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Galileo: Overcoming obstacles

History of EU global navigation satellite systems

SUMMARY

Galileo, the long-awaited European global navigation satellite systems, is at a turning point in its history: it reached initial operational capacity in December 2016 and is expected to be fully operational for 2021. This autonomous European civilian tool, which can be used anywhere on earth, transmits positioning and timing data from space for use on the ground to determine a user's location. Alongside it, the European geostationary navigation overlay system (EGNOS), which improves the accuracy and integrity of the American global positioning system (GPS) over EU territory, became fully operational in 2011.

Despite decades of delays, difficulties and additional costs, Galileo and EGNOS have benefited from the continuous support of all EU institutions, and the European Union (EU) decided to provide the funding needed to complete both programmes. Galileo and EGNOS became the first infrastructure to be owned by the EU.

Delays and cost over-runs can be explained through political, technical, industrial and security issues. It is estimated that by 2020, the EU and European Space Agency will have invested more than €13 billion in these programmes. This public investment, although much larger than that initially planned, matches the cost of similar programmes such as GPS, and is justified by the need for the European Union to have strategic autonomy in the field. The market uptake of the services and data provided by EGNOS and Galileo is a key priority of the European space strategy adopted in October 2016.

In this briefing:

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Establishing European global navigation satellite systems

The first time satellite navigation was mentioned by the European Parliament as one of the applications to be derived from space was in a resolution on space policy in 1981. It was still a decade later before an expert report ordered by the European Commission mentioned that navigation applications could lead to significant market growth, and that Europe could consider investing in an independent navigation system. In 1992, the Commission noted that the signal provided by the US system – the global positioning system (GPS) – could be used but needed to be improved in order to increase accuracy.

Key characteristics of GNSS

Accuracy: acceptable error in positioning.

Integrity: ability of the system to alert of any malfunctioning.

Continuity: capacity to function without interruption.

Availability: fraction of time the signal fulfils the above three characteristics.

In May 1994, the European Parliament adopted a resolution calling 'on the Commission to establish a European strategy for satellite navigation'. The following month, the Commission presented a two-track approach for satellite navigation services, with the implementation of two systems of global navigation satellite systems (GNSS):

- GNSS 1: based on the GPS signal, augmented by additional satellites and ground segments, this system would improve GPS accuracy, integrity and availability but continuity of service would remain an issue. This first system would be known as the European geostationary navigation overlay system (EGNOS);
- GNSS 2: introduced as 'a truly civil internationally controlled service to be provided to the users as a self-sufficient navigation means' to be fully defined, this second track would ultimately lead to the development of the Galileo programme.

According to the Commission, the European GNSS would be developed to satisfy civil needs within the framework of the trans-European transport networks (TEN). The design of the systems would be funded under the fourth framework programme (FP) for research and development (R&D). The systems would be developed in cooperation with the European Space Agency (ESA) – which was already investing in satellite navigation under its R&D programme – and with Eurocontrol, which had called for 'the implementation of satellite navigation as a sole-means navigation system for all phases of flight'.[1]

The Council validated the two-track approach in December 1994, inviting the Commission 'to examine the potential for private-sector financing of these activities'. It added that the initiative would raise EU industry competitiveness in the GNSS sector. The Parliament also supported the Commission approach in January 1995.

Nevertheless, the Commission noted in 1996 that the dual-use potential of GNSS 'make it very difficult for a purely private initiative' and that 'only a government-industry partnership has a chance to provide a breakthrough'. That year, the Council and the Parliament adopted a decision including satellite positioning and navigation systems in the trans-European transport networks, opening funding opportunities for the GNSS.

In January 1998, the Commission adopted a strategy for the development of the European GNSS. EGNOS was seen as a first step but the Commission noted that European autonomy was important in the long term for security reasons, and that industrial capacity was at risk without an EU programme. Regarding the development of GNSS 2, the Commission acknowledged that the best option was to develop a global system, by the EU and all of its international partners. In the event that such an endeavour did not

succeed, the EU would have to opt for an independent European GNSS. The European Parliament approved this strategy in 1999.

The European Community, ESA and Eurocontrol signed an agreement to guarantee a coordinated approach to the development of the European contribution to a global navigation satellite system in June 1998. The agreement covered the development of EGNOS and the preparatory work for the definition and design of GNSS 2.

Bringing Galileo to full operational capacity

In a communication on the implementation of GNSS 2, the European Commission recommended the EU develop its own independent infrastructure for satellite navigation compatible with GPS, in February 1999. The programme – called Galileo – would cost between €2.2 and €2.9 billion and be implemented under a public-private partnership (PPP). Galileo would be developed in three phases: definition (1999-2000), development and validation (2001-2005) and deployment (2006-2008).

Working principles of Galileo

The Galileo system is based on a constellation of 24 satellites (plus six spares) positioned in three circular medium-earth orbits (MEO) at an altitude of 23 222 km). With this configuration, at least four satellites are visible from any given point on earth at any time. This constellation is complemented by a ground infrastructure, including two control centres to manage the satellites and sensor stations worldwide. They help to validate the time and positioning data, to confirm the accuracy and integrity of the signals. The data received from four satellites enable a receiver device to calculate its position on earth with a precision of about one metre.

First phase: definition

The Council adopted a resolution launching the definition phase of Galileo in July 1999. ESA was in charge of the technical design of the programme,[2] and the European Commission of the framework conditions for the PPP to fund the programme. The Council required the programme to be funded largely from private sources.

The Commission published the results of the definition phase in November 2000. Galileo would be made up of a constellation of 30 satellites. In the long term, EGNOS would be integrated with Galileo. The cost of the programme was evaluated at €3.2 billon, to be covered by public funds (€1.1 billion) for the second phase, and by the private sector (€1.5 billion) and the public sector (€600 million) for the third phase. The private sector would manage the infrastructure once operational. The Commission identified additional sources of revenue based on Galileo services.

The European Council validated this plan in Nice in December 2000, and the Council agreed on some arrangements in a resolution on Galileo in April 2001. The next phase required the establishment of an entity to be in charge of the management, administration and financial control of the project. While discussions over this structure and the following phases were ongoing, the US Deputy Secretary of Defense requested that European defence ministers reconsider the Galileo programme on the grounds that it would pose defence issues.[3] The launch of the development phase of Galileo was nevertheless approved by the Council in March 2002 with an agreement that the private sector should cover most of the cost of the deployment phase.

Second phase: development and validation

In May 2002, the Council adopted a regulation to set up a Galileo Joint Undertaking (GJU) and entrust it with two key missions:

- to oversee the implementation of the second phase. The GJU would manage the financial contribution of the EU and launch, under an agreement with ESA, the research and development activities needed for this phase;[4]
- to prepare the framework for the final phases of Galileo under a PPP. The GJU was to conduct the tendering process with the objective of selecting a private consortium to carry out these phases and negotiate the concession contract with the consortium.

The ESA Council had to overcome difficulties related to the adoption of its budget for Galileo and, especially, the return expected for national industries. In May 2003, an agreement was finally adopted by the ESA Council, and the GJU became operational in summer 2003. At the beginning of 2004, the Commission reported that the first experimental satellite was under construction. The integration of the new EU Member States in the programme was well under way, as well as international cooperation, especially regarding compatibility with the American GPS and Russian GLONASS.[5]

The four services of Galileo

Open service (OS): open and free-of-charge service for positioning and timing services.

Commercial service (CS): improved OS service with additional navigation signal and possibility of encryption.

Public regulated service (PRS): Service restricted to government-authorised users, for sensitive applications that require a high level of service continuity.

Search and rescue service (SAR): European contribution to the international search and rescue distress alert detection system (COSPAS-SARSAT).

An initial fifth service, the Galileo 'safety of life' service was re-profiled in 2010, and then abandoned in 2013.

The first part of the development phase consisted of the launch of the two Galileo in-orbit validation elements (GIOVE) satellites in December 2005 and April 2008. GIOVE A and B allowed the validation of the allocation of the frequencies as required by the International Telecommunication Union (ITU) and the overall technical requirements for the programme.[6]

While the technical development of the programme was under way, the Commission and the GJU were preparing for the deployment phase of Galileo. In July 2004, a Council Regulation established the European GNSS Supervisory Authority (GSA) as the European agency to be in charge of supervising the next phases of the programme. While the GJU would select the private consortium to implement the deployment phase, the GSA would conclude the concession contract with the consortium and ensure compliance with the obligations in the contract. It would ensure the defence of public interests were met and supervise the use of the public funds allocated to European GNSS programmes. The GSA was to be the owner of the Galileo infrastructure and was also in charge of the safety and security aspects of the GNSS. The Council also adopted at the same time a joint action regarding the security of Galileo.

In July 2004, the Commission adopted its proposal for the management and funding of the deployment and operational phases. The public sector would have to add around €500 million to the operational phase, reaching a total budget of €1 billion for the 2007-2013 period.

The call for tenders to select the concessionaire for Galileo was launched in October 2003. In December 2003, four consortia were registered as eligible by the GJU. This number was first reduced to three in February 2004, then to two in September 2004. With the GJU delaying the final decision,[7] the two consortia finally presented a joint proposal in June 2005. The negotiation of the 20-year concession contract was supposed to end in December 2005 but was delayed because of disagreements on three major issues:

- design risk: the development phase was not yet finished and uncertainties remained regarding potential failures of the system;
- market risk: revenues were still uncertain to ensure a good return on investment for the private sector;
- third-party liability: the private sector wanted guarantees covering the liability linked to accidents that might occur due to potential failure of the system.[8]

In the meantime, the second part of the development phase consisted of launching four in-orbit validation (IOV) satellites that would be part of the final constellation. These four satellites would allow the validation of the whole system including the ground segment. In January 2006 the contract for the development of the four satellites was signed between ESA and the Galileo Industries consortium.[9]

In June 2006, the timetable for the programme was modified: the development phase was to last until 2009 and the deployment phase was to be completed by 2010. The budget of the development phase was increased to €1.5 billion for the public sector. In December 2006, a Council Regulation was adopted to end the activities of the GJU on 31 December 2006, leaving the GSA as the negotiating entity taking over the GJU tasks.

Necessity to re-profile the programme

Negotiations on the concession contract stopped in early 2007. On 7 March, the merged consortium voiced its concerns on 12 points. A week later, in a letter to the Council presidency, Commission Vice-President Jacques Barrot stated that he had asked the consortium to set up a single Galileo operating company by 10 May in order to complete negotiations by September 2007. The Council approved this deadline in March 2007 and the Parliament renewed its support for the programme in April 2007.[10] The consortium decided to pull out in May 2007, so the Commission had to redefine the programme.

A Commission communication pointed out that the market risk had been 'clearly underestimated in the original plan for Galileo' and that 'the industrial and public governance have proven to be a major factor' in the situation. Mentioning 'the inability of the merged consortium to effectively manage the process', the Commission invited the Council and the Parliament to conclude that the negotiations regarding the PPP should be ended. However, the Commission confirmed that the programme should be maintained, and developed alternative scenarios for its completion. In June 2007, the Council approved these decisions and the Parliament supported the option of the Union fully financing the programme. The European Council asked the Council to take a decision on the programme in autumn 2007.

In September 2007, the Commission proposed its favoured option for the re-profiling of the Galileo programme. The estimated budget for the deployment phase, to reach full operational capacity, was estimated at €3.4 billion, to be fully provided by the Union. The governance would be clarified: the Commission would be responsible for the management of the programme; ESA would be the procurement agent (*maitre d'oeuvre*) under a delegation agreement, taking technical responsibility for the programme; while the role of the GSA would be reviewed to focus on the market preparation.

The Commission's 2004 proposal had provided €1 billion to the programme, already included in the multi-annual financial framework (MFF) for 2007-2013 adopted in June 2006. The re-profiling of the programme meant that the MFF would have to be amended in order to provide an extra €2.4 billion for the GNSS programmes. The Council and the Parliament approved the budget for the programme in December 2007, with the

support of the European Council, and the new regulation for the GNSS programmes in July 2008. Under this regulation, the Union became the owner of the GNSS infrastructure and all intangible assets of the programmes.

Despite a six year delay, Galileo was back on track after the joint efforts of the EU institutions. Full deployment was then planned for 2013. The Galileo Interinstitutional Panel was set up in order to oversee progress.

Deployment phase

The Commission published the call for expressions of interest for the six packages of the Galileo infrastructure in July 2008. Otto Hydraulik Bremen (OHB), a listed German company, won the first order for 14 satellites in January 2010, with the objective to deliver the first one in July 2012. Arianespace would provide the launch services, with the first launch in October 2012. OHB signed a second order of 8 satellites, in February 2012.

The launches of the four IOV satellites were planned for November 2010 and April 2011. However, the first two were launched only in October 2011 and the remaining two in October 2012. These delays were due in part to the need to modify the satellites to remove Chinese-built payloads following the Commission decision that non-European payloads would not be allowed on Galileo. Tests started in May 2013 led to the in-orbit validation of Galileo at the end of October 2013, closing the development phase.

In parallel, the re-profiling of the programme implied reviewing the role of the GSA. In March 2009, the Commission adopted a proposal for a regulation to increase its control over the GSA and provide it with the responsibility for providing security accreditations for the GNSS. The Parliament and the Council adopted the regulation in September 2010 and the GSA was renamed European GNSS Agency.

Preparing the market for Galileo applications

To prepare the market uptake of the services provided by Galileo and EGNOS, the Commission adopted an action plan on GNSS applications in June 2010. The action plan listed 24 actions, such as making receivers compatible with Galileo and EGNOS, launching awareness campaigns in various sectors (aviation sector, maritime equipment manufacturers, agriculture and natural resource management activities, civil protection), adopting regulations promoting the use of GNSS and funding research activities. The Council welcomed the plan in October 2010, and the European Parliament agreed that the action plan was the 'best option for giving a further impetus to the development and application of EGNOS and Galileo'.

The public regulated system

This encrypted navigation service provides a signal that offers better continuity and availability to governmental users. The signal can be used by emergency services or customs, and also for defence applications. Based on a Commission proposal, a decision adopted in October 2011 provides unlimited and uninterrupted access to the PRS to the Commission, the Council, the European External Action Service and the Member States worldwide. Agreements are required to grant access to EU agencies, non-member countries and international organisations. The decision also covered the rules concerning the manufacturing, ownership and use of PRS receivers.

Mid-term evaluation of the GNSS programme for 2007-2013

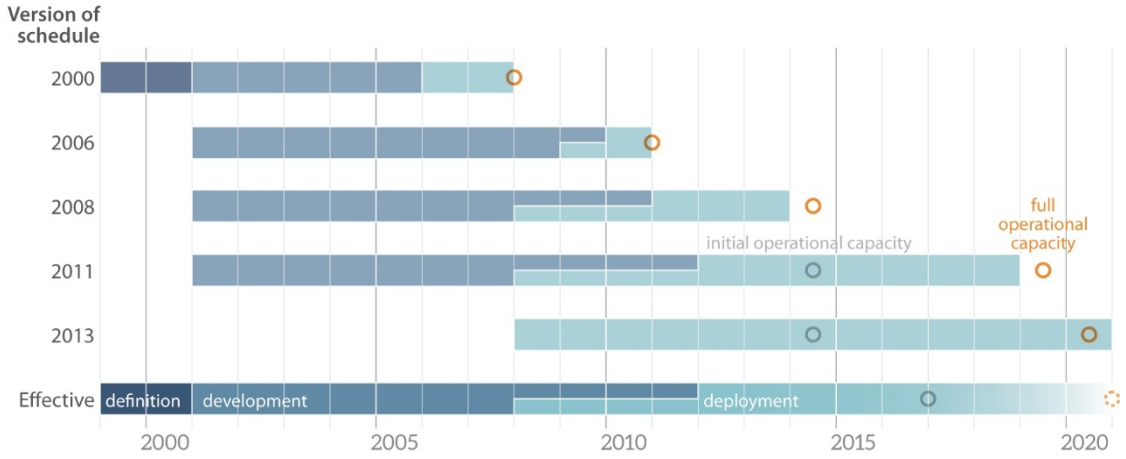
In 2011, the mid-term evaluation by the Commission reported that the system would not be operational before 2014-2015, and that €1.9 billion of additional funding would be necessary over the 2014-2019 period in order to complete a Galileo infrastructure of

30 satellites. These delays and additional costs were justified by unforeseen technical issues to answer 'fresh challenges arising from the materialisation of a number of risks' and the evolving security needs for the infrastructure.

The Commission added that the previous envelope of €3.4 billion was insufficient because of extra costs of the development phase, the increased price of launchers and lack of competition for some work packages. The Commission also evaluated the yearly cost under the operating phase for Galileo and EGNOS at €800 million.[11] Initial operational capacity (IOC) of Galileo was expected for 2014 while full operational capacity (FOC) was delayed to 2019-2020.

In March 2011, the Council took note of the delays announced by the Commission, asked it to review its estimate for the budget increase and requested all actors to avoid any further cost over-runs (Figure 1). In June 2011, the Parliament renewed its support for the programmes, requested FOC to be reached in 2018, and asked for the governance to be reviewed and for the Commission to introduce risk-mitigation policies to keep the costs under control.

Figure 1 – The evolution of Galileo's timetable



Data source: Elaboration on European Commission documents. IOC/FOC: initial/full operational capacity

Current situation of the programme

Funding under the 2014-2020 MFF

Following the mid-term review of the programme, in November 2011 the Commission adopted a proposal for the implementation and exploitation of the GNSS services for the 2014-2020 period. The Commission pointed out the need to set up an effective risk-management system to cover cost over-runs and delays. To reduce the costs and delays, the Commission proposed abandoning the Safety of Life (SoL) service – this service was already provided by EGNOS. It also proposed to review the governance of Galileo by further modifying the role of the GSA.

The updated regulation on GNSS was adopted by the Council and the Parliament in December 2013. The €7.072 billion attributed to the programmes under the 2014-2020 MFF were broken down between:

- completion of the deployment phase of Galileo (€1.930 billion);
- exploitation phase of Galileo (€3 billion);
- exploitation of EGNOS (€1.58 billion); and
- management of the programmes (€562 million).

The regulation confirmed the Galileo SoL service was being abandoned. IOC was expected in 2014-2015 and FOC for 31 December 2020. The security of the programmes became a major concern leading to the adoption of a Council Decision in July 2014. The rules of public procurement were reviewed in order to take better into account the risks and uncertainties inherent in the programmes. The governance was modified with the roles of the Commission, the GSA and ESA being redefined. The GSA was to be responsible for the operational management of the programmes and security accreditations, implying a review of the GSA Regulation adopted in April 2014.

In December 2013, the regulation establishing the framework programme for research – Horizon 2020 – attributed an additional €400 million of funding to support Galileo services and applications, and R&D activities regarding the evolution of Galileo infrastructure (this last part being delegated to ESA).

Additional delays in production and launch

In 2013, OHB had still not delivered the first satellites due for 2012. It appeared that OHB, which had not participated in the building of the first six satellites, lacked experience and adequate technical management. The ESA asked Astrium and Thales Alenia Space to support OHB in order to overcome the difficulties. The first two satellites were launched in August 2014. However, the launch failed to place the satellites on the right orbit. They were later moved to more suitable orbits, where they are still under test in order to decide if they can be integrated in the system.

From IOC to FOC

The 12 other satellites of the first batch were successfully launched between March 2015 and November 2016. With 15 satellites fully operational out of the 18 in orbit,[12] the Commission and ESA inaugurated Galileo IOC on 15 December 2016. The launch of the first four satellites of the second batch is planned for November 2017. The procurement of the third batch of satellites to complete the constellation (eight satellites and six optional satellites) was opened in December 2015 and should be completed in 2017. FOC is still expected to be effective in 2020. In January 2017, ESA reported clock anomalies on five of the Galileo satellites in orbit, but this does not compromise any of these satellites nor the system as a whole.[13]

Making the most of EGNOS complementarity

First steps

Following the 1994 Commission communication on GNSS, the Council had approved the development and implementation of EGNOS in December 1994. It adopted conclusions in March 1995 and measures were taken swiftly to implement EGNOS. Transponders were integrated into two Inmarsat telecommunication satellites launched in 1996 and 1998, providing the basis for the space segment of EGNOS. The agreement signed in 1998 between the European Community, ESA and Eurocontrol – the European tripartite group (ETG) – mainly covered the implementation of EGNOS. Eurocontrol was expected to provide the civil aviation requirements in cooperation with the International Civil Aviation Organization (ICAO), while ESA was charged with the technical development of the system and its validation. The EGNOS Operator

The three services of EGNOS

Open service (OS): open and free of charge service for positioning and timing services (since 2009).

Safety of Life (SoL): service for safety-critical transport applications such as civil aviation which require an integrity warning system (since 2011).

EGNOS Data Access Service (EDAS): terrestrial commercial service to provide the EGNOS signal through the internet to registered users that are not in sight of the EGNOS satellites (since 2012).

Infrastructure Group (EOIG) was set up to support the development of the infrastructure and was to become the operator once the system was ready.[14]

In January 1998, the Commission expected EGNOS initial service to be provided in 2000, and the more safety-critical services to be operational in 2003.

Working principle of EGNOS

EGNOS is based on a network of about 40 ground stations all over Europe receiving the GPS positioning signal. As the position of these stations is known precisely, four master control centres calculate the correction that has to be applied to the GPS signal locally in order to improve its accuracy, from a few metres down to one metre. The deviation data obtained are transmitted by six up-link ground stations to three geostationary satellites that transmit it back to all GPS users equipped with an EGNOS-enabled receiver. However, the main feature of the system is that EGNOS is able to certify the integrity of the GPS signal. In case of errors in position measurements or disruption of the GPS signal, EGNOS warns users within six seconds so that they can disregard positioning information. This enhanced integrity is essential for aeroplane landings for example. EGNOS signal is available more than 99 % of the time across most of EU territory.

Integrating EGNOS into Galileo

The Galileo design presented in February 1999 included a safety of life service that was one of EGNOS' key components. EGNOS would be operational before Galileo but it appeared that they would ultimately provide similar services. In July 1999, the Council invited the Commission to provide for the optimal integration of EGNOS into Galileo. The task of overseeing this integration was delegated to the GJU when it was set up in 2002.

In March 2003 the Commission adopted a communication on the integration of EGNOS into Galileo. EGNOS would constitute a first step to establishing the Galileo SoL service and to prepare the market for Galileo applications. The Commission had already invested €116 million in EGNOS, while the EOIG had provided €100 million. The full cost of EGNOS would be €330 million and its annual operating costs €33 million for the 2004-2007 period. Acknowledging the delays, the operational phase was to start in April 2004.

As far as the integration was concerned, EGNOS would be managed by the same concession holder as Galileo once selected by the GJU. In the meantime, an agreement should be concluded with an economic operator to run EGNOS. This was supported by the Council in June 2003 and by the European Parliament in January 2004. When the GSA was established in 2004, it was planned that the ownership of EGNOS would be transferred from ESA to the GSA, and that the GSA would inherit the responsibility to manage the agreement with the economic operator.

Re-profiling with Galileo

EGNOS infrastructure was completed in July 2005 and EGNOS passed its first operational readiness review. In 2006, discussions were ongoing to transfer EGNOS to the GSA. The Commission had provided €143 million of funding for the programme under the TEN. In 2007, the re-profiling of Galileo affected EGNOS, expected to enter into service in 2008. EGNOS and Galileo would be merged in a single programme and financed entirely with public funds. The Commission then noted that EGNOS costs were so far estimated at €700 million for the EU and ESA, as well as additional costs of €330 million for the 2008-2013 period. The budget of EGNOS was increased due to unforeseen complexities in the system, and to the fact that the aviation sector requested triple redundancy within the system to ensure back-up in case of the failure of one element. This implied the tripling of the ground infrastructure, increasing the costs.

The regulation adopted in 2008 confirmed these changes, with the EU becoming the owner of the two programmes. The EGNOS infrastructure was handed over from ESA to the Commission on 1 April 2009.[15] The Commission contracted EGNOS Satellite Service Provider (ESSP) as the company in charge of operations and service provision of EGNOS.

Table 1 – Estimated Galileo and EGNOS budget from the EU and ESA (in € million)

Year	Total	Galileo				EGNOS	Other
		Definition	Development	Deployment	Operation		
EU							
1990s	42.5	42.5				?***	
2000	550		550				
2007 2008	1 000 2 480		560	2 407		417	96
2013	7 072			1 930	3 000	1 580	562
FP*	603.5						603.5
Total EU	*11 748*	*42.5*	*1 110*	*4 337*	*3 000*	*1 997*	*1 261.5*
ESA**	1 496	86	1 075			273	62
TOTAL	**13 244**	**128.5**	**2 185**	**4 337**	**3 000**	**2 270**	**1 323.5**

Data source: Elaboration on European Commission and ESA data and documents. * FP: Budgets attributed under the framework programmes for research related to GNSS programmes - FP5 (1998 - €37 million), FP6 (2002 - €100 million), FP7 (2006 - €66.5 million) and Horizon 2020 (2013 - €400 million). FP4 (1994) also covered research projects for the development of EGNOS receivers with an amount estimated at €5-10 million (not included here). ** The budget contribution from ESA is based on ESA data covering only the 1995-2012 period. Funding provided for Galileo represents twice the initial budget of €500 million adopted by the ESA Council in 1999 for the 1999-2005 period. *** The EU budget for the first years of EGNOS remains unclear. In 2003, the Commission mentioned €116 million invested in EGNOS, and in 2007 it estimated that €700 million had already been invested in EGNOS by the EU and ESA. The budget here does not take into account non EU/ESA contributions like the €100 million contribution from the EOIG.

Operational phase

EGNOS open service became operational on 1 October 2009, and the SoL service for aviation was launched on 2 March 2011. In 2011, the Commission noted that €417 million would be devoted to EGNOS between 2007 and 2013, and planned an annual budget for operations and maintenance of €110 million for 2014-2020. The Commission also proposed to adapt EGNOS to enhance the open service signal provided by Galileo once operational. The commercial service EDAS became operational in July 2012.

The cancellation of the Galileo SoL service to reduce costs and delays with the adoption of the new GNSS Regulation in 2013 meant that EGNOS would remain the only system providing the SoL service. EGNOS and Galileo would be maintained as two separate systems sharing a limited set of infrastructure. The regulation provided EGNOS with a budget of €1.58 billion for the 2014-2020 period. The changes in the governance of European GNSS implied that the GSA would replace the Commission in managing EGNOS. In 2014, the GSA contracted the ESSP for the service provision of EGNOS until 2020. In July 2015, the Commission adopted an implementing decision in order to update EGNOS and implement the third version of the system to improve the geographic coverage[16] and enhance performance. In September 2015 a new step regarding EGNOS SoL service was achieved with the approval of a new service for aviation called LPV-200, reducing delays, diversions and cancellations in aeroplane landings. EGNOS could also replace traditional systems that required expensive ground infrastructure. The first landing approach using this system was performed on 3 May 2016.

Overview of the key issues

EGNOS was planned to be operational in 2003 for a budget of €300 million, and Galileo was expected to be fully functional in 2008 with a budget of €3.2 billion (including a public contribution of €1.7 billion). EGNOS became operational in 2011 with an eight-year delay, while Galileo should be fully operational in 2021 after a 13-year delay. The estimated combined EU and ESA budget for these programmes up to 2020 is now over €13 billion (see Table 1). For comparison, the updated version of GPS is expected to cost about US$18 billion.[17] Various studies[18] have pointed out key reasons for these delays and costs:

- **Political issues** between Member States regarding the rationale of the programmes and the funding model.
- **Specificities of the space sector industry and the difference in public procurement between the EU and ESA**. ESA procurement is based on geographical *'juste retour'* while EU procurement is based on competition. This led to divisions between companies but also between Member States, which intervened in the interest of their national industries and held up decisions. The PPP was inadequately conceived and the assumptions for its implementation were based on unrealistic revenue. The reliance on one single contractor for the delivery of the different work packages (especially the satellites) also created delays where dual-sourcing would have limited the risks. Finally, some players in the space industry found themselves in a monopoly situation (such as for launch services) which led to increased prices.
- **The complexity of the GNSS systems** that would have required the implementation of a risk-management system.
- **Security and defence implications** led to disputes between Member States but also created additional delays and costs as the design of the systems were reviewed to accommodate changing security needs defined by the Member States.
- **Governance issues**. The GJU was not a strong manager of the programme during the first phases and the Commission did not provide adequate leadership. The roles of the different actors (EU, ESA, their member states, the GJU and the GSA) were not clearly defined. Moreover the EU budgetary framework complicates long-term planning of projects running over several decades. The multi-actor governance also implies that each entity relies on competent staff in a sector where competition for human resources is sharp.

The development of the other global GNSS systems in the world have been managed by a single national defence agency. The European situation is specific, with a complex governance set-up in the space sector that constitutes a key issue of European space policy. The governance for GNSS programmes remains non-optimal, and changes could be envisaged in the future.

Main references

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Endnotes

1 Eurocontrol had created its satellite communication, navigation, surveillance (SATCNS) working group in 1991.

2 The ESA Council adopted an envelope of €500 million in May 1999, for the definition and development of Galileo.

3 The letter from Paul Wolfowitz was addressed to the ministers of defence in EU countries that were NATO members. He claimed that Galileo signals might interfere with the military GPS signals and conveyed his concerns about the security implications of this civilian programme.

4 The GJU could also have benefited from funding from the private sector but this never materialised. It did receive financial contributions from third countries (China in 2003 and Israel in 2004).

5 An agreement was signed with the US on 26 June 2004 (reviewed in 2011) regarding the interoperability of the European and American systems. This implementation of interoperability was also a source of additional technical delays in the programme. A cooperation document was signed with Russia in March 2006.

6 The allocation of radiofrequencies for Galileo was approved by the ITU at the World Radiocommunication Conference in 2000 (Resolutions 605, 606 and 607) and in 2003 (Resolution 609).

7 A communication by the Commission in October 2004 stated that the GJU 'had successfully completed the procedure for selecting the future concession older'. However its decision was postponed several times.

8 The Commission launched an initiative to introduce a regulation on third party liability in 2011 that was abandoned.

9 European Satellite Navigation Industries (ESNIS, often referred to as Galileo Industries) was a consortium of European companies including Thales Alenia Space and EADS Astrium.

10 The European Parliament had already adopted a resolution to support for the programme in 2006.

11 This figure includes the costs linked to the progressive replacement of the space and ground infrastructure in order to update them, as satellites for example are designed to have a 12-year service life.

12 One of the first IOV satellites has been unavailable since May 2014. The two satellites placed on a wrong orbit are operational for the SAR but still under test for the other services. A decision on their status should be taken in 2017. The four satellites launched in November 2016 are operational but still under commissioning. They should be fully integrated in the system for users before summer 2017. Until then, the system relies on 11 satellites.

13 Each Galileo satellite carries four atomic clocks under a quadruple redundancy plan. Anomalies have affected one or two clocks on the affected satellites.

14 The EOIG was composed of national airports and air navigation service providers and the French space agency (CNES). The Commission, ESA and Eurocontrol could not be operators of EGNOS. The EOIG constituted a first step to creating this operator and involving the aviation sector more. They committed to cover one third of the planned cost of EGNOS (€300 million at that time). In 2001 they set up the European Satellite Services Provider (ESSP) as a European economic interest group. ESSP became a limited liability company in 2008, and EGNOS operator in 2009.

15 ESA could not bear the third-party liability associated with EGNOS and could not remain the owner of the structure.

16 EGNOS would then cover the Azores, Canary Islands and Madeira. Coverage of third countries is possible but funding to extend the system to third countries cannot be provided by EU funds.

17 GPS III includes 32 satellites and an update of the ground segment of GPS. The cost estimate is based on the costs mentioned by the United States Government Accountability Office in 2015, procurement from the Air Force budget 2017 and estimates of the launch costs based on the SpaceX contract for the first launches.

18 The main sources for this section are the 2009 European Court of Auditors report, a 2010 College of Europe study, a 2011 European Parliament policy department study, the Commission 2011 mid-term review of the GNSS programmes, a 2015 French Court of Auditors report, and a 2017 European Space Policy Institute report.

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