulation." 8 September 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/MBOC_Modulation>.
[120] Al-Ekabi, Cenan and Mastorakis, Panos. "The Evolution of Europe's Launcher and Flagship Space Initiatives." Eds. Al-Ekabi, Cenan. European Autonomy in Space. Vienna: SpringerWienNewYork, 2015. 44.
[121] The U.S. even threatened at some point to stop negotiations on satellite navigation with Europe.
[122] De Selding, Peter B. "U.S., Norwegian Paths to Encrypted Galileo Service Open in 2016." Space News 18 December 2015.
[123] "Glonass history." 2016. GLONASS 18 December 2016 <https://www.glonass-iac.ru/en/guide/>.
[124] Parkinson, Bradford W. and Spilker, James J. Jr. Global Positioning System: Theory and Applications. American Institute of Aeronautics and Astronautics, Inc. 80.
[125] "GLONASS Future and Evolutions." 5 August 2016. European Space Agency 19 December 2016

GLONASS Federal Programme 2012-2020, which also defines the national PNT policy. The priority for this period is accuracy, expected to be improved four-fold through the implementation of this programme. It should be noted that the spread of the system is supported through its mandatory use by all the public organizations of the Russian Federation and the obligation to sell GLONASS compatible smartphones in Russia[126,127].

As a GPS, GLONASS provides two services: the Channel of Standard Accuracy, transmitted on the L1, L2 and more recently on the L3 frequencies, is a service similar to the GPS open service, while the Channel of High Accuracy, broadcast on the L1 and L2 frequencies, is open to authenticated users, notably for military purposes. It should be mentioned that the access to this signal has been granted to India as part of an agreement in 2010[128]. Regarding performances, they have dramatically improved since the revival of the programme in 2006, but remain inferior to the GPS in most of the cases, in particular in terms of accuracy and stability[129]. Furthermore, the past tribulations of the programme and its potential instability still hinder wide use of GLONASS, preventing its establishment as a standard together with the GPS. Rebuilding this credibility will require demonstrating a capacity to ensure good performances over the time. In this regard, Russian launching activity has never been as low as now and this clearly endangers the programme, which needs satellite replenishment. As at the end of November 2016, less than 23 satellites were active, and the service thus provides suboptimal performances[130]. After successive delays, three satellites should be sent in the first quarter of 2017[131]. One of the main evolutions of the system in the next years will be the shift to the CDMA technique for satellite identification. Currently, GLONASS is the only GNSS using the FDMA technique for this purpose[132]. Progressively shifting to CDMA with the deployment of the third generation satellites (GLONASS–K) will improve accuracy and facilitate interoperability with other GNSS. In the longer run, GLONASS–KM satellites, whose first launch is expected by 2025, should utilise three new open signals ensuring interoperability with other GNSS: L1OCM, similar to the modernized GPS L1C/Galileo E1/BeiDou B1; L5OCM to the GPS "Safety of Life" L5/Galileo E5a/BeiDou B2a; and L3OCM to Galileo E5b/BeiDou B2b (see Annex A.6).

In 2006, the EU and the Russian Federation established a space dialogue through the signature of an agreement. One of the main objectives of the intended partnership was to ensure compatibility and interoperability between Galileo and GLONASS. But the degradation of political relations since 2014 has slowed down cooperation in this field.

BeiDou

The BeiDou Navigation Satellite System (BDS) is the Chinese GNSS military programme. It is sometime called BeiDou-2 to distinguish it from the first step of the programme, which corresponded to a Regional Navigation Satellite System (RNSS) composed of three GEO satellites delivering services only in China and neighbouring areas. Like Galileo, BeiDou has not yet reached Full Operation Capability, which is expected in 2020, but that could happen earlier. The first BeiDou-2 satellite was put into its working orbit in 2007 and between 2010 and 2012, the deployment went on at a rapid pace (14 satellites). After a break, this steady rate of deployment resumed in 2015, with 7 new satellites, including new generation satellites, as of December 2016. Thus, in December 2016, 21 satellites are in orbit and operational, while the nominal constellation will be composed of 35 satellites: 5 GEO, 3 IGSO and 27 MEO satellites[133]. The initial services were declared as early as 2011 and rapid progress has been made in terms of performances since then. In July 2016, China released a White Paper outlining Chinese ambitions and plans in terms of programme development,

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<http://www.navipedia.net/index.php/GLONASS_Future_and_Evolutions>.

126 Alexey Bolkunov, Ingo Bauman. "GLONASS and PNT in Russia." Inside GNSS April 2016.

127 GPS World. "GLONASS to be required for phones sold in Russia." GPS World 12 November 2013.

128 Dikshit, Sandeep. "India strikes deal with Russia on Glonass." *The Hindu* (2011).

129 "GLONASS Performances." 26 May 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/GLONASS_Performances>.

130 Bottlaender, Eric. "Lancements: Russie, silence radio". Air et Cosmos 25 November 2016. (in French)

131 Mirgordskaya, Tatiana. "Global Navigation Satellite System (GLONASS): Status and Development." Presentation. UN-Nepal Workshop on the Applications of Global Navigation Satellite System, Kathmandu, Nepal. 12 December 2016.

132 FDMA: Frequency division multiple access, a channel access method for multiple access protocols giving users an individual allocation of several frequency bands. CDMA: Code division multiple access, a channel access method allowing several users to share a band of frequencies without undue interferences between them thanks to spread-spectrum technology and a special coding scheme.

133 GEO satellite: Satellite in Geosynchronous Orbit (altitude of 35,786 kilometres); IGSO satellite: Satellite in Inclined Geosynchronous Orbit exhibiting an angle other than zero with the equatorial plane; MEO: Satellite in Medium Earth Orbit (altitude between 2,000 kilometres and 35,786 kilometres).

applications and industrial development, and international cooperation[134].

BeiDou will deliver two global services: an open service similar to those provided by other GNSS and an authorized service ensuring enhanced reliability, accuracy and other features, only accessible to authorized (mainly military) users, but little information has been disclosed so far. Regional services include a wide area differential service designed to enhance accuracy (<1 m for positioning compared to <10 m to open service without augmentation), and a short message service allowing users to exchange short messages with BeiDou stations. BeiDou services are broadcast on three frequencies: in the upper L band, B1 (which overlays the Galileo E1 and GPS L1 frequencies), and in the lower L band, B2 and B3 (the latter overlays Galileo E6). The open service use signals located on B1 and B2, whereas the authorized service signals are in the B1, B2 and B3 bands (see Annex A.6).

Cooperation between Galileo and BeiDou has been complicated by past ups and downs in EU-China relations in the field of GNSS. In 2003, while Galileo was still envisaged as a PPP programme, a cooperation agreement signed between the EU and China provided for the association of China with the European programme. The Chinese National Remote Sensing Centre (NRSCC) became a member of the Galileo Joint Undertaking, and China committed to contributing € 200 million to Galileo. But, as noted by the European Court of Auditors, the liquidation of the GJU and the transfer of this agreement to the European GNSS Supervisory Authority tarnished relations with the Chinese party, which was not satisfied with the secondary status it would get in the new structure[135]. As a consequence, in 2006 China decided to independently start its own GNSS programme, BeiDou-2[136]. Chinese-European relations in this field have been poisoned by this poor start[137]. In particular, the Europeans have not managed to prevent China from using the same spectrum location chosen by the Europeans to broadcast PRS signals to transmit their own BeiDou services. This could significantly limit interest in PRS for security or military purposes, since it would be more complicated to jam non-PRS signals without jamming PRS[138]. Nevertheless, the signature of an "EU-China Cooperation on Space Elements of Consensus" in 2012 revived the EU-China dialogue in the GNSS field. In 2016, the Chinese party announced that the frequency coordination between BeiDou and Galileo had been completed, and cooperation mechanisms in the field of compatibility and interoperability were under discussion[139].

A.1.2 RNSS

Regional Navigation Satellite Systems are based on the same principle as GNSS, though they deliver services to a limited area. *A priori*, RNSS can be similar to GNSS services, but because of their limited area of effect, some applications are *de facto* less appropriate: long aircraft routes and vessel navigation for instance. As BeiDou is evolving into a GNSS system, there are currently two RNSS: the Indian Regional Navigation Satellite System (IRNSS or Navic) and the Japanese Quasi-Zenith Satellite System (QZSS).

The IRNSS project was approved in 2006 and the constellation, composed of 3 geostationary and 4 geosynchronous satellites, was completed in 2016. Like GPS, GLONASS and BeiDou, IRNSS is a military programme, developed to ensure access to a Navigation Satellite System within the territory of India and its immediate neighbourhood in case of hostile situations and to monitor Indian borders for mitigation of terrorism and infiltration. Navic is fully autonomous, providing its own two services: a Standard Positioning Service and a Precision Service, both using the L5 and S bands.

QZSS is the Japanese RNSS programme, offering services in the east of Asia and Oceania, especially adapted to the densely mountainous and urbanized Japanese geography. The programme started in 2010, and should reach full operational capability in 2023. Unlike IRNSS, QZSS partially depends on the GPS, that it complements (adding extra satellites to the constellation) and augments (providing augmentation signals improving GPS positioning accuracy). From an American point of view, this system will also be a potential back-up in case of partial GPS failure in this strategic area.

Until 2018, the system will be based on three satellites placed on a highly elliptical orbit and one geostationary satellite, and will provide a limited accuracy of its own. After 2023, the constellation will count 7 satellites, 4 of which will be geostationary, and positioning will be

[134] The State Council Information Office of the People's Republic of China. China's BeiDou Navigation Satellite System. June 2016. Beijing: Foreign Languages Press Co.
[135] Inside GNSS. "Compass: And China's GNSS Makes Four." Inside GNSS December 2006.
[136] Marks, Paul. "China's satellite navigation plans threaten Galileo." New Scientist 8 November 2006.
[137] Gutierrez, Peter. "Brussels View: Remembrance of Things Past." Inside GNSS August 2012.
[138] Gibbons, G., Divis, D. A. and Gutierrez, P. "The GNSS Quartet." Inside GNSS February 2013.
[139] Jiaqing, Ma. "The Progress of BeiDou Navigation Satellite System." Presentation. 59th session of COPUOS. United Nation, Vienna, Austria. 9 June 2016.

possible in most areas without relying on GPS[140]. QZSS will use L1-C/A, L1C, L2C and L5 frequencies to increase the availability of GPS, L1-SAIF for the augmentation of GPS, and the LEX frequency for high precision, compatible with the Galileo E6 signal (see Annex A.6).

Frequency compatibility between Galileo and QZSS, and Galileo and IRNSS has been achieved in recent years under the auspices of the International Telecommunication Union[141].

A.1.3 International Organisations

Several international organisations offer multilateral platforms to foster coordination and cooperation endeavours between different stakeholders, as well as with other actors having an influence on the functioning of the GNSS and RNSS systems.

The International Telecommunication Union

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies. This is the only UN agency composed of public actors (193 Member States, national regulators, academic institutions) and private companies (more than 700). The main task of the ITU is to allocate radio-spectrum to the different services and allot them, as well as satellite orbits and position slots, to states and companies wishing to develop activities requiring those resources, GNSS in particular. The ITU also develops standards in the field of information and communication technologies in order to frame the coexistence of related systems and foster interconnectivity between the associated communities worldwide[142].

The spectrum frequencies and satellite orbit allocations and allotments are regulated through the ITU Radio regulations and plans of allotment, which are reviewed every three or four years during the World Radiocommunication Conference (WRC). The WRC is also the opportunity to discuss rising and urgent global radiocommunication issues. Though the WRC addresses issues much broader than solely GNSS or even space focused issues, it plays a major role in the interactions of those systems, given the critical importance of spectrum allocation. It is the ITU that defined the range of frequencies to be used by the different GNSS. It also provides a framework to discuss bilateral issues between GNSS providers, like coordination to ensure radiofrequency compatibility, as well as multilateral questions, such as the opportunity to extend the bands used by navigation satellite systems.

The International Committee on Global Navigation Satellite Systems

The compatibility and interoperability issues between GNSS can hardly be reduced to bilateral negotiations, because of the existence of other systems in the concerned bands. As a consequence, the will to establish a framework for discussions and interaction mainly between GNSS providers was identified as early as 1999, at Unispace III[143], and led in 2005 to the creation of the International Committee on GNSS (ICG), under the UN umbrella[144].

The members of the ICG are the GNSS and RNSS providers (U.S., EU, Russia, China, India, Japan), but also UN Member States "with a programme to actively promote GNSS applications and services" (Italy, Malaysia, United Arab Emirates) and current or future GNSS augmentation system providers. Associate members include "international and regional organisations and associations dealing with GNSS services and applications" while some international organisations and institutes are present as observers.

The ICG aims mainly at promoting the use of GNSS as well as encouraging compatibility and interoperability between space navigation systems. The ICG is also a platform to exchange information on systems and their services. To fulfil its tasks, the Committee has established a Provider's forum, composed only of the six GNSS and RNSS providers. This is a privileged place to discuss compatibility and interoperability matters and common issues like the protection of GNSS spectrum, interference detection and mitigation, jamming, spoofing, and other matters related to space weather for instance. To support discussions and propose recommendations, the ICG has set up four working groups: "System, Signals and Services", "Enhancement of GNSS Performance, New Services and Capabilities", "Information Dissemination and Capacity Building", "Reference Frames, Timing and Applications". The

140 Kozuka, Souichirou. "The Emerging Legal Debates Around Japan's QZSS." Inside GNSS August 2016.
141 GPS World. "Directions 2016: Galileo — strategic tool for European autonomy." GPS World 18 December 2015.
142 "Overview." International Telecommunication Union 19 December 2016 <http://www.itu.int/en/about/Pages/overview.aspx>.
143 Unispace III (The third U.N conference on the exploration and peaceful uses of outer space) called for new capacity building and cooperation initiatives, and the ICG is the result of one of the "action teams" created at this moment.
144 Aliberti, Marco and Krasner, Stephen D. "Governance in Space." Yearbook on Space Policy 2014: The Governance of Space. Eds. Cenan Al-Ekabi, Blandina Baranes, Peter Hulsroj and Arne Lahcen. Vienna: SpringerWienNewYork, 2014. 157.

ICG holds an annual meeting where results from the different working groups are presented together with programming relevant workshops that will help achieve the objectives set by the ICG for the next years.

A.2 Galileo Uses and Communities of Users

A.2.1 Location-Based Services

Strictly speaking, Location-Based Services (LBS) include applications based on the provision of services or information relevant to the location of the users. Concretely, this term mainly refers to personal uses linked with web applications available on smartphones or tablets (about 90% of LBS devices are smartphones)[145]. This includes personal road navigation, map creation, geo-marketing and location based advertising, emergency location, work performance-oriented applications, sport assistance, games, augmented reality applications and social networking. LBS already constitute one of the most lucrative types of GNSS applications and they will keep this status in the mid-term: until 2023, more than 50% of GNSS chipset revenues should involve LBS applications[146].

The LBS category covers very different applications, while mass market by definition includes numerous actors, thus complicating the identification of general requirements. However, chipset and device manufacturers are very reactive to demand and can relay the agglomerated needs of mass market consumers. Usually, they pay attention to the availability (especially in challenging environments like dense cities), the time to first fix, and the accuracy of GNSS. A clear trend is the increase of LBS multi-constellations chipsets (more than 60% in 2015), including Galileo with the first Galileo compatible smartphones released in July 2016[147]. In terms of opportunities for Galileo, OS and CS are the services most adapted to the requirements of LBS applications.

A.2.2 Road Applications

Road transportation related GNSS applications were the first mass market uses of GNSS. This market, which gathers both professionals and individuals consumers, is the second most lucrative after LBS services, with close to 40% of GNSS chipsets revenue expected to come from these applications until 2023[148]. Most of the GNSS applications in this field are related to smart mobility, and aim at improving the efficiency, productivity, and environment friendliness of road transportation, but also to save money and time through improvements in navigation, fleet management and traffic monitoring. GNSS are also used for safety-critical applications for connected vehicles and hazardous goods tracking as well as liability applications such as GNSS-based tolling operations and traceability of transport of goods. The last types of GNSS uses in this field are the regulated applications: recent examples include the European e-Call, a service sending an emergency call in case of accidents in European countries[149], and digital tachographs to support road enforcement.

This market is changing, as some applications are converging with LBS applications, leading to the decrease of personal dedicated devices sales, replaced by smartphones. On the other hand, this phenomenon is being mitigated by a strong increase in In-Vehicle Systems sales, supported by new connected vehicles functions, as well as regulated applications that will continue to drive growth in the future. In the long run, the spread of autonomous cars, in which GNSS play a key role, presents huge business possibilities for Galileo, but will also cause a huge increase in GNSS criticality and liability issues. These developments will necessitate the creation of new standards and certifications in the coming years, given their potential consequences, notably in terms of safety.

All GNSS road applications benefit from better availability and accuracy, whereas liability-critical applications requirements focus on continuity and authentication functions. As for LBS, most of these applications could be based on OS and CS, the latter being especially adapted to deal with the liability aspect. Galileo SAR, with its innovative return link, is especially suited for safety-critical applications.

A.2.3 Aviation

Though aviation applications are expected to generate only about 1% of GNSS core revenues for the 2013-2023 period, since the beginning of the programme this community of

[145] “Location Based Services.” 18 September 2014. European Space Agency 19 December 2016 <http://www.navipedia.net/index.php/Location_Based_Services>.
[146] European GNSS Agency. GNSS Market Report – Issue 4. March 2015. 10.
[147] “First European Galileo-ready smartphone to hit stores in July.” 14 July 2016. European GNSS Agency 19 December 2016 <https://www.gsa.europa.eu/news-room/news/first-european-galileo-ready-smartphone-hit-stores-july>.
[148] European GNSS Agency. *Ibid. 10.*
[149] It should be noted that this initiative provides that starting from April 2018, all the new cars sold in Europe will have GNSS, including Galileo, on-board.

users has been a main target of Galileo[150]. GNSS aviation applications are regulated to some extent. The regulated part concerns commercial (including business flights in private planes) and regional flights. International requirements and standards are defined by the International Civil Aviation Organization (ICAO), a UN specialized agency. Among those applications, Performance-Based Navigation (PNB) is steadily increasing: an increasing number of procedures regarding different phases of the flight are being designed taking into account the use of GNSS. PNB is expected to provide important environmental and cost improvements. As recommended by ICAO, GNSS are also increasingly used for Search and Rescue purposes. Air Surveillance too progressively relies more on GNSS to automatically report locations to air traffic controllers. Those developments are tending to make GNSS an increasingly critical infrastructure for aviation.

With very few exceptions, GPS (with or without SBAS augmentation) is the only GNSS used in this field, and future developments will focus on two, maybe three constellations-based solutions. The expected integrity, accuracy and continuity of service improvements are especially important in this field where most of the applications are safety-critical. They will notably allow the development of new GNSS-based procedures for airport approaches and ground manoeuvres, and eventually generate savings through improved traffic management and advanced navigation. However, the main milestone will be the replacement of costly current ground based systems, but this will require reaching better performances than those they are currently up to[151]. The major risk for stakeholders is economic, as aviation lifespan engages investments in the long run, meaning the sustainability of GNSS will be a main criteria driving the choice of GNSS complementing GPS. As a general rule, the development of new applications will involve the setting up of certifications complying with safety requirements and international standards.

Unregulated applications mostly concern recreational aviation, and include navigation assistance, infringement alarms, situational awareness of other aircraft and search and rescue applications. In this field, the expectations are close to those of mass market consumers, as described above.

Regarding the opportunities for Galileo services, the aviation community is interested in the OS, eventually with an adequate augmentation system, and in the SAR. Later, the integrity monitoring service will also mainly target this industry.

A.2.4 Rail

GNSS applications for rail include assistance in train command and control, timing and synchronization of on-board equipment, train localization, asset management and passenger information. GNSS non-safety applications are already widespread and the safety applications, which are the most important, are now developing. They could eventually lead to important savings by replacing railway signalling and associated on-board equipment, but GNSS applications are also considered as a backup solution, or part of a hybrid solution. To foster the development of innovative GNSS applications leading to cost reductions, many regional initiatives have been created. In the U.S, the Positive Control Legislation fostered the development of satellite navigation in this field. In Europe, the European Rail Traffic Management System (ERTMS) initiative explores the possibility of GNSS as a complementing system for safety operations[152]. The European Joint Undertaking Shift2Rail intends to accelerate technologies integration, including GNSS solutions. The adoption of GNSS for safety-related applications in this domain will nevertheless need to undergo regulation [153].

In any scenario, shipment of GNSS devices will strongly increase in the coming years[154]. Multi constellation solutions will also be favoured, especially as they will further enhance positioning performances, and, for the safety-related applications, they will enable meeting the high level of integrity and accuracy requirements. Therefore, Galileo's OS and CS, together with the future integrity monitoring services, are those elements corresponding to requirements in the rail domain.

A.2.5 Maritime

In the maritime field, the use of GNSS is regulated by the International Maritime Organization (IMO), which defines requirements for

[150] European GNSS Agency. GNSS Market Report – Issue 4. March 2015. 10.
[151] This is a main difficulty, in particular for the reliability, since it will be required to have less than one failure for 10^9 hours. Currently, even GPS+WAAS does not deliver good enough performances allowing all the procedures to rely only on it.
[152] Gutierrez, Peter. "European Rail Industry Perspective on GNSS: Francesco Rispoli." Inside GNSS July 31 2016.
[153] *Ibid.*
[154] European GNSS Agency. GNSS Market Report – Issue 4. March 2015. 44.

GNSS applications standards[155]. In particular, in May 2016 it recognised Galileo as part of World Wide Radio-Navigation System[156]. The IMO identifies two kinds of GNSS applications for maritime activities: navigation and positioning. Navigation covers the processes of planning, recording, and controlling the movements of a vessel sailing from one point to another, ensuring safety, expediency and environmental protection during the transport. For SOLAS vessels (larger than a certain tonnage), navigation already strongly relies on GNSS, and for smaller vessels, GNSS systems are widespread. The important criteria for the use of GNSS depend on the phases of navigation but include identifying the area of coverage, availability, integrity, as well as accuracy (navigation in restricted waters, port approaches).

Positioning applications are much diversified, including traffic management and surveillance, fishing vessel control, port operations, hydrographical surveying, marine engineering and Search and Rescue applications. Most of them require high accuracy, as well as sufficient availability to provide added value.

In general, the spread of GNSS applications for maritime activities is expected to bring safety and productivity gains. It could also be translated into important savings if the development of GNSS applications allows the removal of costly maritime beacons. Given the maritime requirements at large, multi-constellation GNSS applications are also especially promising in this field (75% of the devices are already more than two constellations compatible). The Search and Rescue applications are expected to further drive the growth of GNSS uses in this field. This implies that besides the OS and the CS, Galileo's SAR will enable numerous applications.

A.2.6 Agriculture

Together with other technologies (including Earth observation and other optical systems), GNSS enables new applications increasing farming efficiency and productivity, reducing environmental impact and benefiting the consumer. In some areas, productivity gains are necessary to better tackle issues such as population increase, urbanization and land or water shortage.

Precision agriculture, as it is called, relies on machinery guidance (including automatic steering), enhanced agrichemical distribution and improved monitoring (biomass, soil condition, yield, livestock tracking). This also includes agro-logistic applications such as asset management, enhanced food traceability and field delineation. Those solutions are rarely only GNSS based, but their enablement generally requires an extremely high accuracy level. GNSS based applications for precision agriculture are growing at a steady rate and will be driven by multi-constellation GNSS (this is currently the case for more than 80% of devices), and the integration of GNSS solutions in larger, multi-sensor capacities. These requirements for added value on GNSS capacities are particularly in line with Galileo's CS, as defined.

A.2.7 Surveying

This field includes GNSS based cadastral surveying (for fiscal purposes especially), GNSS-assisted construction (including machine control), mapping, mining and surveys for scientific purposes (in particular, geodesy), as well as the maritime surveying activities mentioned above. GNSS technologies bring time and capital savings, as well as a qualitative improvement in these activities. The market of related GNSS devices is growing, mainly driven by construction activities.

These activities are the most demanding in terms of accuracy (down to the centimetre for construction), and they are also of greatest benefit if high availability (especially in harsh environments like cities) and a fast Time to First Fix are guaranteed. This is thus a privileged market for the CS of Galileo.

A.2.8 Timing and Synchronization

Numerous infrastructures, some of them being critical, need to be provided with accurate time or to synchronize its different subcomponents on a regular basis. GNSS give direct access to Coordinated Universal Time, as well as the possibility to synchronize receivers at distant locations. In the telecommunication field (90% overall GNSS device shipments) for instance, GNSS are used for synchronization between distant ground based stations or event logging. GNSS are also used in the energy industry where accurate timing within the network is used to optimize power transmission. Last but not least, GNSS timing functions are used in finance and banking, as precise timing is necessary to trace financial operations and to synchronize financial computer systems. The

[155] International Maritime Organization. Revised maritime policy and requirements for a future Global Navigation Satellite System (GNSS). Resolution A.915 (22) Adopted on 29 November 2001. London: United Nations.

[156] International Maritime Organization. IMO Maritime Safety Committee Ninety Sixth Session Summary Report. 11-20 May 2016. London: United Nations. 9.

GNSS requirements depend on the applications, but authentication capacity is especially relevant. Furthermore, some telecommunications, such as satellite communications, need very high timing accuracy (in the order of nanoseconds) for TDMA (Time Division Multiple Access) timing on the satellite links and terrestrial links.

Timing & synchronization applications also benefit from the shift to multi-constellation GNSS, as this increases resilience stability and thus reliance on those systems for critical infrastructures. In 2015, more than 85% of the receivers used for these purposes were already compatible with at least two constellations. The high accuracy of Galileo clocks and its unique authentication mechanism should give it a competitive edge in this field.

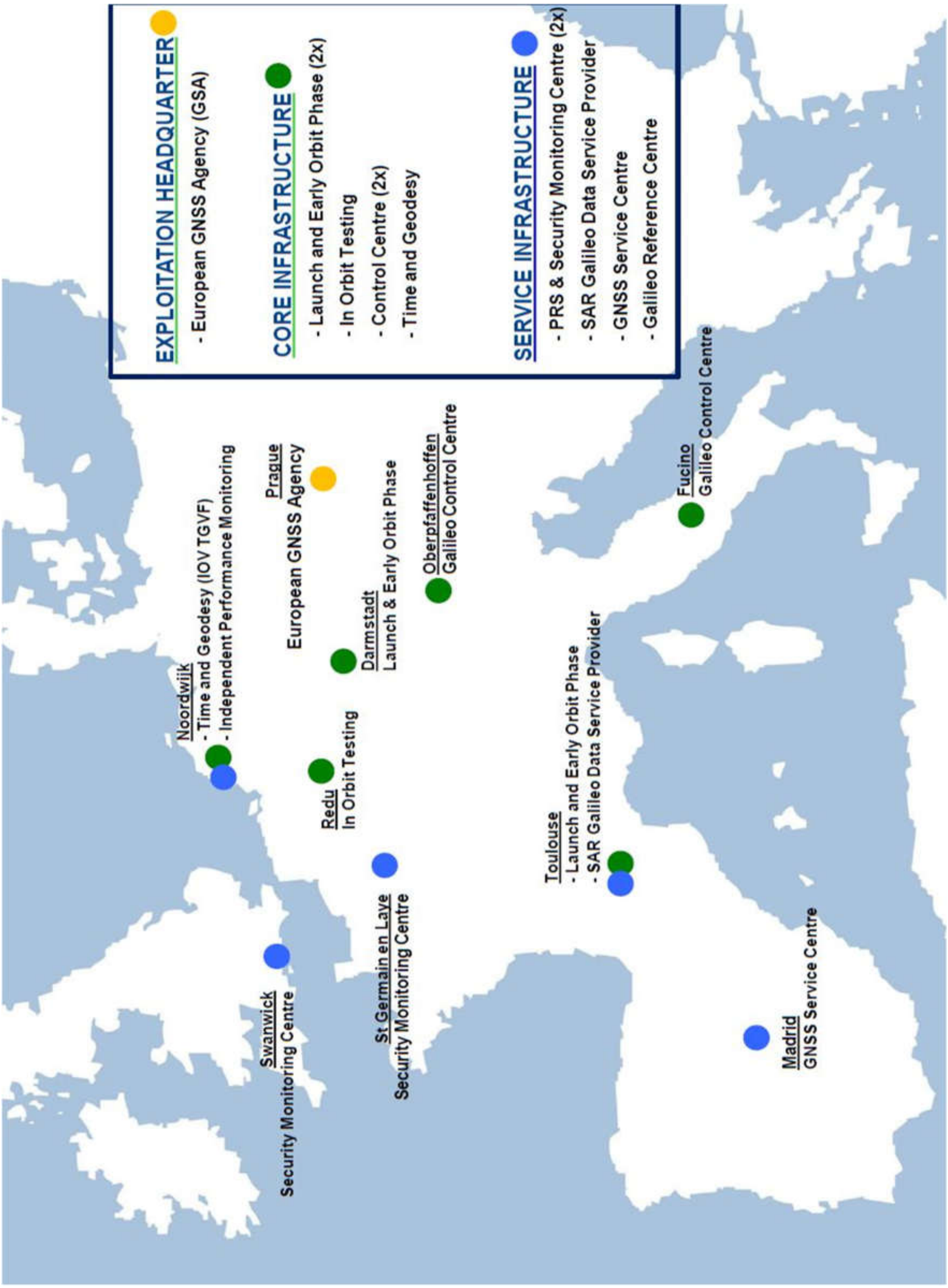
A.2.9 Potential Military Uses

Although Galileo is a civilian system which has neither been conceived for military uses nor funded by the military, it is also an intrinsic dual system, at least because some military activities involving navigation are similar to civilian applications. The clear frontier of the applications that will be authorized has not yet been defined, but various military uses are already envisaged. The most common use is the positioning of forces (at borders or during operations), their navigation, and the harmonisation of their movements. GNSS can also be used for precision delivery of cargos and for combat search and rescue purposes. More specifically, hard military uses of GNSS include precision guidance of munitions to dramatically improve strike effectiveness and avoid friendly fire, and unmanned aerial vehicles navigation.

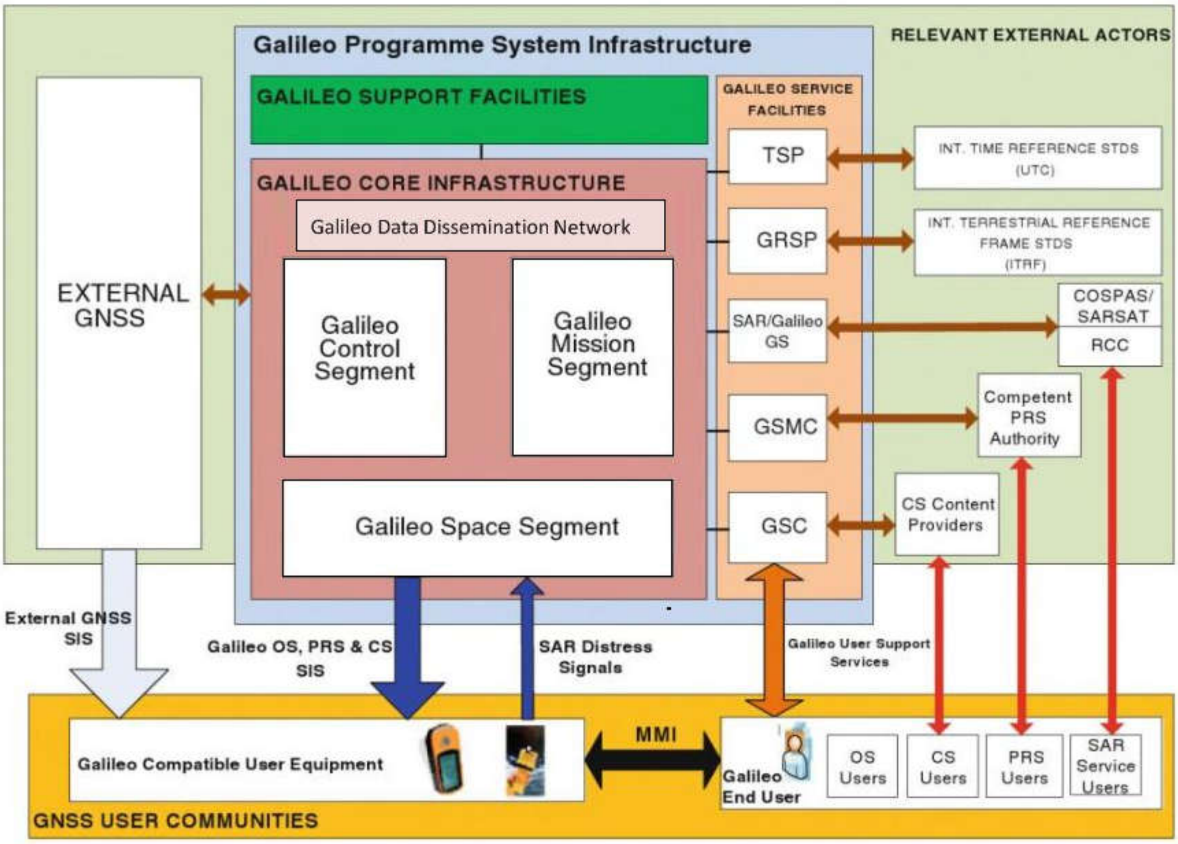
Should military uses be accepted for Galileo, it would involve specific needs. Security requirements and signal resilience would need to be significantly higher, increasing the overall complexity of the system. For instance, the risk of spoofing and jamming from hostile entities are far higher and potentially far more harmful for military applications. Integrity is also a critical criterion, while some uses necessitate a very high level of accuracy and continuity of service. Given the time constant of military programmes, the long term continuation of the programme and thus the commitment of the GNSS provider to ensuring a quality service over the long term is also a major requirement. The use of Galileo by potential enemies is possible, and further complexity emerges from the need to allow friendly forces to be able to deny the use of Galileo, by jamming for instance, while themselves still being able to use it.

Considering the specific military requirements, PRS offers a sound technical basis for these kinds of applications. The military are also interested in the uses of other services such as the OS, for less sensitive purposes.

A.3 Location of the Different Galileo Centres



A.4 Galileo Architectural Overview



A.5 GSA Headcount

As defined in 2013:

	Area of activity	2014	2015	2016	2017	2018	2019	2020
Delegated tasks	**EGNOS Exploitation**							
	Temporary Agent (TA)	15	15	15	15	15	15	15
	Contract Agent (CA), Seconded National Expert (SNE)	2	2	1	1	1	1	1
	Total	17	17	16	16	16	16	16
	Galileo Exploitation							
	TA	29	30	41	43	45	46	47
	CA,SNE	0	1	2	2	2	2	2
	Total	29	31	43	45	47	48	49
	Research & Development (Horizon 2020)							
	TA	5	6	6	7	7	7	7
	CA,SNE	5	5	5	5	5	5	5
	Total	10	11	11	12	12	12	12
Core Tasks	**Security Accreditation**							
	TA	10	10	10	10	10	10	10
	CA,SNE	1	1	1	1	1	1	1
	Total	11	11	11	11	11	11	11
	Security							
	TA	3	4	4	4	4	4	4
	CA,SNE	2	2	2	2	2	2	2
	Total	5	6	6	6	6	6	6
	GSMC Operations							
	TA	18	18	18	18	18	18	18
	CA,SNE	8	8	8	8	8	8	8
	Total	26	26	26	26	26	26	26
	Market Development							
	TA	5	7	7	7	7	7	7
	CA,SNE	3	4	4	4	4	4	4
	Total	8	11	11	11	11	11	11
	Communications							
	TA	1	1	1	1	1	1	1
	CA,SNE	0	0	0	0	0	0	0
	Total	1	1	1	1	1	1	1
	General Administration							
	TA	10	11	11	11	11	11	11
	CA,SNE	14	14	14	14	14	14	14
	Total	24	25	25	25	25	25	25
	Total TA	96	102	113	116	118	119	120
	Total CA,SNE	35	37	37	37	37	37	37
	Total	131	139	150	153	155	156	157

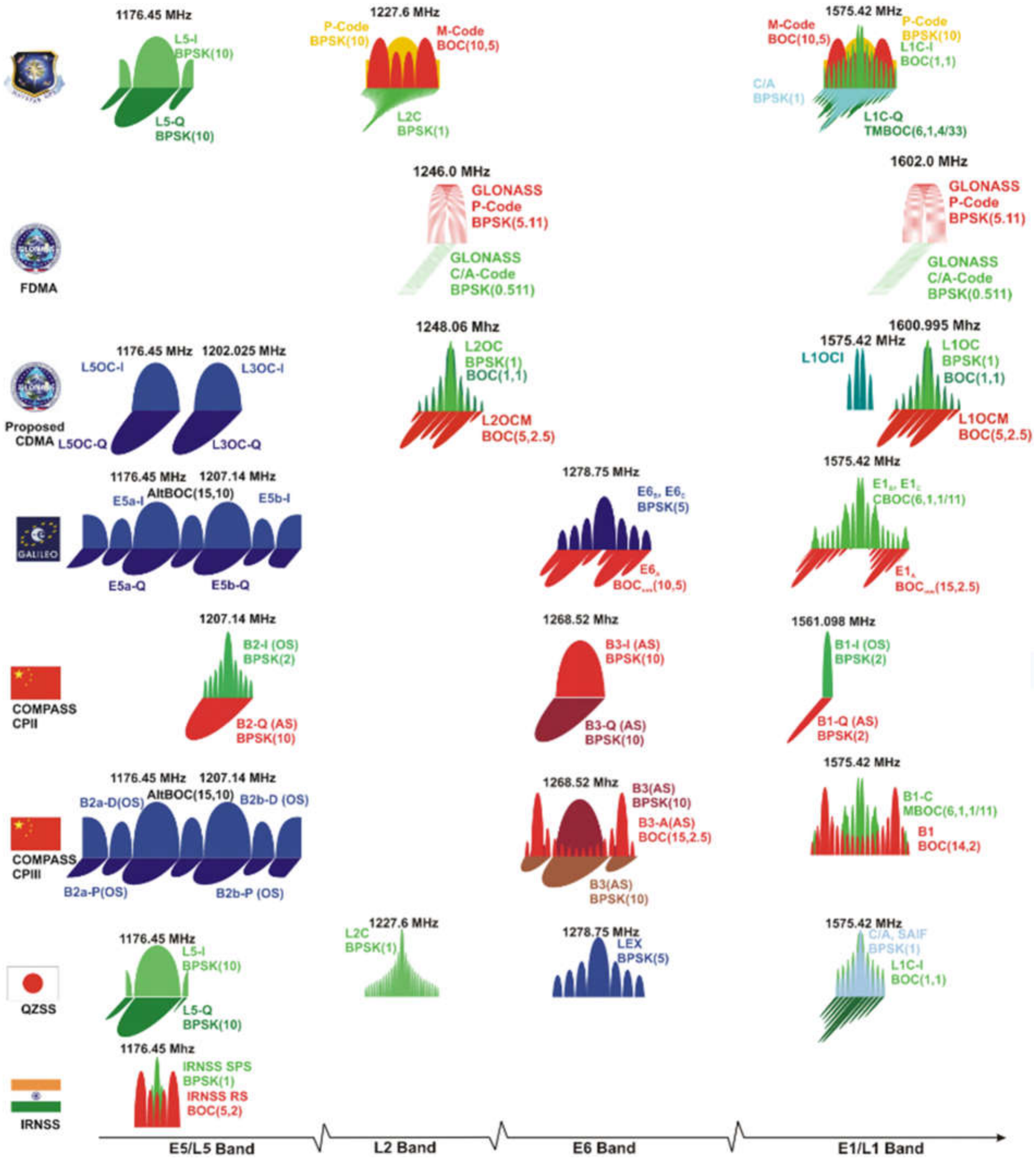
As provided by the GSA Annual Work Programme 2016:

Staff population		**Staff population in 2016**
Officials	Administrator Assistant	
Temporary Agents	Administrator Assistant	108 5
Total Temporary Agents		113

Contract Agents GF IV	31
Contract Agents GF III	6
Contract Agents GF II	3
Contract Agents GF I	
Total Contract Agents	40

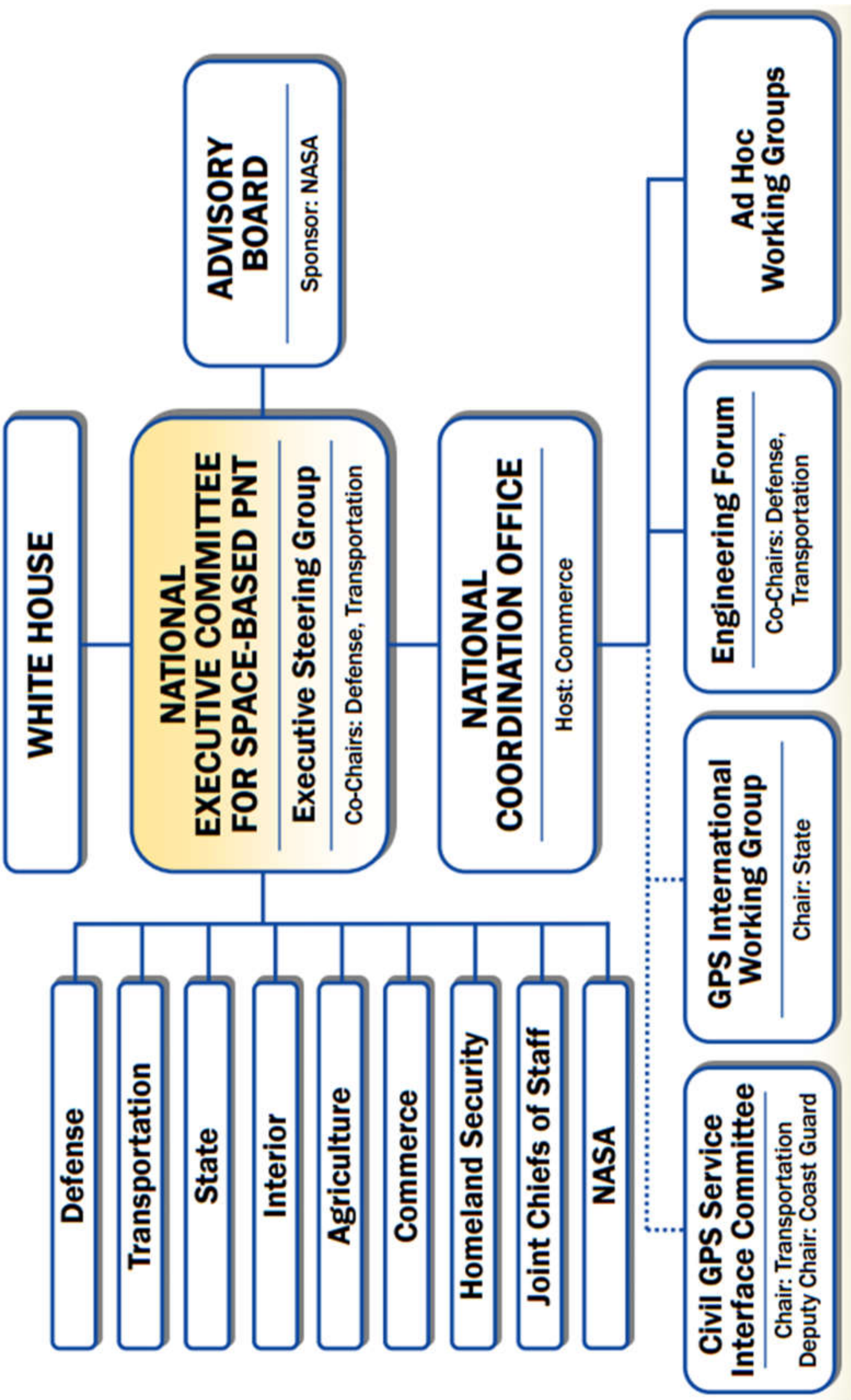
Seconded National Experts	4
Structural service providers[17]	35
TOTAL	192

A.6 Signals Broadcasted by Galileo and the other Navigation Satellite Systems



Frequencies	Navigation Services			Signals characteristics	
	OS	***CS***	***PRS***	***Ranging Code Type***	***Data Type***
E5a	X	X		Open Access	Open Access • Navigation data • UTC time reference • GPS to Galileo interoperability data
E5b **E1**	X	X		Open Access	Open Access • Navigation data • UTC time reference • GPS to Galileo interoperability data • SAR data (E1 only) • Authentication data (future) • Integrity monitoring data (future) • External data broadcast (future)
E6		X		Commercial encryption	Commercial encryption • Commercial data
E6 **E1**			X	Governmental encryption	Governmental encryption • PRS data

A.7 U.S. Organisational Structure for GPS Governance[157]



[157] "U.S. organisational structure for GPS governance." Global Positioning System 19 December 2016 <http://www.gps.gov/governance/excom/orgchart.pdf>.

A.8 List of Interviewees and Contacted Persons

List of Interviewees

Institution	Name	Position/Former Position	Interview date
EEAS	Frank ASBECK	Former Principal Advisor for Space and Security Policy	15/09/16, 16/09/16
ESA	Giuilio BARBOLANI DI MONTAUTO	Former ESA representative at the Brussels office (relations with the EU)	07/09/16
ESA	Javier BENEDICTO	Galileo Project Manager	21/09/16, 12/10/16, 14/12/16
GSA	Jeremy BLYTH	Security Accreditation Board Chairman	15/09/16
EEAS	Carine CLAEYS	Head of the Space Task Force	14/10/16
GSA	Carlo DES DORIDES	Executive Director	24/10/16
EDA	Marco DETRATTI	Project Officer Guidance, Navigation and Control at EDA /Former PRS Officer at GSA	13/10/16
EDA	Davide DI DOMIZIO	Project Officer for Space Programmes	13/10/16
ESA	Didier FAIVRE	Former Director of the Galileo Programme and Navigation-related Activities	27/07/16
GSA	Patrick HAMILTON	Head of Project Control Department	19/08/16
EC	Ekaterini KAVVADA	Former Head of Unit Galileo and EGNOS — Legal and institutional aspects/Head of Unit Galileo and EGNOS —Applications, security, international cooperation	21/09/16
EASA	Patrick KY	Executive Director	09/12/16
EC	Leopold Mantl	Deputy Head of Unit Galileo and EGNOS — Legal and institutional aspects	21/09/16
EP	Marian-Jean MARINESCU	Member of the European Parliament, Member of Committee on Industry, Research and Energy	01/12/16
EDA	Florent MAZURELLE	Former Policy officer at ESA/Policy officer at EDA	13/10/16
ESA	Philippe MICHEL	Head of the Strategy and Programme Departement of the Galileo Programme and Navigation-related Activities	17/10/16
G.Washington University	Scott PACE	Director of the Space Policy Institute at the Elliott School of International Affairs, George Washington University, Washington DC	04/11/16
ESSP (bidder GSOp)	Thierry RACAUD	Chief Executive Officer	29/07/16
EDA	Denis ROGER	Director of European Synergies and Innovation	13/10/16
French Civil Aviation Authority (DGAC)	Benoit ROTURIER	Director of the Satellite Navigation Programme	31/08/16
ESA	Paul VERHOEF	Director of the Galileo Programme and Navigation-related Activities	11/08/16
GSA	Charles VILLIE	Former European Commission EGNOS Project Manager – GSA PRS manager	24/10/16
GSA	Paul WEISSENBERG	Senior Advisor to the Executive Director	19/08/16

List of Contacted Persons

This list includes people ESPI contacted but with whom – because of the potential interviewee's timetable – interviews unfortunately did not take place.

Institution	**Name**	**Position/Former Position**
GSA	Mark BACON	Deputy Chairman of the GSA Administrative Board
EP	Etelka BARSI-PATAKY	Former Member of the European Parliament, rapporteur of the reports for a regulation on the implementation of European satellite radionavigation programmes
SGDSN	Philippe BERTRAND	Task Officer
GSA / German Ministry of Transport and Digital Infrastructure	Sabine DANNELKE	Former chairwoman of the GSA Administrative Board and Head of Division Telematics in Transport at the Ministry of Transport and Digital Infrastructure
EP	Monica HOHLMEIER	Member of the European Parliament, Chair of the Sky and Space Intergroup
EC	Philippe JEAN	Head of Unit Galileo and EGNOS — Legal and institutional aspects/ Former Head of Unit Galileo and EGNOS — Applications, Security, International Cooperation
EDA/ex Eurocontrol/Ex GJU	Caroline MANTL	Lawyer SES and SESAR at EDA/ Former Senior Legal Expert at Eurocontrol/Former Legal Expert at Galileo Joint Undertaking
German Ministry of Transport and Digital Infrastructure	Tobias MIETHANER	Head of the Department Digital Society
EC	Matthias PETSCHKE	Head of the EU Satellite Navigation Programmes Directorate

List of Acronyms

Acronym	Explanation
BDS	BeiDou Navigation Satellite System
CDA	Crypto Distribution Authority
CDMA	Code division multiple access
CEPT	European Conference of Postal and Telecommunications Administrations
CFSP	Common Foreign and Security Policy
CMS	Common Minimum Standards
CNES	Centre National d'Etudes Spatiales - French Centre for Space Studies
COMSEC	Communication Security
COSPAS-SARSAT	Cosmicheskaya Sistyema Poiska Avariynich Sudow (Space System for the Search of Vessels in Distress) - Search And Rescue Satellite-Aided Tracking
CPA	Competent PRS Authorities
CS	Commercial Service
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CONNECT	Directorate-General for Communications Networks, Content & Technology
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
DG HOME	Directorate-General for Migration and Home Affairs
DG MOVE	Directorate-General for Mobility and Transport
DLR	Deutsches Zentrum für Luft - German Aerospace Centre
DoD	U.S Department of Defense
DoT	U.S Department of Transportation
EAAS	European External Action Service
EASA	European Aviation Safety Agency
EC	European Commission
EDA	European Defence Agency
EEAS	European External Action Service
EGNOS	European Geostationary Navigation Overlay Service
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FDMA	Frequency Division Multiple Access
FOC	Full Operational Capability

Acronym	Explanation
FP7	Seventh Framework Programme, European Union research and development funding programme
GAGAN	GPS Aided GEO Augmented Navigation
GCC	Galileo Control Centres
GCS	Galileo Control Segment
GDDN	Galileo Data Dissemination Network
GDP	Gross Domestic Product
GJU	Galileo Joint Undertaking
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistyema - Global Navigation Satellite System
GMS	Galileo Mission Segment
GMSC	Galileo Security Monitoring Centre
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRC	Galileo Reference Centre
GRSP	Geodetic Reference Service Providers
GSA	European GNSS Agency (formerly European GNSS Supervisory Authority)
GSAP	Galileo Security Accreditation Panel
GSC	European GNSS Service Centre
GSMC	Galileo Security Monitoring Centre
GSOp	Galileo Service Operator
GSS	Galileo Sensor Stations
GTRA	GNSS Threat Response Architecture
HR	High Representative of the Union for Foreign Affairs and Security Policy
ICAO	International Civil Aviation Organization
ICG	International Committee on GNSS
IMO	the International Maritime Organization
IOV	In-Orbit Validation
IRNSS	Indian Regional Navigation Satellite System
ITU	International Telecommunication Union
KPI	Key Performance Indicators
LBS	Location-Based Services
MCC	SAR Mission Control Centre
MFF	Multiannual Financial Framework
MSAS	MTSAT (Multi-Functional Transport Satellite) Satellite Augmentation System
NOTAM	Notice to airmen
NATO	North Atlantic Treaty Organization
NRSCC	National Remote Sensing Center of China
OCX	(Next Generation) Operational Control System
OS	Open Service

Acronym	Explanation
PNB	Performance-Based Navigation
PNT	Positioning, Navigation and Timing
PPP	Public-Private Partnership
PPS	Precise Positioning Service
PRS	Public Regulated Service
QZSS	Quasi-Zenith Satellite System
RCC	SAR Rescue Control Centre
RNSS	Regional Navigation Satellite System
SAB	Security Accreditation Board
SAR	Search and Rescue Service
SBAS	Satellite-based augmentation systems
SDCM	System for Differential Corrections and Monitoring
SNAS	Satellite Navigation Augmentation System
SOLAS	International Convention for the Safety of Life at Sea
SPS	Standard Positioning Service
SSRS	System-specific Security Requirements Statement
TDMA	Time Division Multiple Access
TEN	Trans-European Networks Frame
TSP	Time Service Providers
TTC	Telemetry Tracking and Control
ULS	Up-Link Stations
UN	United Nations
WAAS	Wide Area Augmentation System
WAGE	Wide Area GPS Enhancement
WRC	World Radiocommunication Conference

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About the Authors

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Amiel Sitruk holds a Master of General Engineering from École des Mines de Saint-Etienne and a Bachelor of Economics from Université Jean Monnet. He is now completing a Master of International Security at Sciences Po Paris. At the European Space Policy Institute, he has been conducting research on the governance of European GNSS programmes. Previously he worked in the local CEA (Alternative Energies and Atomic Energy Commission) representation at the French Embassy in Moscow, where his analysis mainly focused on the Russian nuclear industry.

Serge Plattard

Serge Plattard is Senior Resident Fellow at ESPI, seconded from CNES, and Honorary Professor of University College London (UCL) where he lectures. He has worked lately on space governance and is in charge now of space security studies at the institute. In October 2015, he was elected Chair of the IAF Committee on Space Security. Prior to his Vienna posting, he served as Counselor for science & technology at the French Embassy in London, succeeding a three-year term as the founding Secretary General / CEO of ESPI.

After obtaining a doctorate in nuclear physics from Université d'Orsay, he conducted research at the French Atomic Energy Commission (CEA) and in the United States. He later turned to scientific diplomacy, working for the French Ministry of Foreign affairs in Paris, as well as in New Delhi, Tokyo and Washington DC. In 1998, he joined CNES as Director of International Relations.

He has been Vice-Chair of the International Relations Committee of ESA, and French Delegate at the Council of the European Southern Observatory (ESO).

Serge Plattard taught at Université d'Orsay, Université Paris-Dauphine and at the French Business School ESSEC.

He is a founding member of Euroscience and member of the International Academy of Astronautics (IAA).

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