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POLICY DEPARTMENT
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Economic and Monetary Affairs

Employment and Social Affairs

Environment, Public Health and Food Safety

Industry, Research and Energy

Internal Market and Consumer Protection

Space Market Uptake in Europe

Study for the ITRE Committee



DIRECTORATE GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

Space Market Uptake in Europe

STUDY

Abstract

This study, provided by Policy Department A at the request of the ITRE committee, aims to shed light on the potential applicability of data acquired from the EU Galileo and Copernicus satellite systems in both the public and private sector, and on the reasons why such potential still remains largely underutilized. The regulatory framework, market characteristics and policy actions that are being taken to make use of space data, are comprehensively analysed. The study also addresses recommendations for different policy levels.

This document was requested by the European Parliament's Committee on Industry, Research and Energy.

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LIST OF ACRONYMS

| | |
|-----------------|---|
| EARSC | European Association of Remote Sensing Companies |
| EEA | European Environmental Agency |
| EEAS | European External Action Services |
| EC | European Commission |
| EGNOS | European Geostationary Navigation Overlay Service |
| EO | Earth Observation |
| EP | European Parliament |
| ESA | European Space Agency |
| EU | European Union |
| EUMETSAT | European Organisation for the Exploitation of Meteorological Satellites |
| GEOSS | Global Earth Observation System of Systems |
| GDP | Gross Domestic Product |
| GMES | Global Monitoring for Environment and Security |
| GPS | General Positioning System |
| GNSS | Global Navigation Satellite System |
| GSA | Global Satellite Agency |
| LBS | Location Based Services |
| MFF | Multiannual Financial Framework |
| NASA | National American Space Agency |
| NOAA | National Oceanic and Atmospheric Administration |
| OECD | Organization for Economic Co-operation and Development |
| OP | Open Service |
| SAR | Synthetic Aperture Radar |
| SATNAV | Satellite Navigation |
| TFEU | Treaty on the Functioning of the European Union |
| US | United States (of America) |
| VHR | Very High Resolution |

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EXECUTIVE SUMMARY

Background

The launch of the European Union (EU) Space Policy in 2007 gave a new momentum to the implementation of the two European space flagship programmes Copernicus (Earth Observation) and Galileo (GNSS - Global Navigation Satellite System). Whereas Galileo is still in its deployment phase, Copernicus has already entered the exploitation phase. So far, roughly EUR 6 billion have been funded by the EU for the design and development of the two programmes and more than EUR 11 billion have been earmarked in the 2014-2020 programming period.

Key rationales for EU intervention in the space sector include: i) the need to develop an independent European space satellite infrastructure, ii) the advantage of putting together resources and expertise from ESA and Member States, and iii) the opportunity to benefit from the development of a satellite-based services and products that would contribute to the achievement of the Europe 2020 objectives¹.

Objective and methodology of the study

Dissemination and exploitation of space data across the EU is currently constrained by manifold barriers which prevent the market of space data from growing. This study aims to assess the current state of development of the European downstream space market, and also shed light on the potential use of services and products based on space data and information in both the public and private sector.

The study is grounded on a desk and field analysis that aims at putting together a diversified spectrum of opinions to reduce the bias related to the interests of specific groups. A total of 30 people were interviewed among which policy makers and public authorities at EU level, the European and national Space Agencies, representatives of the space industry and regional public authorities, experts and users.

To draw lessons for Europe, the experience of the United States (US) in supporting the development of applications and services based on space data is also reported in a comparative perspective. The analysis is complemented by five case studies that illustrate how the data and information available from Copernicus and Galileo can be used for developing public and commercial products and services in different sectors.

Downstream market segments

Space data can find a variety of institutional and commercial applications in many market segments. In the area of navigation system, applications are currently dominated by two major areas: in-vehicle satellite navigation and hand-held location based services. The GNSS downstream market has been growing fast in the past years and has still a great potential to grow. Demand mainly originates from the private sector. Currently the signal is provided by the US Global Positioning System (GPS). Once fully developed and available, supposedly by 2020, the Galileo signal, combined with the GPS, will bring large improvements in terms of precision and reliability of the service.

Copernicus offers services for the following domains: natural resource management, land monitoring, oceanography, meteorology, defence and security (including disaster

¹ 'Europe 2020' is the European Commission's strategy for a smart, sustainable and inclusive growth (Brussels, 3.3.2010, COM(2010) 2020).

management and humanitarian action). Generally, demand for EO data and information is driven by the public sector to develop services that benefit citizens, public administrations and businesses. Sectors where the potential for developing commercial services is higher include precision agriculture, insurance services and oil and gas exploration activities.

The European downstream space market is highly fragmented. Besides a very limited number of large players, mostly vertically integrated space companies, the market is made up of many specialised micro, small and medium enterprises that mostly works for local suppliers. The US IT giant, such as Google, have had so far a dominant position in handling, processing and distributing EO data to a large audience of users.

Barriers to space market uptake

Although progress in the market update of EO and GNSS-based services has been fast, the uptake of the European downstream space market has been so far below expectations and is still largely below the level attained by the US. Several barriers have constrained the development of this sector, including policy barriers, market constraints, governance difficulties, technical issues and, to a lesser extent, lack of skills (Table 1).

Delays in satellite launches and insufficient industrial policy support actions are the most critical barriers preventing the development of value added products based on Galileo services. Differently, a weak data distribution system, combined with a complex governance framework, are the most critical factors holding back a faster development of products and services based on Copernicus data.

Table 1: Barriers to space market uptake

| Type of barrier | Barrier | Galileo | Copernicus |
|-------------------------------|---|-----------------|-----------------|
| Policy/strategy issues | Lack of an EU space industrial policy | <u>High</u> | <u>High</u> |
| | Insufficient and delayed support actions for the downstream sector | <u>Critical</u> | <u>High</u> |
| Market issues | Fragmentation of EU space markets | <u>High</u> | <u>High</u> |
| | Insufficient public and private demand | Low | <u>High</u> |
| | Dependency of the downstream market from non-EU technologies | <u>High</u> | <u>High</u> |
| Governance | Non-systematic involvement of industry representatives | Medium | <u>High</u> |
| | Complex governance framework | Nil | <u>High</u> |
| | Insufficient collaboration amongst Member States | Nil | Medium |
| Technical issues | Other possible implementation delays | <u>Critical</u> | Low |
| | Weak data and product distribution system | Nil | <u>Critical</u> |
| | Interoperability | Nil | Medium |
| | Differences in space data access across EU | Nil | Medium |
| Lack of skills | Shortage of technical skills to manage space data, resistance to change | Low | Medium |

Source: Authors.

Existing instruments for promoting space market uptake

Different instruments have been put in place by the European Commission to promote the uptake of a market based on the use of space data. These include: (i) an increasing budget dedicated to space research for the development of innovative and marketable products and services; (ii) legislative actions creating an incentive for a larger use of space satellite data by public and private users, such as the e-call system Directive² making the introduction of GNSS-enabled in-vehicle technology mandatory; and (iii) dissemination activities to raise awareness about Copernicus and Galileo programmes and encourage the use of space data amongst EU citizens, public systems and businesses. All these initiatives have advantages and disadvantages that are illustrated in this report. In parallel, Member States have developed their own initiatives to encourage a larger use of space data. For instance, the United Kingdom and France have been developing national space data hubs to improve the existing European data distribution infrastructure. The European Space Agency is supporting the development of marketable applications through its Business Incubation Centres.

Recommendations for future policy action

Although the EU support to space data market uptake has increased in the recent years, higher efforts are needed to tackle the barriers currently constraining the market development and to maximise the benefits for the industry and the citizens. Overall, there is need for a long term explicit and common EU space industrial policy for the development of the downstream market, setting clear objectives and targets. To this end, an enhanced coordinating role of the EU could better help reap the benefits of Member States and ESA systems that currently run separately or in parallel. “Soft” measures which build on existing arrangements should be promoted as much as possible before introducing new instruments or additional regulatory requirements.

More specifically, different lines of actions are possible at different levels, from strategic initiatives to more technical ones, as summarised in the next Table.

Table 2: Recommendations

| Level of action | Recommendation |
|-------------------------|--|
| Policy/ strategy | Develop an EU space industrial policy |
| Market | Combined support to space research and business development programmes (incubators, venture capital) |
| | Harmonization of national procurement rules |
| | Review of the existing EU legislation to understand where space data can be used |
| | Awareness raising activities |
| Governance | Enhanced coordinating role of the EU |
| | Include the perspective of users/business in developing Copernicus services |
| Technical level | Avoid further delays in the deployment of the Copernicus and Galileo programmes |
| | Reinforce the IT solutions to distribute EO data, including pre-processed EO products |
| | Harmonise the access to national space data |
| | Provide equal access to EO data across EU Member States |

Source: Authors.

² Directive 2007/46/EC and Regulation (EU) 2015/758.

1. INTRODUCTION

1.1. Background of the study

Since the beginning of the space age in late 50s, the "space economy"³ has become an important driver in the development of modern societies and nowadays the exploitation of space is considered as an important contribution to economic growth, social well-being and sustainable development. One of the main rationales for investing in the space sector relies on the expectation that data transmitted by the satellites can find a huge variety of practical applications in many sectors, which in turn entail numerous social, economic and environmental benefits. A study of the Organisation for Economic Cooperation and Development (OECD), published in 2011, reported that "most reliable estimates suggest that the revenues derived from the wide diversity of space-related products and services amounted to some USD 150-165 billion in 2009" (OECD, 2011). Four years later, OECD's estimate of the space market was considerably increased: "2013 commercial revenues generated by the space economy amounted to some USD 256.2 billion globally (OECD, 2014).

The involvement of the European Union's institutions in the space matter is recent. It is at the beginning of the 2000's that the European Commission (EC) recognised the importance of developing a European Space Policy. However, it was only with the Treaty of Lisbon in 2009 that the European Union (EU) formally introduced right and competence to define and implement its own space programmes⁴. The European Commission's communication "Towards a space strategy for the European Union that benefits its citizens" (EC, 2011a) identifies among the key objectives for the EU space strategy the need to promote technological and scientific progress and to ensure that space applications are developed to the benefit of European citizens. The need to secure independency and autonomy from non-European satellite infrastructure and the economic opportunities associated with the market potential of the space sectors are also important goals.

Over the last ten years the EU institutions have contributed to the development of infrastructures and services related to the implementation of the European Space Policy⁵. The bulk of these investments went to financing two EU flagship space programmes, namely the **Galileo global positioning and navigation system** and the **Copernicus Earth Observation system**.

To meet the overall objectives of the EU space programmes, the development of a European downstream market of services and applications enabled by geospatial and positioning data and information is vital. In particular, the development of downstream satellite-based services and applications is expected to bring substantial innovations that will contribute to the achievement of the Europe 2020 objectives. By boosting the space data market uptake, the EU thus aims to contribute to the EU strategy for growth, jobs and

³ The OECD Space Forum defines the space economy as activities including the space industry with core activities in space manufacturing and satellite operations, plus other consumer activities that derives from applications and services developed out of space investment.

⁴ Article 4.3 of the Treaty on the Functioning of the European Union.

⁵ This implied not only an increasing expenditure for developing applications, technologies and infrastructures for the space activities, but also the need of putting in place proper modalities of collaboration with the European Space Agency (ESA) and Member States. See the following documents: European Commission (2003). "White Paper – Space: a new European frontier for an expanding Union. An action plan for implementing the European Space Policy", COM(2003) 673 final, 11.11.2003; European Commission (2003). "Green Paper – European Space Policy", COM(2003) 17 final, 21.01.2003; Council of the European Union (2003). "Council Decision on the signing of the Framework Agreement between the European Community and the European Space Agency", Brussels, 7 October 2003, 12858/03.

industrial competitiveness, generate wider socio-economic and environmental benefits, and capitalise on the large investments made for space infrastructures and services⁶.

The main issue at stake addressed by this study is whether and how a market for space products can emerge in Europe, which could be its main driving forces (can private demand unleash the expected growth potentials from the space sector, and under which conditions?), and how an effective EU space policy should deal with possible bottlenecks and obstacles hampering such development.

1.2. Scope of the study

This analytical study aims to provide the European Parliament with an understanding of the market potential associated to the use of space data coming from the satellite infrastructure system established under the Copernicus and Galileo programmes. Specific objectives of the study are related to the development of the downstream sector (i.e. applications and services) related to the use of spatial geo-information (Copernicus) and location and positioning services (Galileo) in the European Union. This includes:

1. making an inventory of sectors - both for private and public sector users - that have the largest and unexplored market potential;
2. providing an overview of the policy and regulatory measures undertaken by EU institutions and Member States to foster commercial development of applications and services based on space data;
3. identifying existing bottlenecks which discourage European companies, and especially SMEs, from entering into this market;
4. assessing EU possible actions (e.g. policy and regulatory instruments) for a larger use of technologies based on information and data provided by the two space programmes; and
5. comparing the experiences of the EU and the United States, where the use of space data is more widespread and consolidated, to learn lessons about a more effective development of the downstream sector of space technology markets.

1.3. Approach to the study

The study is grounded on a desk and field analysis that aims at putting together a diversified spectrum of opinions, to reduce the bias related to the interests of specific groups. The combination of different tools allows to matching the needs of ensuring a far-reaching and impartial understanding of the subject of this study, as well as the deep disentangling of perspectives.

The documentary analysis reconstructs the policy and legal framework of EU action in the space sector. It is based on both official EU and European Space Agency (ESA) policy and legislative documents and on space policy and programme documents issued by Member States. Independent studies and reports, along with position papers released by space industry organizations, were also included in the desk analysis. When providing a description of market trends in geo-services, the most recent data available are used.

⁶ In 2013 the EC evaluated overall returns to be between EUR 95 billion and EUR 125 billion over the next two decades. Specifically, the European navigation satellite system is expected to generate economic and social benefits worth around EUR 60-90 billion over the next 20 years, and the benefits of the Copernicus programme are estimated at almost EUR 35 billion by 2030 (EC, 2013a).

Nevertheless, because this is a fast changing and growing market, figures might already underestimate the actual size of the market⁷.

The opinions of key stakeholders complement and integrate the desk analysis. These opinions were collected through semi-structured face to face or telephone interviews that focused on themes that are less explored in the literature, such as judgments on the effectiveness of the existing instruments used by the EC to promote a space data market uptake in the EU, along with opinions about the different constraints to a larger commercial and public use of space data in the EU. To gain an unbiased view over these key issues, stakeholder mapping was carefully carried out to include representatives from the following different categories: i) policy makers and public authorities at EU level in their role of regulators of the EU Space Policy; ii) the European Space Agency as implementing body of the Copernicus and Galileo programmes, but also as organisation directly representing some EU Member States; iii) other European agencies supporting the European Commission's space objectives, like the European Global Satellite Agency (GSA) and the Joint Research Centre; iv) other national space agencies operating satellites systems for Earth Observation; v) scientific experts from the academia or affiliates to think tanks; and last but not least vi) representatives of the business sector in the EU, including industrial federations and space clusters. In selecting stakeholders, specific effort was made to account for the perspective of users in order to avoid an all too institutional view of the challenges at stake.

A total of 30 interviews were carried out as part of the interview programme⁸. Interviews had a number of core questions that were asked to all groups of interviewees, in order to create a solid evidence for the conclusions and recommendations of this study. The core questions addressed the major research areas of this study (i.e. What is holding back the development of a downstream sector based on satellite data in the EU as compared to the US? What could be possible EU actions? What have been the shortfalls/advantages of the existing approach?). At the same time, more specific questions were prepared to fully benefit from the specific knowledge of each category of interviewees.

The analysis is complemented by five case studies (Annex 2) that illustrate how the data and information available from EO (Earth Observation) or GNSS (Global Navigation Satellite System) can be used for developing public and commercial services in different sectors. Each case study is developed following a common template that provides background information about the major features of the technology, examples of commercial downstream services, market opportunities and threats.

Finally, the study requires taking into account some technical aspects related to the characteristics of satellite data and of their use. However, the report minimizes technical details, in order to be easily understood by an audience of non-experts and to be effectively used to inform discussion and policy debate.

The report is structured as follows. Section two is policy oriented. It provides an overview of the EU space policies and of the two flagship programmes Copernicus and Galileo, along with summary information about EU Member States and US policies and programmes for promoting the use of satellite data. Section three is market-focused. It illustrates the market trend and potential of geo-spatial data and positioning services in the downstream market segment. It also provides a critical analysis of the obstacles that hinder the

⁷ The complete list of sources used to underpin this study is provided in the Bibliographical References section at the end of this study.

⁸ A detailed list of people interviewed by type of stakeholder is provided in Annex 1.

development of a space data market in the EU. Section four investigates the effectiveness of the existing instruments that have been deployed by the EC to promote the space market uptake. Section five concludes and recommends possible lines of action for the European institutions. The Annexes provide detailed information on the mini case studies (Annex 2), the US space policy framework and downstream market (Annex 3).

2. THE EU SPACE POLICY

KEY FINDINGS

- The **EU Space Policy** dates back to 2007. Its establishment was driven by (a) the political necessity of an **autonomous European satellite infrastructure**, (b) the expected **direct and indirect economic and social benefits** stemming from the expansion of the European space sector, and (c) the willingness to **pool together resources and expertise** available among Member States.
- The EU space industrial policy lies on the action of **the EU, the European Space Agency and Member States**. ESA focuses on core space activities, whereas EU on applications, with a coordinating role. Member States carry out their own initiatives in the space sector, which is an area of shared competences with the EU. Other agencies and institutions have some responsibilities for the implementation of the programmes: the Global Satellite Agency (GSA) for Galileo and the EEA, EUMETSAT, EMSA, FRONTEX, SATCEN and ECMWF for Copernicus.
- **Together with the European Geostationary Navigation Overlay Service (EGNOS), Galileo makes up EU's global navigation satellite programme.** It is expected to be fully operation by 2020. The EU cost for the definition, validation, and development phases of the project cost amounted so far to **EUR 5.23 billion**. Other **EUR 7 billion** have been earmarked for 2014-2020 by EU for Galileo and EGNOS projects. 40 % of global GNSS equipment models have already adopted Galileo.
- **The Copernicus programme was designed to ensure access to geo-spatial images and data in support of policy decision making.** It has already started providing information, but the full constellation is expected to be in place by 2020. The cost of the Copernicus space component until 2013 amounted to around **EUR 2.4 billion** (about 70 % from ESA, 30 % from EU). **EUR 4.29 billion** have been earmarked by the EU within the 2014-2020 Multiannual Financial Framework for Copernicus.

2.1. Strategic goals of the EU space policy

The European Space Policy was formally established in 2007 in a Resolution jointly adopted by the Council of the European Union and the Council of the ESA. The policy aimed at establishing Europe as one of the global space leaders and laid down four priority areas: i) space climate change, ii) the contribution of space to the Lisbon strategy, iii) space and security, and iv) space exploration. The policy also gave priority to the further development of Galileo, the European global navigation satellite system, and Copernicus, the European Earth Observation programme.

The legal framework of the EU space policy rests on article 189 of the Lisbon Treaty that introduced shared competence in space for the EU and Member States, while excluding any harmonisation of national policies⁹. While this article reflects the need to harmonize national space policies and legislations towards a common European

⁹ Article 4 of the Treaty on the Functioning of the European Union (TFEU).

Space Policy, it does not set an obligation for Member States to integrate their space policies.

The supranationalization of the European Space Policy was driven by the need to overcome Member States fragmented approach to space and to put together resources and existing expertise. Another key factor was the need to ensure independency of the EU in accessing to space infrastructure and space information. It was during the outbreak of conflict in Yugoslavia, when the GPS (Global Positioning System) signal quality was reduced by US military authority, that vulnerability and dependency of EU countries from non-European technologies became apparent. Galileo programme became a "must have for Europe" as soon as it became apparent that Europe was increasingly dependent on Global Navigation Satellite System (GNSS) in several sectors and needed to achieve independency from other non-European GNSS (Sigalas, 2011).

Acknowledging the relevance of space-derived services and applications for society and business, **the EU Space Policy is set to serve three types of needs. The social dimension** touches upon citizens' well-being that depends on environmental and climate change, civil security and emergency response to crisis. **The economic dimension** is linked to the capacity of the space sector to generate innovations, knowledge and products that can be applied to mass markets, increase competitiveness of European industries and create new job opportunities. Finally, **the strategic dimension** contributes to granting European independency in supplying satellite information to European governments and businesses, and to make the EU a major player and contributor to global scientific knowledge development (EC, 2011). In this context, the EU Space Policy is considered a pillar of the whole Europe 2020 strategy¹⁰ and its "Industrial Policy" flagship initiative in particular.

As the economic crisis worsened in Europe, the need to maximize opportunities for the development of commercial services became more pressing. The Competitiveness Council Resolution of 2008, underlined that the EU space programmes are expected to provide substantial market opportunities, especially for SMEs, through the development of value-added downstream services. The objective of independency was thus increasingly followed by the need to demonstrate contribution of the EU space programmes to the implementation of the Europe 2020 strategy for growth and to support economic recovery of Europe. Similarly, the European Parliament (EP), recognizing that space is a strategic asset for the independency and prosperity of Europe, called for developing a European space industrial policy to support the emergence of a European downstream market that would help further develop Europe's industrial and scientific base. In particular, the EP stressed the importance of establishing a regulatory framework and standardization programme for the downstream market segment and encouraged a stronger involvement of European SMEs in space-related activities (EP, 2008).

Orientations for a potential European space industrial policy are included in a number of communications issued by the European Commission between 2011 and 2013¹¹. These communications highlight the urgent needs to establish a truly European space market by setting up coherent and stable regulatory frameworks, ensuring technological non-dependence in space-based services and applications, and improving global

¹⁰ European Commission (2010). "Europe 2020. A strategy for smart, sustainable and inclusive growth", Communication from the Commission COM(2010) 2020 final, 3 March 2010.

¹¹ These are: i) Towards a space strategy for the European Union that benefits its citizens, COM(2011) 152, and iii) EU Space Industrial Policy. Releasing the Potential for Economic Growth in the Space Sector COM(2013) 108.

competitiveness of the EU industrial base. To achieve these objectives a number of legislative and non-legislative actions were foreseen, such as improving general framework conditions (e.g. legislation concerning the dissemination of satellite data), support research and innovation in the space sector, expand the use of available financial instruments, especially to increase SMEs participation, improve space procurement approach, secure EU autonomy in launch services, and finally ensure sustainability of EU space activities (EC, 2013).

Building on the evidence that already an estimated 6-7 % of Gross Domestic Product (GDP) in Western countries depends on satellite positioning and navigation (EC, 2011c), the above communications emphasizes the need to achieve non-dependency in all sectors of the space value chain. A more coordinated EU industrial policy response, that also includes the telecommunication sector, is seen as critical to respond to increasing competition from other space-faring nations, such as the US, Russia or China, which have large institutional markets based upon synergies between military and civil use of space activities.

An effective EU space industrial policy has to rely on the collaboration between the EU, ESA¹² (European Space Agency) and Member States. In this respect, the Treaty on the Functioning of the European Union (TFEU) establishes that the EU may "*promote joint initiatives, support research and technological development and coordinate the efforts needed for the exploration and exploitation of space*"¹³. In addition to this, the "*Union shall establish any appropriate relations with the European space agency*". Therefore, **implementation of the EU space policy rests on three actors: the Member States, the EU and ESA**. The collaboration between the EU and ESA is established in a framework agreement of 2003¹⁴. While ESA focuses on space components, such as launches and space exploration, the EU concentrates on space applications and has a federating and coordinating role for the EU space policy and programmes. In particular, the EU provides the political, administrative and financial framework that gives coherence to the European Space Policy.

A number of Member States¹⁵ also have space activities at national level that follow both civil and military purposes, although military investments remain limited. To limit duplications and promote technical synergies the EC has proposed to integrate Member States' space activities into programme planning discussions (EC, 2011a). Beside this, more specific governance agreements, that also include other EU institutions, such as the Global Satellite Agency (GSA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), guide the operationalization of the two European space flagship programmes (Davies, 2013).

2.2. The EU space flagship programmes

The two pillars and priorities of the EU space policy are the Galileo and Copernicus programmes (Space Council, 2010c). Each of them is presented in details in the next subsections.

¹² ESA is an intergovernmental organization including EU Member States (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, , Slovakia, Slovenia, Spain, Sweden, and the United Kingdom) and non EU countries (Norway, Canada and Switzerland).

¹³ Article 189 of the TFEU.

¹⁴ Council of the European Union. Council Decision on the signing of the Framework Agreement between the European Community and the European Space Agency. Brussels, 7 October 2003. 12858/03 2003.

¹⁵ Member States with the larger space budget are in order France, Germany, Italy, UK and Spain (ESPI data, 2011).

2.2.1. The Galileo programme

Galileo is the European navigation satellite system to provide global positioning services, and operates under civilian control. The complete Galileo system will consist of a constellation of 30 satellites and the associated ground infrastructure. It is integrated with the already existing European Geostationary Navigation Overlay Service (EGNOS), which uses geostationary satellites and a network of ground stations to improve accuracy and reliability of the US GPS signal.

As set out in the EC Regulation 683/2008, the objectives of the European GNSS programmes are to:

- provide uninterrupted GNSS services and a strategic advantage for Europe;
- reinforce the resilience of the European economic infrastructure by providing a backup system in case of signal failure; and
- maximise socio-economic benefits for European civil society.

Fostering the development of applications and services based on Galileo and EGNOS was added as an additional objective in EC Regulation 1285/2013. This increased and made more explicit linkages with the EU industrial policy. General reported benefits of GNSS are vast and include increased productivity, cost and time reduction, improved health and well-being, generation of new production process and product markets, reduce injury and loss of life, increase security, and improve the environment (Leveson, 2015). Unlike other non-European GNSS, such as the US GPS, the Russian Glonass and the forthcoming Chinese BeiDou, Galileo has been designed to remain under European civilian control (EC regulation, 2008a). This has several implications, especially in terms of establishing the type of services provided and conditions for accessibility.

Specifically, Galileo is set to provide five services (Hernández et al., 2015).

- The Open Service (OS) will provide navigation, position and timing worldwide free of charges. The OS will lay at the heart of many enhanced satellite navigation applications that already led to the development of mass market (e.g. geo data businesses).
- The Public Regulated Service (PRS) will be an encrypted service designed to achieve higher robustness to ensure the functioning of key public services in case of emergency, such as terrorist threat or natural disaster.
- Search and Rescue Service (SRS) will be a unique service provided by Galileo that allows people in distress to be located and confirm that help is on its way.
- The Integrity Monitoring Service (previously called safety of life services) will provide vital integrity information for life critical applications (e.g. en-route guidance for airplanes).
- Finally, the Commercial Service (CS) will be another characteristic feature of Galileo. This will be a fee-based service meant to deliver authentication and higher accuracy. The CS aims at recovering part of the costs of establishing Galileo and support innovation through new functionalities (Hernández, 2014). At the time this report was drafted, the CS has not been finalized yet.

The Galileo programme is structured along four phases. A definition phase, a validation and development phase - both concluded, a deployment phase that was launched in 2008 and

is still on-going, and an exploitation phase that is due for completion in 2020¹⁶ (EC, 2013d). The first two operational satellites for Galileo were launched on 21 October 2011, followed by other launches in 2012, 2014 and 2015. One-third of the Galileo constellation is currently in orbit. The EC aims to ensure the provision of initial Galileo services, the free open service, the encrypted public regulated service and the search and rescue function, by 2016 (EC, 2015a). Although the launch programme had some delays due to technical reasons, the number of satellites currently in orbit allows the provision of the foreseen preliminary services.

The EGNOS programme has been operational with its open service and safety of life service since October 2009 and March 2011 respectively (EC, 2013d). EGNOS is accessible in Member States, but can be extended to other regions, such as candidate countries, countries in the European Neighbourhood Policy, or third countries associated with the Single European Sky (EC, 2013). It provides the following benefits to users: i) improve accuracy of location to nearly one meter, ii) access integrity data, and iii) accurate and reliable synchronization with Universal Time Coordinated. Primary sectors where EGNOS can have a market influence include transportation and communications. Besides these, it can also be deployed in other sectors, such as agriculture, surveying and tourism.

After seven years of combined activities of the EC and GSA, the penetration rate of Galileo in all GNSS equipment models sold worldwide stems at 40 %. This shows that **the industry is investing significantly in developing Galileo solutions well ahead the programme full availability**. EGNOS has been already adopted by 70 % of the receiver models and is already providing tangible socio-economic benefits. For example, in agriculture almost 80 % of European farmers equipped with GNSS manage their harvesting and other farm operations with EGNOS. In aviation, calls for grant and other supporting actions favoured the implementation of EGNOS-based landing procedures in 132 European airports (data provided by the GSA).

The definition, validation and development phases of Galileo have been co-financed by the EU and ESA, whereas the deployment phase is entirely financed by the EU. For the period 2007-2013 the EU contribution to the Galileo and EGNOS programmes amounted to approximately EUR 3 550 million. This budget has been allocated to different activities, namely completion of the Galileo development phase, the Galileo deployment phase, and the operation of EGNOS. In addition to this, the definition, validation and development phase of Galileo previously (before 2007) required an EU contribution of around EUR 1 680 million. The total cost of implementing EGNOS has been around EUR 1 100 million, including an ESA contribution of EUR 400 million and no additional budget is needed for completion. The annual operating costs of Galileo are estimated to be approximately EUR 800 million per year, while the expected revenue is estimated to be about EUR 80 million per year. To complete Galileo space and ground infrastructure, and to allow exploitation of Galileo and EGNOS, a budget of EUR 7 billion has been earmarked for the current financing period (EC, 2013f).

Given the scale of the investment, securing funding for the EU GNSS programme was not easy. In addition to this, the programme incurred in several cost overruns, as Member

¹⁶ Definition phase: preliminary phase in which the structure of the system are designed and its elements determined. Development and validation phase: construction and launch of the first satellites, establishment of the first ground-based infrastructure and all the work and operations necessary to validate the system in orbit. Deployment phase: construction and maintenance of space and ground-based infrastructures; preparation of the subsequent phase. Exploitation phase: management, maintenance and improvement of infrastructures, development of future generations of the system, certification and standardisation operations associated with the programme, provision and marketing of services, cooperation with other GNSS (EC 2013d).

States had different views about the programme rationale. For instance, there was not agreement on the funding model that was initially set to be framed in a public-private partnership that collapsed in 2007. Member States finally agreed that financing of ambitious space programmes has to rely on public budgets, as the large R&D and infrastructure costs can hardly be recovered. As a consequence, after several negotiations, the existing financing framework is set to cover adequately the costs for completing Galileo (IAI, 2011).

The institutional architecture of the Galileo programme rests on division of tasks between the EC, ESA and the recently established GSA¹⁷. The EC has overall responsibility for managing funds and implementing the two European satellite navigation systems. Partnership with ESA for the deployment phase of Galileo is regulated by a delegation agreement signed in July 2014, which establishes that ESA acts as design and procurement agent on behalf of the EC (EC, 2013d). Responsibilities for supporting the development of commercial downstream user applications are assigned to GSA, which is preparing the market for the take up of Galileo and supporting use of EGNOS. Besides this role, GSA has also been entrusted for ensuring the security of the Galileo and EGNOS programmes by operating the Galileo Security Monitoring Centre (GSMC) and by ensuring the functioning of the Security Accreditation Board. GSA also manages EU GNSS research under the Horizon 2020 Programme and since 2014 ensures operations and service provision for EGNOS (GSA, 2014).

2.2.2. The Copernicus programme

The Copernicus programme, previously known as Global Monitoring for Environment and Security (GMES), is the joint undertaking of the EU, Member States and ESA **designed to ensure access to geo-spatial information in support of policy decision making**. The programme is set to provide information in the fields of environment and security to make contributions in the EU policies, including transport, agriculture, forestry, fishery, environment, civil protection and security, humanitarian aid and international cooperation, energy and the internal market. As an autonomous EO system it also constitutes the European contribution to the Global Earth Observation System of Systems (GEOSS)¹⁸. As set out in the EC Regulation No 377/2014, Copernicus is also expected to contribute in maximizing the socio-economic benefits by promoting the use of EO in applications and services.

Copernicus programme architecture is made of three main building blocks.

- Coordinated by ESA, the *space component* consists in collecting EO data from space through Copernicus dedicated satellite (the Sentinels) and Contributing Missions¹⁹ from national or commercial providers. Sentinel data are acquired, processed and distributed by the Ground Segment.

¹⁷ Regulation (EU) No 912/2010 of the European Parliament and of the Council of 22 September 2010 setting up the European GNSS Agency, repealing Council Regulation (EC) No 1321/2004 on the establishment of structures for the management of the European satellite radio navigation programmes and amending Regulation (EC) No 683/2008 of the European Parliament and of the Council.

¹⁸ GEO is a partnership of 100 governments and 97 international organizations (as of October 2015) established to link Earth observation resources world-wide across multiple sectors, such as agriculture, biodiversity, climate or natural disasters, and to make those resources available through the Global Earth Observation System of Systems (GEOSS) for better informed decision-making.

¹⁹ Contributing Missions are EO missions built for different purposes, but offering part of their capacity to Copernicus. These include EU/ESA MSs, EUMETSAT, commercial and international satellites. Even when the full constellation of Sentinel satellites is available, Contributing Missions will continue to provide relevant complementary data.

- Coordinated by the European Environmental Agency (EEA), the *in situ component* complements satellite data with observation data from ground, sea and air-borne sensors. These infrastructures are managed by Member States and international bodies with which the EU needs to establish specific agreements to ensure access to all relevant data.
- Led by the EC, the *service component* transforms space and in situ data into a set of information (primarily thematic maps) that are delivered to users to develop a vast array of services. The system is designed to provide information in six domains (or *core services*). These are: i) atmosphere monitoring, ii) marine environment monitoring, iii) land monitoring, iv) climate change, v) emergency management, and vi) civil security. Specifically, Copernicus is expected to provide information on the state of the atmosphere and of the oceans, on land use for spatial planning, on climate change for mitigation and adaptation, on natural and man-made disasters to provide a better response, and on the state of the Union terrestrial and maritime borders (EC, 2014).

Almost all Sentinel missions are based on a constellation of two satellites and a total of six missions are foreseen. The Sentinels have different technical features, but they are complementary and support a large variety of earth monitoring services (see Table 3 below).

ESA operates the Sentinels Scientific Data Hub that provides free and open access to the Sentinel user products to registered users. By August 2015 more than 220 000 Sentinel-1A products were available for download and more than 10 000 users were already registered in the data hub. The first sample of Sentinel-2A products was published on July 2015. Since the opening of the service in October 2014, nearly 1.7 million Sentinel-1A products have been already downloaded²⁰. Data access is likely to increase steadily with the availability of Sentinel 2 data. While Sentinel 1 data are relatively more difficult to handle because they are based on radar technology (Synthetic Aperture Radar - SAR) that mainly targets a very specialized group of users, Sentinel 2 data are based on optical (multispectral) technology that produces photographic images of the Earth that, most likely, will be used by a wider public.

Copernicus has a complex institutional architecture that reflects the large varieties of services provided. The programme is based on a partnership between the EU, ESA and the Member States. Overall responsibilities for programme's coordination and supervision fall with the EC. Partnership with Member States is meant to exploit existing national capacities and infrastructure (i.e. in-situ assets and contributing missions). Member States are responsible for the development and maintenance of the in-situ assets within their jurisdiction. The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) is in charge of the operation of dedicated missions in accordance with its expertise. ESA is in charge of implementing Copernicus space component, which includes the definition of the programme's architecture, the development and procurement of space assets, data access and the operation of dedicated missions. The EEA coordinates the in-situ infrastructure that consists of a large number of facilities managed by regional, national and intergovernmental bodies within and outside Europe. Responsibilities for implementation of the service components are shared amongst several European agencies, such as the EEA, the European Agency for the Management of Operational Cooperation at the External Borders of the Member States of the EU (FRONTEX), the European Maritime

²⁰ ESA data from <https://scihub.esa.int/news/News00032>.

Safety Agency (EMSA), the European Union Satellite Centre (SATCEN), and the European Centre for Medium-Range Weather Forecasts (ECMWF) (EC, 2014).

The design and pre-operational phases of Copernicus were assisted by a number of transitional governance support bodies, such as the GMES Bureau or the GMES Partners Board. At present, for the operationalization of Copernicus, the EC is assisted by two different committees. The Copernicus Committee, initially GMES Committee, consists of national representatives that assist the EC with the implementation of Copernicus regulation. The Copernicus User Forum is an advisory body that is responsible for advising the EC about user's requirements and better liaising with the private sector. Finally, in June 2015, the unit "Space Data for Societal Challenges and Growth" was established within DG GROW to make the existing data dissemination system more robust and improve thus Copernicus data outreach. The unit is investigating industrial policy measures for the downstream sector that would encourage the use of space data by the private sector.

In terms of funding, the EC and ESA co-founded the development phase of Copernicus, which mostly consisted in developing the necessary space infrastructure. Until 2013 EUR 2 400 million were devoted to the space component of Copernicus project - of which around 70 % (EUR 1.68 billion) were earmarked by ESA, and 30 % by EU (i.e. 720 million). The implementation phase, consisting in developing pre-operational services, was supported through the budget of the sixth (2003-2006) and seventh (2007-2013) Framework Research Programmes. The operational phase relies on EC funding and, for the next years, has been secured in the 2014-2020 Multiannual Financial Framework (MFF) of the EU. The financial envelope for the implementation of the activities referred to in Articles 5, 6 and 7 of the EC Regulation 377/2014U, i.e. respectively Copernicus service, space and in situ components, is set at EUR 4 291.48 million for the period 2014-2020. Most of the financial envelope (around 3.4 billion) is referred to the programme space component. The decision to include Copernicus funding within the MFF was difficult²¹, but essential to secure continuity of the service and for the development of downstream businesses (Allgeier et al., 2015).

²¹ In 2011, in its Communication A Budget for Europe 2020 [COM(2011) 500 final, 29.6.2011], the EC proposed that GMES be funded outside the MFF. The proposal was subsequently rejected by the EP in its Resolution P7_TA(2012)0062 of 16 February 2012.

Table 3: Families of Copernicus satellites: key features and services

| Mission | Service domains | | | | | |
|--|---|--|---|---|---|--|
| | Atmosphere monitoring | Marine environment monitoring | Land monitoring | Climate change | Emergency management | Civil security |
| Sentinel 1: Provides all-weather, day and night radar imagery for land and water services. When both satellites will be operational, it will provide images of the entire Earth every six days. | | <ul style="list-style-type: none"> - Marine, coastal monitoring - Oil spill and polluter - Iceberg monitoring - Wind and wave information - Algal blooms and jellyfish invasion | <ul style="list-style-type: none"> - Food security and crop monitoring - Forests, rivers, lakes - Snow cover - Urban mapping - Tectonic areas | <ul style="list-style-type: none"> - Sea ice, ice sheets and glaciers - Soil moisture | <ul style="list-style-type: none"> - Disaster mapping - Humanitarian aid - Land surface motion | <ul style="list-style-type: none"> - Maritime surveillance - Monitoring infrastructure stability - Border surveillance |
| Sentinel 2: Provides high resolution optical imagery for land services. When both satellites are operational, it will have a five days revisit time. | | | <ul style="list-style-type: none"> - Food security and crop monitoring - Forests, rivers, lakes - Snow cover - Urban mapping - Ecosystems and sensitive habitats | <ul style="list-style-type: none"> - Land cover, snow cover, rivers and lakes | <ul style="list-style-type: none"> - Disaster mapping - Humanitarian aid - Land surface motion | <ul style="list-style-type: none"> - Monitoring infrastructure stability - Border surveillance of - Support peacekeeping intelligence |
| Sentinel 3: Primarily an ocean mission, provides high-accuracy optical, radar and altimetry data for measuring sea surface topography, sea and land surface temperature, and ocean and land surface colour. | <ul style="list-style-type: none"> - Clouds and aerosol detection | <ul style="list-style-type: none"> - Marine, coastal monitoring - Oil spill and polluter - Algal blooms and jellyfish invasion - Sea surface topography and temperatures | | <ul style="list-style-type: none"> - Sea and land surface temperature - Cloud top heights and cloud cover | <ul style="list-style-type: none"> - Global wild fires detection | |
| Sentinel 4: Provides data for atmospheric composition monitoring, with high temporal frequency (1 hour). The instrument will be placed on two geostationary Meteosat Third Generation satellites. | <ul style="list-style-type: none"> - Atmospheric chemistry - Air quality - Climate trace gases - Stratospheric ozone and solar radiation - Volcanic ash plumes | | | <ul style="list-style-type: none"> - Long-lived greenhouse gas and aerosol | <ul style="list-style-type: none"> - Long-lived greenhouse gas and aerosol | |
| Sentinel 5: Provides data for atmospheric composition, air quality monitoring, long range transport of atmospheric pollutants. The instrument will be placed on the polar orbiting MetOP-SG satellite. | <ul style="list-style-type: none"> - Atmospheric chemistry - Air quality - Climate trace gases - Stratospheric ozone and solar radiation - Volcanic ash plumes | | | <ul style="list-style-type: none"> - Long-lived greenhouse gas and aerosol | <ul style="list-style-type: none"> - Long-lived greenhouse gas and aerosol | |
| Sentinel 6: Provides high accuracy altimetry for measuring global sea-surface height, primarily for operational oceanography and for climate studies. | | <ul style="list-style-type: none"> - Marine, coastal monitoring - Sea surface topography and temperatures - Wind and wave information | | <ul style="list-style-type: none"> - Sea ice, ice sheets and glaciers - Sea and land surface temperature | | |

Source: Authors based on <http://www.copernicus.eu/main/sentinels>; The Copernicus Space Infrastructure. Presentation prepared by Thomas Beer, Policy Coordinator, Copernicus Space Office, ESA-ESRIN, Frascati (Italy), 16 January 2014; European Commission, 2015b.

Table 4: Key features of Galileo and Copernicus

| | Galileo | Copernicus |
|-------------------|--|---|
| Objectives | Establish and operate the first EU global satellite navigation and positioning infrastructure specifically designed for civilian purposes. | Ensure access to Earth Observation information in support of policy decision making. |
| Schedule | 2005: launch of Giove-A 2008: launch of Giove-B 2011: launch of Sat.1 and Sat.2 (IOV-1) 2012: launch of Sat.3 and Sat.4 (IOV-2) 2014: launch of Sat.5, Sat.6, Sat. 7 and Sat.8 2015: launch of Sat.9 and Sat.10 2016-2020: launch of other satellites | 2014: launch of Sentinel-1A 2015: launch of Sentinel-2A, Sentinel-3A, precursor mission for Sentinel-5 2016: launch of Sentinel-1B and Sentinel-2B 2017: launch of Sentinel-3B Around 2020: launch of Sentinel-4A, Sentinel-5A, Sentinel-6A |
| Governance | EC: overall responsibility for managing funds and programme implementation ESA: design and procurement agent on behalf of the EC for the deployment phase GSA: (a) supporting the development of commercial downstream user applications; (b) ensuring the security of the programme; (c) managing EU GNSS research under the Horizon 2020 programme | EC: overall responsibility for programme coordination and supervision ESA: implementing the space component Member States: development and maintenance of the in-situ assets within their jurisdiction EEA: coordination of the in-situ infrastructures EUMETSAT: in charge of the operation of dedicated missions ECMWF, EEA, EMSA, FRONTEX, SATCEN: implementation of service components |
| Costs | EU funding of the definition, validation and development phase up to 2013: EUR 5 230 million Funds earmarked by EU for the Galileo space and ground infrastructure, and for exploitation of Galileo and EGNOS, in the 2014-2020 funding period: EUR 7 000 million | EU contribution to the space component costs up to 2013: about EUR 720 million ²² Funds earmarked within the 2014-2020 Multiannual Financial Framework of the EU for Copernicus: EUR 4 291 million |

Source: Authors based on European Commission, 2013d; European Commission, 2013f; European Commission, 2014b; ESA 2013.

²² In addition to 1.68 billion by ESA. Costs for the implementation phase between 2003 and 2013 are not included.

3. THE MARKET POTENTIAL OF SPACE DATA APPLICATIONS

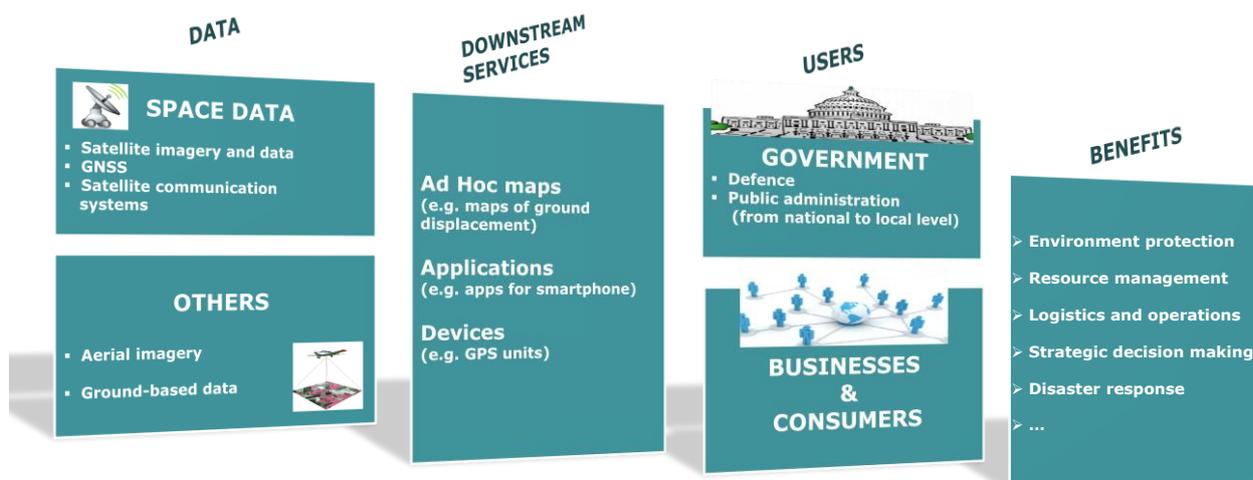
KEY FINDINGS

- In the next two decades the European global navigation satellite programme is expected to generate economic and social benefits worth around **EUR 60-90 billion**. The estimated turnover annual potential of the EU Earth Observation downstream services market to be reached in the long term (by 2030) is estimated at around **EUR 2.8 billion**, of which more than 90 % should stem from Copernicus-enabled downstream market.
- The **main downstream markets** for GNSS applications are hand-held location based services (53 %) and in-vehicle satellite navigation systems (38 %). The former has the greatest potential to grow. Demand for EO value added services mainly originates from the public sector and a various commercial markets with a lot of unexplored potential. Relevant market segments relate to natural resource management, defence and security, land monitoring, oceanography and meteorology.
- **Value added applications in Europe are mostly driven by SMEs**. The GNSS downstream market is expected to increase by 8.3 % per year between 2013 and 2019. The number of European EO services enterprises has grown by nearly 8.7 % since 2010.

3.1. Overview of the market of geo-spatial services

The downstream segment of the space economy value chain is made of companies that provide commercial services, products and applications to final consumers. These companies are generally not connected to the traditional space industry, but their business depends on the provision of satellites signals and data (OECD, 2014). **The term 'geo-spatial services' is used to identify services and applications based on satellite data that integrate digital mapping with location based data.** These products include space imagery, navigation devices on-line mapping, and other services (Figure 1). By integrating these services in portable devices, such as tablets and smartphones, large societal changes can be achieved and business opportunities can be created. A few illustrative examples of how even small businesses can benefit from geo-services include the following: restaurants and hotels increasingly depend on geo-enabled recommendation services, construction companies base their land acquisition activities upon geospatial services, farmers use a combination of mapping and environmental information to optimize crop management and yield. Citizens can also largely benefit from geo-spatial services. For instance, the smartphone app HappySun, provides real-time information about UV solar radiation intensity. The service can help tourists and citizens to protect themselves from solar radiation by monitoring the local environmental conditions based on geolocation from GNSS and images coming from different ESA's Earth observation satellites. Similarly, the smartphone app obsAIRve has been developed to allow citizens monitor the air quality (more on this in Annex 2).

Figure 1: The geo-spatial service industry in a nutshell



Source: Authors.

The market of geo-spatial services changed radically in 2005 when Google Inc. made available Google Earth and Google Map services. These services were based on a completely different business model that consists of the free provision of already processed data via internet to a mass of non-experienced users. The purpose of Google Earth was to position itself as a broker, rather than a supplier of maps. The example of Google Earth was then followed by other US IT companies, such as Virtual Earth from Windowsline, whereas the EU response came late and was not able to provide products with similar success amongst users (Blamont, 2008).

In a few years Google Earth become the major portal for accessing to geocoded information for mass users. The impact on the space industry supplying space imagery has been disruptive, as distribution modalities became the most relevant factor in the development of the imagery business. Although the information provided by the raw Google products is incomplete, and lacks ancillary data that are essential from a scientific point of view, such as revisiting time, integrity, data source, or geo-referencing, the availability of these services are increasingly questioning the choices of space agencies that are concerned of seeing themselves as passive providers of data to Google or other similar IT companies (Blamont, 2008).

Box 1: The US space data dissemination policy

The possibility for Google to access to a huge volume of space data and to use them to develop its services and applications was made possible by the US Earth Observation data distribution policy, grounded on the principles of open and free dissemination. The NASA data policy is clear, concise and unambiguous and allows all commercial, research and federally sponsored entities to have the same level of access to the space data. The policy establishes that data collected by federal agencies is disseminated at no more than the cost of dissemination and that government documents cannot be protected by copyright law.

Source: Annex 3.

Two reports commissioned by Google²³, one for the US and one for the global market, illustrates double-digit annual growth rates for the geospatial service industry. In spite of the prolonged economic downturn, the industry enjoys a period of sustained growth. The overall sector contribution to global GDP is reported to be at 0.2 %. The US report places the whole sector at 73 USD billion in revenue with 500 000 jobs. The global report, which uses a different methodology, estimates the global revenue to be between 150 and 270 USD billion (Ball, 2013). The broaden use of geo services is reported to have many economic and societal impacts. These include time and fuel saving costs, emergency response, education and competition. Using geo-services in routing and logistics would save up to 22 USD billion in fuel costs and time and provide higher demand for skilled workers. In agriculture geo-services can led to better use of water and fertilizer that could result in a cost reduction between 40 and 110 USD billion per hectare (Oxera, 2013).

The European satellite navigation and EO service industries are still emerging in Europe, and they are expected to bring about significant gains in terms of enterprise and job creation. **Galileo and EGNOS are expected to generate economic and social benefits worth around EUR 60-90 billion over the next 20 years** (EC, 2013). At the same time, a study estimated that **“EO downstream services total market annual value potential is expected to reach EUR 2.8 billion by 2030, of which EUR 2.6 billion could be attributable to the Copernicus-enabled downstream”** (SpaceTec Partners, 2013).

The following sections illustrate in more detail the major market trends and opportunities for EO data and positioning service.

3.2. The downstream market of navigation satellite systems

3.2.1. Market segments of navigation systems applications

Civilian applications of the US GPS started developing as soon as the GPS constellation became operational. At first the signal available for civilian application was intentionally degraded (‘Selective Availability’) to limit the precision of positioning to about 30 meters. GPS was redefined as a dual purpose military and civilian system with the 1996 US Global Positioning System Policy, and as a result of the new policy in 2000 the US made available non-degraded, worldwide satellite-based positioning and timing services for civilian use. The signal is available for free, but with no guarantee of continuity of service. Since then, a new market of GNSS-enabled products and services has been flourishing (EC, 2010c).

Interviews pointed out that independency from other non-European global satellite navigation system is the major value added of Galileo. From an end-user perspective, Galileo and the GPS system have similar technical features. While greater precision and reliability can be obtained by combining the two signals together, Galileo specific services are unlikely to be developed. A notable exception is the Galileo Search and Rescue Service, which is not provided by any alternative GNSS.

GNSS applications are generally of two types: safety-critical applications, which are based on precision signals, and non-safety-critical applications that depend on standard signals from satellites. Navigation satellite based services are becoming pervasive in business and citizen everyday life and have a large market potential that has just started developing. As showed in Figure 2, **applications are currently dominated by two major areas: in-vehicle satellite navigation (SATNAV) and hand-held location based services (LBS)**, which will continue to form the largest part of the market. So far all civil

²³ Oxera Consulting (2013) and The Boston Consulting Group (2012).

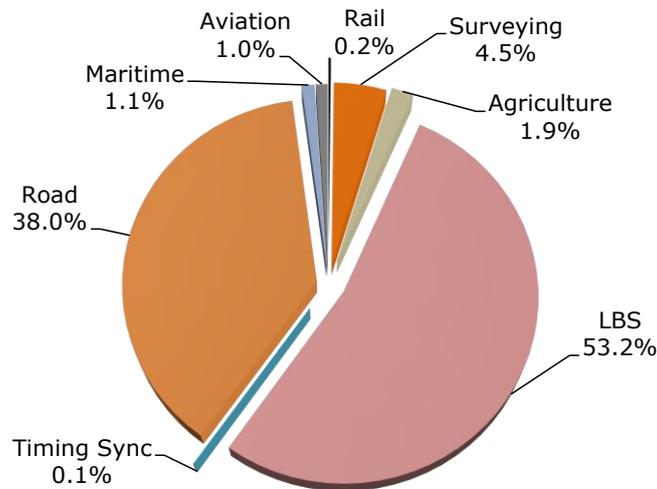
applications have been developed on the GPS signal, while the availability of signals from other constellations is expected to bring more innovation and larger improvements in terms of precision applications and continuity of service (Frost, 2012).

Table 5: Type of applications of the GNSS market segment

| | |
|-------------|---|
| LBS | <ul style="list-style-type: none"> • Navigation, Mapping and GIS • Geo marketing and advertising • Safety and emergency • Enterprise applications • Sports, Games and augmented reality, social networking |
| Road | <ul style="list-style-type: none"> • Smart mobility applications (navigation, fleet management, satellite road traffic monitoring services) • Safety-critical applications (connected vehicles, dangerous goods tracking) • Liability applications (road user charging, insurance telematics) • Regulated applications (enhanced digital tachographs, management of emergency call) |
| Aviation | <ul style="list-style-type: none"> • Regulated applications (performance-based navigation, emergency locator transmitters, automatic depended surveillance) • Unregulated market (moving maps, infringement alarms, situational awareness applications, personal locator beacons) |
| Rail | <ul style="list-style-type: none"> • High density/low density command & control systems • Asset management • Passenger information systems |
| Maritime | <ul style="list-style-type: none"> • Navigation (for sea and inland waterways) • Positioning (traffic management and surveillance, search and rescue, fishing vessel control, port operations, marine engineering) |
| Agriculture | <ul style="list-style-type: none"> • Farm machinery guidance, automatic steering, variable rate application • Yield, biomass, soil condition monitoring, farm machinery monitoring and asset, livestock tracking • Geo-traceability, field delineation. |
| Surveying | <ul style="list-style-type: none"> • Cadastral, construction, marine, mine surveying • Mapping |

Source: Authors based on the GSA Market Report 2015.

Figure 2: Major GNSS-based applications market segments, based on cumulative core revenue 2013-2023



Source: GSA Report, 2015.

For each market segment, a large number of GNSS applications is being developed targeting institutional and military customers, mass consumers and businesses. **The sector with the highest potential to growth is LBS**, because of the rapid penetration of smartphones. GSA reports that in 2013 the European *App economy* generated EUR 17.5 billion in revenues and employed 1.8 million people, while the contribution to the EU economy and labour market is forecasted to be of EUR 63 billion and 4.8 million people by 2018 (GSA, 2015). The rail and transport service is a mature market whose growth perspective depends upon the introduction of diversified business models or regulations (e.g. the eCall directive). One of the strongest potential in this market segment is related to the diffusion of unmanned vehicles (Frost, 2012).

Box 2: The eCall emergency system

The so-called eCall system consists of an in-vehicle technology that detects serious crashes and automatically notifies the emergency to the rescue service via the European emergency number 112. The system is aimed to reduce the response time for emergency services. The role of satellites is crucial to send accurate information about the position of crashed vehicles and the direction of travel.

Directive 2007/46/EC requires the installation of the eCall system in all new types of passenger cars and light duty vehicles. As for Regulation (EU) 2015/758, the fitting of this system will be mandatory from 31 March 2018. Article 5 of the Regulation, indicating specific obligations for manufacturers, includes the obligation to "ensure that the receivers in the 112-based eCall in-vehicle systems are compatible with the positioning services provided by the Galileo and the EGNOS systems. Manufacturers may also choose, in addition, compatibility with other satellite navigation systems" (EP and EC, 2015).

Source: Authors based on European Parliament and European Council, 2015.

Other market segments have a small market share, as these applications are not targeted to mass consumers. Due to technological maturity, variety of use, and possibility to integrate the navigation satellite system with satellite images, survey and mapping is a promising market segment. Precision agriculture has emerged in the US, which currently dominates the market, and is rapidly expanding in Asia. An emerging market segment for

GNSS applications is timing and synchronisation that is expected to be employed in different sectors, including finance, telecommunication and energy (Frost, 2012).

3.2.2. Industry's structure and growth potential

Comprehensive estimates of recent global GNSS market size come from the GSA, which has released four market reports starting from 2010. The GSA market report makes a distinction between three groups of companies operating in the **GNSS downstream industry**. These are the following (Figure 3):

- **component manufacturers**, producing receivers for stand-alone use or integration into systems (e.g. chipsets, antennas),
- **system integrators** (mostly car manufactures), that integrate GNSS capability into larger products or GNSS devices, and
- **value-added service providers**, which improve access and use of GNSS.

GNSS devices supply is mostly driven by large industrial groups, whereas the highest development potential for SMEs and start-up rests in developing GNSS-based applications.

Figure 3: The GNSS downstream value chain



Source: Authors based on GSA, 2015.

Over the past decades the downstream market has been growing at double digit rates (Frost, 2012). The 2015 GSA report emphasizes how ubiquitous GNSS are becoming. In 2014, 3.6 billion GNSS devices were reported to be in use and to be growing in each region of the world. **In 2015 GSA predicts that the global GNSS downstream market will increase by 8.3 % per year between 2013 and 2019 and will slow down to 4.6 % till 2023.** Although these figures are more conservative than those presented in the past edition of the GSA market Report, they still outpace global GDP growth that is forecasted to be at 6.6 % per year in the same period.

The European GNSS industry share of the global sector went from 20 % in 2009 to 25.8 % in 2012. This is a good improvement that however does not compare well with European performance in other high tech sector where the estimated EU market share is 33 % (GSA, 2015). European companies have a stronger position in components manufacturing (23 %) and in system integration (26 %) especially in road and rail. **Value added applications in Europe are driven by SMEs.** Among the top 10 world companies, in terms of revenue achieved in 2012, only two are European. These are Tomtom and Here Global. Both companies are from the Netherlands and provide navigation, mapping and location services. European players are strong in developing applications for LBS. Europe has also been an early adopter of GNSS in rail where Europe has a leading position. Other markets are either dominated by Northern America or Asian companies (GSA, 2015).²⁴

²⁴ Regional market share of value added applications are as follows: Europe - 21 %, North America - 44 %, and Asia plus Russia - 34 % (GSA, 2015).

At the regional level, the region with the highest growth is expected to be the Middle East and Africa (19 % per year), followed by Asia and the Pacific (11 % per year) and the mature markets of Europe and North America (8 % per year). By 2013 the largest installed base of GNSS devices will be in Asia and the Pacific region (GSA, 2015).

Europe has a leading position in GNSS security and resilience domains. European companies are also well-positioned to compete in a number of new GNSS application and service markets that leverage the capabilities of all global constellations. These include amongst others, autonomous vehicles for different transportation modalities, the Internet of Things²⁵, big data, smartphones and the apps economy, and multimodal logistics (GSA, 2015).

Table 6: Top European companies in the GNSS downstream industry

| Segment | Company | Area of activity | Country |
|-------------------------------|-------------|--|---------|
| Component manufacturing | Laird | One of the company main activities is to supply wireless systems products enabling connectivity and remote smart systems, with primary markets in automotive, telecoms, industrial and medical sectors. The company is a major player in the design, manufacture and delivery of automotive antennas, with state-of-the-art designs including satellite radio, GPS, cellular, AM/FM. In 2014 it had 9,000 employees and its revenues amounted to 932 USD million (328 USD million from the Wireless Systems division). http://www.laird-plc.com/ | UK |
| | Cobham | Cobham SATCOM develops, manufactures, sells and supports satellite and radio communication terminals and earth stations for land, marine and airborne applications. Its 2014 revenues amounted to 834 GBP million, and it employs about 11,000 employees. Http://www.cobham.com/ | UK |
| System integrators | Volkswagen | The company is the fourth GNSS system integrator in the world, first in Europe after the non-EU Toyota, Garmin and General Motors (GSA 2015). It employs over 46,000 R&D staff worldwide to develop innovations in a variety of relevant areas including navigation systems. http://www.volkswagenag.com/ | DE |
| Value added service providers | Here Global | The company is a global leader in the mapping and location intelligence business. It builds high definition maps and combines them with cloud technology to enable real-time location services in a broad range of connected devices, from smartphones and tablets to wearables and vehicles. In the automotive segment the company is a leader, with its maps powering four out of five cars in-car navigation systems in North America and Europe, and its location platform is used by leading internet companies. The company has about 6 250 employees, with net sales of 970 EUR million in 2014. It belongs to Nokia. https://company.here.com/here/ http://company.nokia.com/en/investors | NL |

²⁵ The International Telecommunication Union defines the Internet of Things as “a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies”.

| Segment | Company | Area of activity | Country |
|---------|---------|--|---------|
| | Tomtom | TomTom's core technology assets are maps, traffic and navigation services. These assets are used in portable navigation devices, embedded navigation systems, smartphone applications, and web-based applications. TomTom provides global map coverage with fully navigable maps for 126 countries. Its traffic service is available in over 40 countries, providing drivers highly accurate measurements of traffic jams and delays for better route calculation and expected times of arrival. Over 77 million TomTom portable navigation devices have been sold in 35 countries. The company's core markets are Europe and North America. It has over 4 000 employees and its consolidated revenues amounted to 950 EUR million in 2014. http://annualreport2014.tomtom.com/ | NL |

Source: Authors based on different web sources.

3.3. The downstream market of Earth Observation

3.3.1. Market segments of EO applications

The downstream market of Earth Observation applications can be divided in five overall areas, which more or less reflect the different domains of the Copernicus services: i) natural resource management, ii) defence and security, iii) land monitoring, iv) oceanography, and v) meteorology. These are in turn divided in smaller segments, such as agriculture, forestry and fishery.

Table 7: Examples of applications by EO market segment

| | |
|------------------------------------|---|
| Natural Resource Management | <ul style="list-style-type: none"> • Environmental Monitoring: environmental accounting; climate change impact assessments in productivity and yields; air pollution monitoring • Agriculture: crop yield foresee; crop classification; crop health • Forest: deforestation/degradation maps, illicit logging • Energy: gravity field maps for oil and gas exploration; surface monitoring • Water: algal blooms, water quality management |
| Defence and Security | <ul style="list-style-type: none"> • Homeland security: sea borders monitoring, high risk areas precision mapping • Humanitarian: humanitarian movement and camps monitoring • Disaster management: large waves forecast, volcanic activity monitoring |
| Land monitoring | <ul style="list-style-type: none"> • Land use/Land cover: assessment, monitoring and reporting of the distribution of the major land cover classes, land suitability evaluation, land accounting • Cartography: geological mapping • Consumer services |
| Oceanography | <ul style="list-style-type: none"> • Transport: ice-free passages for shipping monitoring, ship monitoring • Coastal zone/engineering: water depth mapping, ocean level and surface monitoring |
| Meteorology | <ul style="list-style-type: none"> • Professional • Weather Forecast |

Source: European Commission, 2008b; EARSC, 2015a; Annex 2.

The level of maturity of different segments varies greatly, from public service meteorological applications (the highest) to consumer services (the lowest) (EC, 2008b). However, the market is vibrant and changes quickly. As an example, in 2015 EARSC²⁶ already had to modify the taxonomy for the EO services market that it released in 2012 (EARSC 2015a). The document was later modified to be a living document that accounts for the many changes and innovations that occur in this market. The availability of new data from Copernicus' satellites is also expected to bring about a reshape of the future market for EO services. The downstream business is also changing quickly thanks to the availability of new technologies for rapid data processing, analysis and dissemination (EARSC, 2015).

Typically, the client of EO products and services are public organizations (Box 3). It is often reported that government is to remain the most important client, implying that the market will be business to government or government to government, resulting thus in the provision of services from government to citizens (Noort, 2013). However, **while governments are set to remain the most important customers of the civilian remote sensing satellite industry, commercial uses are forecasted to increase.** Companies are currently preparing for the uptake of the commercial market as recently evidenced by the increasing share that commercial sales represent in DigitalGlobe's²⁷, or the acquisition by Airbus's Geo-Information Services division of two SPOT satellites in the absence of a specific government contract (Forecast International, 2015).

Box 3: Examples of EO services developed for institutional customers

Examples of enterprises developing downstream services addressed to institutional users are:

- In the field of maritime security, the Bulgarian Astra Paging Ltd is one of the largest providers of Automatic Identification Systems used for vessel tracking services. Its customers are both government agencies and commercial operators. It processes data from over 85,000 ships.
- In the field of environmental monitoring for health care, EOMAP GmbH & Co. KG is an independent German company selling Earth observation services for monitoring aquatic environments. EOMAP products are focused on the monitoring of water quality parameters such as turbidity, suspended matter, chlorophyll-a and harmful algae blooms using satellite data. This information for both inland and coastal waters is essential for identifying long-term trends and highlighting emerging problems over large areas.

Source: Annex 2.

Demand for commercial EO services still addresses niche markets with a lot of unexplored potential. In an online database²⁸ developed by Eurisy²⁹ to keep track of satellite-based applications in private and public sectors, only 13 EO services were developed for the private sector, mostly in the agriculture sector, in front of 43 applications designed for the public sector. **The 2015 EARSC (European Association of Remote Sensing Companies) survey confirms that public customers are dominant with**

²⁶ EARSC is the European Association of Remote Sensing Companies. Its mission is to promote the use of EO technology and especially the companies in Europe which offer EO-related products and services.

²⁷ DigitalGlobe is an American firm leading the market for the provision of commercial high-resolution Earth imagery.

²⁸ <http://www.eurisy.org/good-practices.php>.

²⁹ Eurisy is an association of European national space agencies plus ESA. It promotes the use of satellite applications, including those emerging thanks to the European Programmes Copernicus and Galileo.

approximately 65 % of the market share in terms of revenues, followed by other industrial customers (30 %) and international organizations (4 %) (EARSC 2015b). In particular, an increase in demand from local administrations has been noticed. Public customers are also prevailing in purchasing satellite data (50 % with over one third to defence customers). EO companies tend to focus on their domestic market. Provision of services for security and defence is the largest market segment, followed by environment, pollution and climate, and the oil and gas industry.

Demand for EO services in the public sector varies greatly, depending on specific country needs or to the administrative level at which satellite data are used. In a mapping exercise of user needs amongst a number regional authorities in Europe, the project DORIS_NET identified 50 different thematic needs where EO data can be applied. These were grouped in the following categories: sustainable development and nature protection (35.7 %), management of urban areas (16 %), emergency (14.3 %), agriculture, forestry and fishery (14.2 %), regional and local planning (5.4 %), transport (5.4 %), health (5.3 %) and tourism (3.6 %). In terms of spatial resolution needs, demand is higher for high (65 %) and medium resolution (35 %) images (DORIS_NET, 2013). As for the motivation for using satellite data in **public administrations**, Eurisy found out that the **large majority of usage is based upon the need to respond to socio-economic or environmental challenges**, followed by improved public services and support policy implementation. Cost-effectiveness of satellite-based solutions, as compared to other technologies, was also a reported driver for adoption (Eurisy, 2015).

In the commercial market, a study conducted by Space.Tec in 2012 identified five sectors with the highest market development potential. These were agriculture, oil and gas, non-life insurance, water transport and electricity generation from renewable energy (Space.Tec, 2012). Results from interviews conducted for the present study, confirm that **agriculture and insurance are the two sectors where most space-derived data applications are expected to be developed as commercial services**.

Box 4: Examples of EO services developed for the oil and gas market

Geospatial analysis is a critical tool for knowing which sites are most promising for drilling and for making decisions faster. Besides supporting oil and gas exploration activities, satellite imagery can help development operations, monitoring of producing fields, assessment of facilities, pipeline corridor planning, or emergencies and hazards management. As the oil and gas companies further expand their exploration activities into outlying, remote and inaccessible areas, satellite data will play a larger role in their operations to reduce staff on the ground and costly surveys.

Some examples of commercial satellite-based downstream services and of European companies offering such services to the oil and gas industry are:

- **Monitoring of surface deformation:** The Italian SME Tele-Rilevamento Europa is world leader in surface deformation monitoring services, being able to measure surface deformation to millimetre accuracy.
- **Offshore satellite positioning services**, provided for instance by the large Dutch private company Fugro.

- **Gravity field maps: GReD is a small Italian University spin-off offering to oil and gas companies** global gravity field maps estimated from satellite. The core of its business is its in-house developed algorithms and software that give state-of-the-art solutions to their customers.

- **Radar imaging:** ARESYS is an Italian SME historically serving the oil and gas market. Its expertise covers airborne and space borne radar technologies, along with pipeline acoustic monitoring systems and seismic and geophysical prospection systems.

Source: Annex 2.

The last edition of the EARSC survey offers for the first time an insight into **European industry's perception about the usefulness of Copernicus**. The current perceived impact of Copernicus on the EO service sector **is positive, but limited**, being 1.16 on a scale of -5 to +5. The number of products developed upon Copernicus services is also very limited due to the early stage of development of the programme's operational phase. While climate and air monitoring services are perceived to be dominated by the public sector, land monitoring is the service that most interest private European businesses. The public sector and the export markets represent the largest business opportunities for products and services based on Copernicus data and services.

3.3.2. Industry's structure and growth potential

The downstream industry of EO services is made of two actors, namely: data providers, that own or license commercial satellites, and information product providers, that turn raw data into thematic information. The EO service value chain include sellers of satellite data and companies that provide value-adding process, such as i) integration of multiple data sources, ii) interpretation and reporting, iii) customization, and iv) user support services. The downstream business also includes consultancy companies, downstream geospatial services that acquire already processed satellite data, and dedicated software and hardware companies serving them.

Figure 4: The EO downstream market value chain



Source: Authors.

Globally the commercial revenue of remote sensing companies increased from USD 1 billion in 2009 up to USD 1.5 billion in 2013 strongly driven by demand from the US government and a good industry performance. The number of civilian remote sensing satellites also increased with the civilian industry outpacing military spacecraft launch. **In Europe, turnover trend for the EO systems** have been mixed, from EUR 736.9 million in 2010 to **EUR 818 million³⁰ in 2013** following a peak of EUR 881 million in 2012. A relevant trend has been the increase in institutional programmes that have both civilian and military purposes (Al-Ekabi, 2014).

³⁰ I.e. USD 1 086 million.

The last EARSC survey amongst its European members³¹, depicts a fast changing market due to the emergence of new business models, which are based on vertical integration (e.g. Google acquisition of Skybox Imaging) and new technologies (e.g. micro satellites in the US that compete with aerial images) that allow to improve space imagery resolution. The EARSC database includes 451 companies, accounting for an average annual growth of nearly 8.7 % since 2010. **The sector has a dispersed and fragmented structure with a predominance of micro (63 %) and small enterprises (32 %), most of which are innovative start-ups.** The largest number of EO service companies can be found in countries which have a history of investment in space activities, including in order UK, Germany, Italy and France (Table 8).

Total employment projection in 2014 stems at 6,811 employed people with an average annual growth of 11 % since 2006. Most of the new jobs have been created within small companies. The projected total revenue of the sector in 2014 was EUR 910 million, which is 7.6 % higher than the 2012 revenue. Although this is a positive result, it is important to notice that **in the period 2007-2011, the annual growth rate was approximately 10 %. The market segment with the highest growth has been the value-adding segment, which in 2014 represents 44 % of the EO service market.**

According to Forecast International³², the increasing demand for Earth imagery will push satellite production up to 200 units in the next 10 years. **The demand for remote sensing services both from private and institutional customers is expected to increase** driven by a number of factors. These are: i) strong geopolitical changes in the Mediterranean basin that created a large area of instability and increased demand for security, surveillance and intelligence services; ii) international environmental commitments for tackling climate change that drive the demand for environmental monitoring services; iii) changes in the energy market that requires a more efficient production and distribution systems.

Table 8: Largest EU remote sensing companies

| Company | Area of activity | Country |
|---------------------------------|--|---------|
| Airbus Defence and Space | Large industrial group operating in all segments of the space value chain. In the downstream business, thanks to exclusive access to radar and optical satellites, it has a large portfolio that includes the entire geo-information value chain. It provides services from data acquisition to data management and processing to a large variety of institutional and commercial clients. http://airbusdefenceandspace.com/ | FR |
| e-GEOS | It is an ASI (Italian Space Agency) (20 %) and Telespazio (Finmeccanica/Thales group) (80 %) company. As the European hub for Very High Resolution data, e-GEOS grants unique access to the COSMO-SkyMed, GeoEye-1, IKONOS, Radarsat, Envisat, QuickBird and WorldView and IRS satellites. It develops products for both civil/institutional (e.g. environmental monitoring, rush mapping) and military customers (e.g. security and intelligence, maritime surveillance). It serves a variety of public and private clients (oil & gas and rail sectors). E-Geos employs more than 300 people. http://www.e-geos.it/ | IT |

³¹ The survey actually includes also Canadian company as Canada is a member of ESA.

³² Forecast International, Inc. is an US company providing market intelligence and analysis in the areas of aerospace, defence, power systems and military electronics.

| | | |
|-------------------------------|---|----|
| GAF | <p>Founded in 1985 as a small private sector enterprise, it is the European leader in consulting services and geo-information. It manages more than 500 projects concerning mainly the field of remote sensing and digital image processing. GAF AG operates in the Industry and Private sector and for international institutions. It provides sustainable solutions in resources management and offers a comprehensive end-to-end service portfolio: Earth Observation data, geo-products, integrating space technologies.</p> <p>https://www.gaf.de/content/earth-observation-imagery</p> | DE |
| Eurosense | <p>It offers different geo-information services: aerial photography, aerial laser scanning for height measurement, processing and interpretation of satellite images, topographic maps. It aims to create highly accurate and technological solutions as well as training and consultancy in different fields. The EUROSENSE-group employs a staff of about 200 highly specialized members.</p> <p>http://www.eurosense.com/documents/our_expertise/spaceborne.xml?lang=en-gb</p> | BE |
| Blackbridge | <p>It provides infrastructure, products and services across the geo-information value chain. It focuses on providing end-to-end solutions (satellite operations, ground station services, data centre and geo-cloud solutions). Its primary customers are government organizations, energy and resource industries. Active in more than 20 countries, Blackbridge operates commercial Earth Observation system, including the RapidEye constellation of 5 spacecraft, a spacecraft control centre, reception facilities for enabling uplink/downlink services, and a ground segment for acquiring and processing over 5 million km² of imagery every day.</p> <p>http://blackbridge.com/rapideye/about/contact.htm</p> | DE |
| European Space Imaging | <p>Founded in 2002, it is a leading supplier of global very high-resolution satellite imagery and derived services to customers in Europe, North Africa and Commonwealth of Independent States. Operating a multi-mission capable ground station enables optimized image collection results taking into account real-time weather information and giving customers the highest degree of flexibility.</p> <p>http://www.euspaceimaging.com/</p> | DE |
| DMCii | <p>DMCii is a UK company that has imaged the Brazilian Amazon since 2005, and is currently working across Africa and Indonesia. Its satellites are also Third Party Missions under the GMES programme, and the company is currently engaged in imaging the whole of sub-Saharan Africa. DMCii images are used in a wide variety of commercial and government applications, including agriculture, forestry and environmental mapping.</p> <p>http://www.dmcii.com</p> | GB |

Source: Authors based on different web sources.

4. OBSTACLES TO SPACE MARKET UPTAKE IN THE EU AND POLICY RESPONSES

KEY FINDINGS

- Although progress has been fast, the uptake of the European downstream space market has been below expectations. **Several barriers have constrained the development of this sector**, including: political barriers, market constraints, governance difficulties, technical issues and, to a lesser extent, lack of skills.
- The **insufficient and delayed support actions** for the development of the downstream sector and **implementation delays** are the most critical barriers preventing the development of value added products based on Galileo data. **Weak data and product distribution**, but also the **complexity of the governance framework** and other barriers limit the development of the downstream market of Copernicus-based data.
- The EC has promoted the uptake of a market based on the use of space data with **different instruments that delivered mixed results**.
- EU **support to space research** has increased, but is still low if compared to the US R&D budget for space. Higher efforts are needed to promote the development of marketable products and services.
- The EC **regulatory power** in both the space and non-space specific area could create opportunities for a larger use of space data. The EC could also act to improve the general business enabling conditions, for example by increasing the access to venture capital, not necessarily through the introduction of new regulations.
- **Dissemination activities** are carried out to raise awareness about Copernicus and Galileo programmes amongst EU citizens and to encourage the use of space data in the public system and in the business community.

4.1. Existing barriers to space data market uptake

Location and positioning services, as well as EO services, have emerged more recently in the EU. Although progress has been fast (GSA, 2015), most interviewees agreed upon saying that **the uptake of downstream services based on space data has so far been below expectations**. The weaknesses of the EU space market relate to many factors, from market specific constraints to policy and regulatory barriers.

4.1.1. Policy, strategic approach issues

A very general remark on the approach pursued by the EU in designing its space programmes, is that these are **focused too heavily on institutional and scientific needs**, with only a secondary focus on the development of commercial services and applications. With regards to the commercial sector, there is a widespread perception that European national space agencies, including ESA, have been **primarily concerned with the upstream space market**, serving the needs of the main scientific programmes managed by the agencies themselves, or of big industries. In addition to this, Member States with the strongest tradition in the space sector, often had a public owned incumbent that discouraged the development of a diversified downstream private sector. This has resulted in a lack of attention for policies and infrastructure that would have rapidly made

available a large quantity of data to the downstream market segment. In the US, investments in space are more driven by user-needs. In particular, in developing their space programmes the US have a more forward looking approach that considers the needs of a variety of data users, hence supporting potential market developments. A characteristic feature of the US approach is to make use of scientific advisory teams that provide advice on a regular basis. This establishes a bridge between the programme developers and the future users and ensures that the federally sponsored data access management and data processing always benefit from the latest knowledge.

In 2008 ESA laid down the policy that should have governed the provision of Sentinel data. Free, unlimited and open access to information produced by GMES services and data was strongly advocated. Such an approach was based on the need to maximize the beneficial use of Sentinel data and to foster the uptake of information based on space data (ESA, 2008). The full and open data access policy was further supported in an EC Communication in 2009 (EC, 2009). However, **it was only in 2013 with Regulation No 1159/2013 that the EU finally established that "users shall have free, full and open access to GMES dedicated data and GMES service information". A number of restrictions, that concern security, intellectual property, and privacy issues, were added.**

Recent data show that European micro and SMEs are the largest users of free satellite data (EARSC, 2015b). Uncertainty over conditions of access, continuity of service, price and data policy for EO data was reported to having been an inhibiting factor for the development of commercial applications in the EU. Despite Regulation No 1159/2013 2103 sets the full and open data access, there is still not a comprehensive data policy that coherently addresses open access with issues related to intellectual property, privacy and security. Data standards, interfaces and archive policy have not been fully developed yet. Moreover, data access policies for data obtained through Sentinel and Contributing Missions have not been harmonized yet.

Table 9: Examples of Member States' policies for satellite data access

| Country | Policy |
|----------------|---|
| Germany | The Earth Observation Centre (EOC) of the German Space Agency (DLR) manages Earth observation data and products from missions and scientific projects inside the "German Satellite Data Archive". EOC Earth observation data and products are accessible via several data portals. Most of them address primarily the needs of the scientific user community. Some, such as the daily weather images, temperature, and ozone maps, are designed for the general public. There is no uniform data policy governing the use of the EOC data and products. Instead, missions and projects define their own terms and conditions with the objective to promote widespread use of the data to the extent possible. |
| Italy | As for Decree-Law n. 95 of 6th July 2012, in order to support the development of applications and services based on geospatial data and to develop the Earth Observation technologies for the purpose of environmental protection, risk mitigation and scientific research, all the data and information acquired from the soil, airplane and satellite platforms in the activities funded by public resources, are made available to all national potential users, including private, <i>within the limits imposed by reasons of national security protection</i> . To this end, the public research institute ISPRA is in charge of cataloguing and collecting geographic, territorial and environmental data produced by all activities funded by public resources. On the other hand, the private operator Telespazio Spa delivers engineering and management services for the Italian satellites of the COSMO-SkyMed programme. It is in charge of the acquisition, processing and distribution of derived data upon payment of a fee. |

| Country | Policy |
|------------------------|---|
| France | Funded by the "Investissements d'Avenir" French national investment programme, the EQUIPEX GEOSUD project is aimed at providing actors of scientific research and public policy with free access to a set of French space-based products and services, processing capabilities and calculations, networking of actors. The program is also open to private players in the context of partnerships with, or subcontracting to, public actors. The products of Copernicus Sentinel satellites are distributed for free through the PEPS platform. |
| United Kingdom | The Climate, Environment and Monitoring from Space (CEMS) facility is designed to give any type of users access to extensive data holdings and a range of applications, tools and services that help them analyse this data more effectively. CEMS provides users with a virtualised environment allowing easy access to space data and various associated services. It is expected to provide the national access point for Copernicus Sentinel-1 & 2 data, but also many other data sets, tools and entire thematic domains, for greater commercial and academic benefit. |
| Belgium | Free access to hotspot data is granted to scientists and public authorities. No mechanisms are in place to provide private users with access to space data and to involve them in the downstream market. |
| The Netherlands | Both raw and pre-processed data provided for free for national private and public users by the national space agency (NSO). |

Source: Authors based on national space agencies websites, interviews and other sources.

A key policy issue is also the definition and possible further modifications of the Core Services provided by Copernicus programme, as the most valuable EO data is often offered at different levels of data processing. Because interests at stake are different, a sort of economic optimum scenario is to be devised following an understanding of the specific value chain for each core services. In principle, services that could be developed by the private sector should be left to the market to develop with the guarantee of a minimum public service provision. For instance, in the US, public institutions (with a wide definition of public institution which not only includes federal agencies such as NOAA or NASA, but extending for instance also to public universities) are strictly forbidden to offer services that can be offered by private companies, which increases market opportunity for private service providers (EC, 2008b). However, such clarity has not been provided yet by Copernicus regulation. Today, **what most deters investments in the downstream business is uncertainty over possible changes in the provision of the core services that would alter existing competition rules** (EARCS, 2013). European industry is also concerned about having equal chance to be involved in the supply of Copernicus Services vis-à-vis public sector bodies (EARCS, 2015).

The EU does not have a space industry policy that reflects the specific needs of each sub-sector and that sets a coherent regulatory framework for the emergence of a European market for space products and services (EC, 2011a). The lack of a coherent industrial space policy strategy also limits the possibility to explore at best synergies with telecommunication satellites. Technologies that are developed for communication satellites can also be integrated into navigation and EO applications. While the US have put in place investments and market enabling policies that favour market development of the downstream sector, investments in Europe are still too much oriented towards meeting the needs of industries and big players in space data distribution and reselling. It was only in the summer of 2015, that a dedicated unit was established within the EC to look at the value chain of space data use to create a more coherent European industrial approach.

Box 5: The UK space policy and the example of the Catapult approach

Within EU member countries the UK has developed one of the most innovative approach to support the development of its space sector and today has the one of the most vibrant EO service downstream sector in Europe (EARSC, 2015b). Before 2011, when the UK space agency was established, the space sector was not on the top of government priorities. Subsequently, its contribution to the UK economy and society was recognised and led to the design of a space sector specific development strategy³³. The strategy sets the UK's ambition for a space sector with a target of GBP 19 billion turnover by 2020, which will correspond to nearly 8 % of the world's space economy. Recognizing that the highest growth in space markets will be in space-based services and applications using space data, the strategy focuses on expanding UK's share of the global market for services and applications and the related manufacturing activities. The strategy addresses the entire space sector ecosystem including the specific needs of SMEs in terms of finance, business, skills and information support, and promotes the use of specific instruments that champion the use of space data in other sectors of the economy (UK Space, 2014).

Catapult is a network of technology and innovation centres where businesses, scientists and engineers work together on research and development projects to take innovations to the market. Amongst these centres, the Satellite Applications Catapult's was established in 2013 to encourage the exploitation of space data to support economic growth and job creation. Besides making high-tech facilities available for the centre's users, such as specific EO facilities, the Catapult is based on an innovative approach to support the downstream space market that integrates all aspects of the value chain from satellite data acquisition to products commercialization. In particular the following support services are made available:

- Access to satellite data through an EO Data Exploitation Platform (the Data Hub) which supports different thematic exploitation platforms and through the opportunities offered by the developing UK collaborative ground segment. The Data Hub allows non-scientific users to use satellite data effectively.
- Provision of information systems which enable rapid development of applications and delivery of services. Applications development platforms are intended to support data management, processing, analysis, dissemination and visualization. The Applications and Solutions team helps develop software that integrate satellite and non-satellite-derived within applications.
- Commercialisation of ideas ensures that scalable business models are developed and that the products and services developed are really commercial. Technical, financial regulatory barriers are all addressed by multi-disciplinary teams, while the process of prototyping and testing is made as quick as possible.
- Strategic focus and integration with telecommunication satellite technologies is also an interesting aspect of the Catapult approach. In this respect, activities focus on sectors that are believed to have the highest possible economic impact. Current programmes are: market exploration (e.g. smart cities, health, food supply chain) technology exploration (faster access to satellite data), maritime (e.g. fishing monitoring and vessel efficiency) and transport (e.g. reliable positioning and autonomous vehicle).

Source: Authors based on <https://sa.catapult.org.uk/>.

³³ A UK Space Innovation and Growth Strategy 2010 to 2030.

4.1.2. Market constraints: fragmentation, immaturity, low awareness in related sectors

According to the European EO service industry, the **lack of a structured European market where clients are willing to pay for EO products is the largest barrier for a further development of downstream businesses** (EARSC, 2015b). EU downstream market also has specific challenges that mostly rest on the fragmentation of national markets and the barriers in exploiting synergies between civil and military use of satellite technologies. As a matter of fact, the market of satellite enabled products and services heavily relies on public customers, especially at its early stage of development. However, the European space industry is based on commercial sales and has a smaller budget as compared to other international competitors that apply more synergies between civil and military use of space-based services and applications. Security and defence has been the key customer for the development of Earth observation products and services, especially when based on very high-resolution imagery.

The funding of European R&D is less than a half that of US, and the European institutional (public) market is smaller than in the US. More in details:

- Approximately 25 % of the United States' civil space budget is spent on R&D, while in Europe only 10 % of unconsolidated sales turnover is spent on R&D.
- NASA's civilian budget alone is approximately four times bigger than the total European civilian space budget (expressed per capita).
- In 2009, the United States' budget for the space sector was almost 10 times higher than the European budget (EC Communication, 2013).

In Europe, it is estimated that **about 50 % of the overall market is driven by public institutions, which implies that without the public sector demand the development of the downstream sector is limited** (EARSC, 2015d). Within European public administrations, awareness about the potential use and benefits of using space data for the provision of public services is far from being widespread. While some member countries are more active in advocating the use of space data in public administration, others still rely on more traditional technologies (e.g. aerial imagery). Similarly, the 29 companies included in the Galileo Services associations reported an insufficient support from the EU to stimulate downstream products and services.

Nevertheless, within the context of decreasing public budgets, demand from the private sector is not sufficient to stimulate a further increase in the supply of satellite-based services and applications. Besides a few exceptions, willingness to pay for geospatial information is still limited in the private sector (EARSC, 2015d). This does not compare well with the US, where military contracts are used by manufacturers to finance their investment to develop products for the commercial market. The push effect of defence and security is far more limited in Europe. Other conditions that allow the US downstream business to flourish, such as consolidated collaboration networks between private companies and universities for the development and commercialisation of EO-based services, and availability of venture capital, are much less established in Europe.

The existence of many public stakeholders and the implementation of different national and ESA's space industrial policies, without always the necessary coordination, creates a very fragmented institutional market. While in principle most EO markets in Europe are open to foreign suppliers, there is a tendency to procure value added services from local providers (EC, 2008b). Differences in language and procurement procedures across Europe discourage participation in national tenders, especially for SMEs that have limited administrative capacities.

Independency of the downstream market from non-European technologies is also an issue of concern among both policy makers and industry representatives. European institutional, research and private users are largely dependent on US IT giant companies (e.g. Google, Amazon, Apple, Microsoft) for preliminary satellite data management and manipulation. These companies enjoy a de facto monopoly position, as they are the interface through which the large public get user-friendly access to satellite data and information. Opportunities for European players could lay in areas that are not already covered by these companies, for instance, by better guaranteeing continuity and quality of information for users. The products generated by big IT companies satisfy mass users, but have a low degree of customization on specific local needs which European counterpart could offer.

Independency of the downstream market is also at risk in the field of navigation satellite systems. As acknowledged by the EC, the independency of the EU navigation satellite infrastructure has to be followed by the development of positioning and timing information applications, which are already so pervasive in the life of citizens and business (EC, 2010). A position paper released by Galileo Services Association³⁴ reports that *"The targeted European autonomy will be achieved if and only if Galileo is widely used with equipment designed and manufactured in Europe, as well as applications and services developed in Europe"*. This is especially relevant for strategic sectors such as defence and security (Galileo Services Association, 2015).

European companies are also subject to increasing competition from emerging space-faring nations such as China and India. The European GNSS downstream industry laments to be suffering from a competitive disadvantage as compared to industries from other regions, such as Russia, US, China, Japan, where dedicated national programs directly support the industry through dedicated funding for R&D and manufacturing, ad hoc regulations and large public (military) procurement (Galileo Services Association, 2015).

4.1.3. Governance: unclear settings, public/private role

In 2010 the Space Council underlined the importance of identifying an operational scheme for the governance of the two EU space flagship programmes in the long term that would have been based on collaboration between space agencies, service providers and end-users (Space Council, 2010). The full potential of data and information based on satellite data depends on the balanced combination of different interests of security, public interest and commercial development. With particular reference to Copernicus, **the space programme management remains fragmented while coordination of different actors, including the Member States, the ESA, EUMETSAT proved to be a challenge**. This has serious implications both in terms of developing a downstream market based on the use of satellite data, and in terms of accountability concerning an efficient use of public resources (EC, 2011a).

The need to establish more appropriate relationships emerge as the EU tried to increase the economic profile of space matters. Between 2011 and 2012 a number of EC communications³⁵ identified many key issues for the EU industrial space policy and possible scenario for new partnership between ESA and the EU. These refer to different funding rules, and specifically to the conflict between geographic return in ESA financial procedures

³⁴ Established in 2002, the Galileo Services association consists of key European and non-European players in the GNSS downstream industry.

³⁵ Towards a Space Strategy for the European Union that Benefits its Citizens and Establishing Appropriate Relations between the EU and the European Space Agency COM(2012) 671 final.

and EU Financial Regulation rules that are based on the principle of best value. Asymmetry in membership is also an issue of concern, as ESA membership includes countries that are not part of the EU and have voting rights on issues that concern the EU. There are also no mechanisms that ensure that the position of EU Member States in ESA, as in other international organizations, is consistent with EU Space Policy. The Competitive Council of May 2014 nuanced the position of the EC by adopting a lighter version of the EC proposal where all decisions about future EU relations with ESA are postponed until more evidence is available on the effect on Europe's space industrial base (Council of the European Union, 2014).

Given its institutional complexity, the Copernicus programme is mostly concerned by critical governance issues. In this respect, a study prepared in 2011 identified the need to give the Copernicus programme a sound governance framework as a top priority (Booz & Company, 2011). First, the programme lacks an institutional body that would aggregate the many functions and services that have been assigned to different organisations. Centralization is critical to achieve a critical mass in terms of demand and expertise. Second, to deliver its full economic and societal benefits, Copernicus needs to be user-driven. A key issue in this regard is the capacity of the programme to meet user needs and to change to accommodate new requests and market development. The existing Copernicus User Forum is not truly able to establish a liaison between decision makers and users (Allgeier et al., 2015).

While the EC attaches increasing importance to develop the downstream businesses to justify the scale of the public investment, there are no provisions for a formal engagement of the EU industry on the management and evolution of Copernicus within the existing governance framework. The downstream industry had no voice in the definition of missions and programmes, while the impartial advice delivered by advisory bodies was too biased towards scientific and technical requirements rather than based on user needs (EARSC, 2015c). There are still **no official communication channels that allow the industry provide systematically its views on important matters for the development of the downstream market**, including the definition and modification of Copernicus data and product list and decisions about new data use and next generation of Sentinel infrastructure (EARSC, 2013b).

Coordination of Member States' space policies has improved in recent years, but there are still areas where collaboration is too limited. Each member state is in a different stage of development of the space sector, with differentiated objectives and policies. For instance, some of the Member States have their own space assets managed by national space agencies (e.g. Belgium, France, Germany, Italy, Spain, or United Kingdom), while others relies only on Copernicus or third-parties satellites (commercial or non-EU missions). Attempts to achieve better complementarity between EU and Member States space initiatives had limited effect (EC, 2011). Collaboration exists and proved to be successful for the delivery of public services, but is very limited in the commercial sector where Member States are very protective of their national industrial assets.

National space programmes are sometimes in competition with each other and multiply single national missions rather than moving towards a European constellation of satellites (e.g. the Italian COSMO-SkyMed vs. the German TerrSAR-X or the French Pléiades vs the Spanish Deimos). Similarly, at the end data user level, the highly fragmented context of Europe often makes difficult to combine Copernicus with nationally-owned data, as access rules are different. For instance, some member countries resist to the principle of granting full open and free access to their space imagery archives. Space downstream activity services also need standardisation to have access to a larger and unified market (EC, 2013). European data resellers confirm that the national distribution systems of

satellite data follow too many different rules, lacking of transparency and predictability (EC, 2014c).

4.1.4. Technical issues: data distribution framework, interoperability, implementation delays

All interviewees agreed upon saying that the open data access policy was appropriate, although decision was not taken quickly enough to account for the fast changing landscape of space data technologies. In comparison with the data distribution system of the US, **the EU data and products distribution and sharing infrastructure system looks rather inefficient, especially in terms of facilitating access to commercial operators.**

First, the data that have been made available from Copernicus programme are raw and need to be processed in order to be used for commercial purposes. The challenge is thus to enable small companies to play with data and create marketable services and products out of it. However, this currently requires a high level of technical and scientific competences and increases the cost of access. US missions, such as Landsat at high resolution, MODIS (Moderate Resolution Imaging Spectroradiometer) or VIIRS (Visible Infrared Imaging Radiometer Suite) at low and moderate resolutions, included a significant investment in providing, fast, free, unlimited and unsupervised access to data in near-real time to all users, at a variety of processing levels. This guaranteed access to the lowest level data, necessary for scientific investigation, but allowed the SMEs to rely on pre-processed data for generating value added datasets. Furthermore, with an open access policy already in place, it was immediate for web-based data services, such as Google and Amazon, to enable users visualize massive amounts of data, without the added burden of managing the data themselves (Box 6). The advantage of these services stems from the possibility to test and rapidly develop new products using entire archives of data, rather than selected individual scenes. Existing plans to make accessible the EU open archive for only three months, does not compare well with the US system where data are always available back to 1972.

Secondly, Copernicus lacks a holistic approach to data management because data distribution is based on fragmented data sources. EU Copernicus data and products are spread in many different archives, formats and portals. The Copernicus core service segment (with 6 thematic areas and relative product portfolios), the EUMETSAT Satellite Application Facilities network (with 8 Application facility and product catalogues) and the ESA Earth Online catalogue represent just three examples of different, and sometimes overlapping, large product repositories, hosting huge amounts of information that are difficult to explore and navigate into. Decentralisation was chosen to build upon existing expertise available in different European institutions, but the lack of an overly coordination mechanism makes data use less effective. As an example, to facilitate access for the user community and to private companies that would use this information to develop commercial services, Nereus, a network of European regions using space technologies, suggests to establish a dedicated European Copernicus data distribution infrastructure (Nereus, 2013).

Thirdly, as pointed out by the people interviewed for this study, product repositories are not user-friendly. The existing IT system that supports distribution of Sentinel data is not based on a user-friendly interface, and the time for accessing to ESA's data is longer as compared to the NASA/USGS equivalents.

Box 6: The key role of the IT platform for an effective distribution of EO data

In 2008 the US government established to grant free access to its space imagery archives. This created new opportunities for turning these images into dynamic maps and mini-movies for the use of governments, researchers, and civil society. By collecting and sequencing images collected by Landsat satellites it was possible to show the environmental evolution of specific regions of the world. This opportunity was sought by Google, which had the computing power to assemble all the available images. In 2009 Google struck a deal with the USGS, that manages Landsat archives, and the entire Landsat archive was ingested for free into the Google Cloud processing system. To deal with the massive stream of data, the construction of a new digital pipeline was needed. Processing of millions of satellite images was also complex. Although resolution is relatively limited (30m), the results of this immense work show retreating glaciers, emptying reservoirs, reduced forest areas and increased urban expansion. The project got the attention of the Mexican government that contracted Google to map the health status of its forest areas. Google put a thousand computers to process simultaneously nearly 53,000 images provided by Landsat and delivered its product in a working day, while a single computer would have needed three years to complete the process.

Source: Authors based on <http://world.time.com/timelapse/>.

Combining Sentinel data with data from Member States and the US satellites, would open new possibilities for using EO data. This is in principle possible, but is limited by a number of technical challenges. For instance, Sentinel and Landsat use different spatial resolution and geometric resampling strategies. For the first time the Sentinel 2 and Landsat 8 (the latest US mission) were pre-launch cross calibrated, but this is still rare. At the same time, EO data users tend to specialize with data from a specific satellite infrastructure. All these, combined with the weaknesses of the Sentinel data distribution policy, make interoperability more challenging and less common. Access to Copernicus data and products is also unequal across Member States. This depends on local conditions for high speed internet connection, but also on the development of countries' space and ground infrastructure. As an example, CNES, the French space agency, has developed the PEPS platform (Plateforme d'Exploitation des Produits Sentinel) to offer French users high-performance access to Sentinel data. Similarly, the UK Space agency has set up a space data hub to facilitate access to satellite data from different sources.

The images provided by the Sentinels are of medium/low spatial resolution, enough to respond to the need of monitoring environmental changes, for which the programme was primarily designed. The decision to provide medium/low resolution images was also driven by other political considerations, and in particular by the need to avoid competition with Member States that provide high-resolution imaging. As a consequence, Copernicus relies completely on contributing missions for very high-resolution imagery, acting thus as a purchaser and not as a provider (SpaceTec Partners, 2013). However, as highlighted by many interviewees, **the highest potential for developing commercial services and applications rests on high resolution images** that are provided either by dual purpose satellites (i.e. satellites that combine civilian and military purposes) or commercial satellites. The use of Copernicus for security purposes is also limited by the coarse geometric resolution of the imagery delivered. The European External Action Services (EEAS) is currently purchasing high quality resolution images from northern American or European commercial providers.

Finally, most of the benefits related to the development of applications and services based on the EU GNSS will materialize only after the full infrastructure is complete (EC, 2010a). The same applies to the Copernicus programme. It is thus of

outmost importance that services are made available as programmed, to avoid missing further opportunities (EC, 2011c). Following current plans, Galileo services should be available within 2016, and the full system should be operational by 2020. GSA data shows that multi-constellation is already becoming a standard feature in user equipment with GPS naturally present in all devices, followed by the Russian GLONASS. However, Galileo programme schedule already puts Galileo in fourth position, when three GNSS constellations are sufficient for providing accurate data (Galileo Service Association, 2015). Furthermore, delays in the Galileo launch schedule and in the overall system and service availability was reported to have negatively affected the public perception of the programme.

4.1.5. Lack of skills and awareness

According to some EU official documents (see EC, 2013b) Europe is facing the challenge of securing enough human resources to support the development of its space industry and the related emerging sectors. However, it is relevant to notice that interviews conducted for the present study have not considered skill shortage as a major constraint to the development of marketable services and applications based on space data. Similarly, the 2012 EARSC survey on the EO service industry reports that lack of staff is not perceived as a serious issue by private companies (EARSC, 2013b).

A rather different issue concerning the lack of adequate skills relates to the public administration staff consciousness of the potential of information generated by Copernicus, and their willingness and capabilities to use this source. A survey conducted by Eurisy on public administrations using satellite-based applications, showed that **in-house expertise is not a necessary condition for using these technologies, but it is a driver of more proactive action** (Eurisy, 2015).

Lack of specialised technical and scientific skills could prevent also private enterprises from exploiting the opportunities offered by the space data. As already mentioned in the previous section, granting free and easy access and distribution to a variety of pre-processed space-based products could attract the interest of new commercial users who do not have the competences and experience to manage the raw data made available from the Copernicus programme.

Much more critical is **resistance to change consolidated technologies**, such as aerial imagery, that holds back a more rapid adoption of satellite generated data within the public systems, especially in smaller countries. In this regard, it is expected that the increased awareness about the potential of space data and easier access to these data will result in a higher demand, in order to progressively substitute or supplement traditional aerial imagery.

Table 10: based on the use of space data

| Type of barrier | Barrier | Galileo | Copernicus |
|-------------------------------|---|----------|------------|
| Policy/ strategy issues | Lack of an EU space industrial policy | High | High |
| | Insufficient and delayed support actions for the downstream sector | Critical | High |
| Market issues | Fragmentation of EU space markets | High | High |
| | Insufficient public and private demand | Low | High |
| | Dependency of the downstream market from non-EU technologies | High | High |
| Governance | Non-systematic involvement of industry representatives | Medium | High |
| | Complex governance framework | Nil | High |
| | Insufficient collaboration amongst Member States | Nil | Medium |
| Technical issues | Other possible implementation delays | Critical | Low |
| | Weak data and product distribution system | Nil | Critical |
| | Interoperability | Nil | Medium |
| | Differences in space data access across EU | Nil | Medium |
| Lack of skills | Shortage of technical skills to manage space data, resistance to change | Low | Medium |

Source: Authors.

4.2. Instruments for promoting space market uptake

The Fifth Space Council resolution of 2008 recognises the urgency of promoting the “development of an appropriate regulatory framework to stimulate [...] downstream services, in particular with the objective of guaranteeing sustained access to spectrum for all space-based applications”. Likewise, the European Commission Communication on the EU Space Industrial Policy of February 2013 accounts the establishment of a comprehensive regulatory framework as one of the main objectives of the EU space industrial policy. Reducing dependency from GPS only enabled application is seen as critical to achieve the objectives of Galileo and Egnos programmes. Market shares of EU companies remain low, especially in relation to the innovative potential of European companies (EC, 2010c).

The 29 companies included in the Galileo Services Association reported an insufficient support from the EU to stimulate downstream products and services. This does not compare well with the US, where, as an example, military contracts are used by manufacturers to finance their investment to develop products for the commercial market (de Selding, 2015). Similarly, the EASARC reports the lack of a clear industrial and effective policy for the European space sector, as compared to other space-faring nations.

So far, **the EC has promoted the uptake of a market based on the use of space data with different instruments that delivered mixed results.** These interventions can be grouped in three categories, including support to R&D, regulatory power, and dissemination activities.

4.2.1. Support to space research

The EU Regulation 1285/2013 establishes that “the appropriate instrument to finance research and innovation activities relating to the development of GNSS-based applications

is Horizon 2020", the current EU Framework Programme for Research and Innovation and successor of FP7. **Acknowledging that space budget on R&D remains low (10 %) in the EU as compared to the US (25 %), Horizon 2020 seeks to overcome fragmentation of national space research activities by establishing European level space research and innovation activities** (EC, 2011).

The budget for Space under Horizon 2020 is proposed to be 1,737 million euro for 7 years, which represents a 20 % increase as compared to the past programming period (Cosmos news³⁶). The space component has been designed to prioritize the use of data and services from the EU GNSS programme and Copernicus. In particular, enabling exploitation of space data is a specific line of activity aiming at supporting innovative satellite-based downstream services. This should lead to improved space data handling and dissemination to maximize societal benefits of the EU satellite infrastructures (EC, 2010).

The recently finalized FP7-programme managed by GSA delivered 45 products, 150 demonstrations and 13 patents out of 90 funded projects. Galileo based applications are being developed, however due to unavailability of the services they are currently only Galileo ready (GSA data). Most interviewees agreed upon the usefulness of the EU research programmes in supporting the development of applications and services based on space data. These programmes have been a vital source of financing in an innovative sector where EU companies have many difficulties in raising money for developing new products. Programmes were designed to be as close as possible to the market. For instance, since FP7, calls related to the space sector required participants to include a business plan.

For the period 2014- 2015, the space component of Horizon 2020 is structured along seven themes: i) Applications in Satellite Navigation, ii) Earth Observation, iii) protection of European assets in and from space, iv) Competitiveness of the European Space Sector: Technology and Science, v) space exploration and science, vi) International Cooperation in Space matters; and vii) Outreach and Communication. The first and the second thematic calls are those more relevant to support the downstream business. They support both the development of new services and applications based on satellite data and awareness rising activities.

A novelty in Horizon 2020 is the Open Research Data Pilot, which aims to improve and maximise access to and re-use of research data generated by projects, and the setting up an SME-dedicated financing window (Space-SME-2015-2:SME Instrument). The SME instrument is structured along three separate phases: i) a feasibility study, ii) activities, such as prototyping, that assist with bringing a project to industrial readiness and maturity; and iii) indirect support measures and services, including assistance for internationalization, marketing plans, skill development and additional fund raising. The call was open in December 2014 and is based on a multiple cut-off deadline model that terminates in November 2015. It is too early to assess the effectiveness of this specific SME window.

In spite these supportive actions were generally well received, the experience of past European research programmes highlighted a number of barriers that either discourage participation of enterprises or do not promote effectively the development of marketable products. In particular:

- The time frame of FP7 - H2020 projects seems more adapted to research centres. Enterprises need to achieve results faster than what is usually foreseen in the EU projects.

³⁶ <http://ncp-space.net/first-proposal-for-horizon-2020-the-fp7-follow-up-programme/>.

- The programmes have so far been limited to supporting space data processing for future potential use, rather than to developing marketable products. It has been instrumental for designing Copernicus Services, but little supported market forward looking initiatives.
- Projects have a large scale and often involve different partners. This structure discourages participation from smaller private companies, especially SMEs. These are often included to comply with selection criteria, but actually private companies tend to have a marginal role.
- Funds dedicated to space research are quickly over-subscribed and dominated by academic and institutional players that have the necessary administrative and project design capacity.
- The proportion of applications that eventually reach the commercialization phase is still too limited.
- The research projects supported through the European Research Programmes have too weak linkages with user and market needs to be used effectively to develop marketable products. The balance is often in favour of scientific rigor than on projects that can be quickly turned into profitable businesses.

What needs to be significantly reinforced within the EU support to R&D for the downstream space sector is the assistance to market development. In this respect, the ESA Business Incubation Centres (BICs)³⁷, have established a more effective model for addressing the needs of emerging entrepreneurs. By July 2015 more than 200 start-ups companies from ESA member countries have received support in the form of technical and commercial assistance. Another example of programme organized by ESA that supports marketable innovation based on EO data is the Copernicus Master, which, since 2011, has awarded 30 innovative projects. In the 2014 edition only 26 % of applications came from research institutes or universities. All the rest were either submitted by individuals or private companies. Besides the cash prize, which are generally of small amount, winners receive a number of services that include technical and marketing support, publicity, access to experts in variety of relevant areas and access to non-open satellite data.

Member countries are also setting up national programmes to fund R&D projects for the downstream sector. In the UK, Innovate UK and the Natural Environment Research Council have just launched a programme that will invest up to GBP 3.75 million in collaborative R&D projects and relevant technical feasibility studies to stimulate the use of satellite data in the agro-food sector. In Belgium, to execute the decision of the Council of Ministers concerning the implementation of the Belgian space strategy, the State Secretary for Science Policy approved the long-term STEREO III programme with priorities actions in monitoring of vegetation and evolution of terrestrial ecosystems, management of the environment, land cover and climate changes, epidemiology and humanitarian aid, and security and risk management. In Italy, during 2015 the Italian Space Agency issued a call for the development of new satellite missions and payloads and for joint Israel-Italian R&D projects. These programmes comprise activities for the exploitation of the research output and the development of pre-operational products and services.

³⁷ There are currently 11 BICs across Europe, namely: Noordwijk (The Netherlands), Darmstadt (Denmark), Rome (Italy), Bavaria (Germany), Harwell (UK), Redu, Geel and Mol (Belgium), Sud France located in Aquitaine, Midi-Pyrénées and Provence-Alpes-Côte d'Azur (France), Barcelona and Madrid (Spain), Portugal. New centres will open soon in Sweden and Czech Republic.

4.2.2. Regulations

EC legislative actions affecting the downstream market can be grouped in three categories.

- **Regulations that directly concern the space sector, which are spectrum, export control and data access policies.** Spectrum policies mostly concerns telecommunication satellite, whereas the EC has recently clarified its satellite data access policy along the principle of free and open access. Export markets are key for European countries with small domestic markets. While export control practices are generally harmonized across Europe, the dual use of some space technologies has actually led to a fragmented market where complex and non-transparent national frameworks put excessive burden on exporters. The need to protect national security interests has thus far increased dependency from national procurement systems and hampered the development of a larger European commercial market for satellite-based applications (Aranzamendi, 2011).
- **Non-space specific regulations that create opportunities for a larger use of space data in different sectors.** Copernicus and Galileo promote technologies that apply transversally in many area of competence of the EU, such as agriculture and fishery. In this context, as long as space-based services and applications enter in a commercialization phase, non-space specific regulations also become either barriers or opportunities. As an example, EU policy measures on roaming tariffs have fostered the use of smartphones and apps across the EU borders. A price reduction of over 80 % since 2007 resulted in a 630 % increase of the roaming market (GSA, 2015).

Following Eurisy's field work with end-users in the public and private sectors the sectoral areas where satellite-based information showed to have proven benefits include: environmental monitoring and management, emergency communication, sustainable energy, transport, broadband access, border control, and agriculture (Eurisy, 2012). In this respect, a number of cases are used below as illustrative examples of how EC legislative acts can support the supply of services and applications based on space data in the public and private sectors.

The demand for geospatial data and services is strongly driven by EU and Member States' policies and rules that require the use of space data to underpin policy decisions or to monitor the environment. In this respect, an important example is the INSPIRE Directive³⁸. The directive came into force in 2007 to be implemented in various stages up to full implementation by 2019. It aims at building a European Spatial Data Infrastructure by achieving interoperability of spatial data collected by Member States and encouraged Member States to make use of data and services resulting from Galileo and Copernicus. Much of the preparatory work for INSPIRE and Copernicus was done in cooperation to ensure that the data generated by Copernicus would have matched with INSPIRE data specifications.

The use of GNSS systems can also be promoted with sector specific regulations and directives. Transport is for instance a sector where this process has already started. In 2011 the EC released a communication for amending the existing tachograph legislation³⁹ to make full use of new navigation satellite technologies. In particular, thanks to the new digital tachographs it will be possible to record the location of the

³⁸ Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE).

³⁹ Council Regulation (EEC) No 3821/85.

end and start of the driver's working day to enforce driving time rules⁴⁰. The mandatory introduction of GNSS-enabled in-vehicle system for emergency call to 112, a universal European emergency number, will be based on accurate and reliable positioning information provided by Galileo and EGNOS. The EC regulation requires receiver manufactures to ensure compatibility with both Galileo and EGNOS⁴¹ and is thus expected to drive demand for new devices and increase citizens' awareness about the European GNSS programmes. In maritime transport, the directive 2002/59/CE, related to the creation of a common monitoring and informative system of naval traffic, made automatic identification system (AIS) instruments mandatory on vessels with a gross tonnage. The directive created thus a market for satellite-based AIS receivers.

So far, the EC has not yet made a comprehensive review of all its legislation to understand where space data and products could be used. For instance, in fishery there is the requirement for vessels to be tracked, in agriculture companies are required to submit data to prove the volume of production to be eligible for grants, but in the sector specific regulation there is no mention about using space data. Similarly, the Marine Strategy Framework Directive⁴², which requires Member States to achieve or maintain good environmental status of the marine environment, does not mention the possibility to use data generated by Copernicus to monitor the state of European seas and oceans.

The use of Sentinel data and services can also be used to support compliance with EC directives in Member States. As an example, in December 2013, the EC adopted a Clean Air Package⁴³ as over a third of the EU's Air Quality Management Zones still exceeded the limits for particulate matter (PM10) and a quarter exceeded the limits for nitrogen dioxide (NO2). There are 17 EU countries that are subject to infringement procedures for exceeding PM10 limits. The combination of satellite and in situ data can help evidence infringements in particulate and nitrogen dioxide limits. However, if EU regulations do not mention the space data and explicitly make their use legal, nobody at national level would be encouraged to use them.

- **General business enabling conditions.** These are the context conditions that help establish a favourable business environment. In Europe, the area that emerged more prominently in discussion with policy makers and industry representatives is public procurement. Because demand from the public sector is so important at the early stage of development of satellite-based services, the lack of a federating agency for European national procurement in the space sector, and differences in public procurement processes hamper the creation of a single European space market. By contrast, in the US, the procedures defined by the Office of Federal Procurement Policy⁴⁴ provide a uniform term of reference for the US industry.

Besides this, access to venture capital is more limited in Europe than in the US and limits support for innovative ideas. In 2011 ESA set up the Open Sky Technologies Fund to provide seed-capital investments to companies using space-related

⁴⁰ Regulation (EU) No 165/2014.

⁴¹ REGULATION (EU) 2015/758 of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service and amending Directive 2007/46/EC.

⁴² Directive 2008/56/EC of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

⁴³ A Clean Air Programme for Europe Brussels, 18.12.2013 COM(2013) 918 final.

⁴⁴ https://www.whitehouse.gov/omb/procurement_default/.

technologies or satellite applications in non-space applications. The funds initially raised up EUR 15 million.

Nevertheless, the use of regulations for market development is often controversial, especially when it is perceived to add additional administrative burdens to business. As an example, in June 2015 a proposal for a directive⁴⁵ for the production and dissemination of satellite data for commercial purposes was withdrawn, after having been released one year before. The directive was intended to establish a comprehensive regulatory framework for improving legal coherence in the EU space market and facilitate the emergence of a European market for space products and services. Specifically, the EC proposal aimed at regulating access to high resolution images taken by satellites to harmonize conditions for access across Member States. It also aimed at putting in place consistent rules for security check of high resolution images. Some Member States opposed the regulation, as they considered it would have added an unnecessary burden to businesses. They also deemed that security concerns were not properly addressed and did not take account of new technological progress (Torvey, 2015). The proposal was also mildly supported by the EARSC, whose position is more oriented towards supporting enabling interventions that establish a favourable climate for companies to take advantage of new market opportunities, rather than introducing new regulations.

Transposing EC directives within Member States and European region systems often progresses unevenly and delivers mixed results. It is also a long process that does not match well with the need to kick start the satellite downstream market. A softer and alternative approach, which is suggested by Eurisy, would be to make explicit references to satellite-based information and services in EU sectoral policy, directives and regulations without including obligation of their use. This can be further complemented with introducing similar references within EU transversal programmes, such as Cohesion Policy and the Programme for the Competitiveness of Enterprises and SMEs (COSME) (Eurisy, 2012). This approach has the advantage of rising awareness in EU regions about the potential use of satellite-derived information for public policy monitoring and decision making, without establishing obligations, especially in public administrations that are not yet ready to use these technologies.

4.2.3. Dissemination activities

In a survey conducted in 2012 by TNS Political & Social network in the 27 Member States of the EU it resulted that only 38 % of EU citizens have heard of the Copernicus programme. Figures were slightly better for the Galileo programme that was reported to be known by 57 % of the respondents. Country differences also emerged strongly (EC, 2012). These figures clearly underpin the need to set up larger and more effective dissemination activities.

Dissemination activities carried out so far by EU institutions had three different targets.

- **Raise awareness about Copernicus and Galileo Programmes amongst EU citizens.** An example of these initiatives is the European Space Expo, a showcase exhibition of Galileo and Copernicus that uses entertaining and engaging technologies to illustrate the benefits of the EU space programmes for EU citizens everyday life, the economy and job creation.
- **Encourage use of space data in public systems, including at the local level.** Between 2013 and 2014 the EC conducted several "User Uptake" initiatives to support

⁴⁵ Directive of the European Parliament and of the Council, COM(2014) 344 final, Brussels, 17.06.2014.

the use of Copernicus services. These include training events, a series of webinars providing background information and training materials for Copernicus products and services (land, marine and atmosphere monitoring and emergency management), and test cases in different domains. The FP7 programme supported two initiatives that aimed at increasing awareness in European local administrations about the benefits of using satellite data and information. These were the DORIS_NET (Downstream Observatory organised by Regions active In Space – Network) project, which established regional contact offices to facilitate the use of space technologies at local level, and the GRAAL project, which supported regional and local authorities in matching user needs with information available through Copernicus. Both projects authored publications⁴⁶ that aimed at building strong cases for the adoption of EO data by regional public authorities. Similarly, a joint ESA-NEREUS publication provided a collection of articles that give an insight into how Copernicus is being tested in new applications and services across Europe⁴⁷.

Member countries are also promoting a larger use of satellite data in public administrations. Since 2007, the French ministry of the environment has been issuing plans⁴⁸ for fostering the use of geospatial and geo-positioning data for environmental monitoring and supporting policy decisions. The ministry is also concerned with developing a Copernicus national user community. The plan is also intended to assist France with better implementing national environmental legislation, along with EU Directives that concern the environment, such as Directive 2007/60/EC on the assessment and management of flood risks or Directive 2008/50/EC on ambient air quality and cleaner air for Europe. Similarly, in the UK the Space for Smarter Government Programme guides the uptake and use of space data and products across government departments.

- **Encourage business to use data available from the European satellite infrastructure.** Because the market of GNSS is more mature as compared to EO services, dissemination activities targeting the business community appear better structured and targeted. First, these activities fall under the responsibility of a single agency, the GSA, rather than being dispersed in different initiatives. Secondly, the GSA is able to reach out to stakeholders along the entire GNSS value chain, including interaction with the chipset and receiver manufacturers. As part of its mandate the GSA already started regularly organizing user fora for each market segment concerned by GNSS technology, such as connected car, business aviation, maritime, railways, agriculture, and surveying. Sector specific brochures have also been developed in different EU languages to illustrate the benefits of using GNSS-technologies in business. Thus far, no equivalent dissemination model has been developed for EO data and products for the commercial market.

Overall, all these initiatives have been deemed useful and relevant by the people interviewed for this study. Case studies that illustrate the quantitative and qualitative benefits of satellite-derived data and products confirm this. However, as compared to the US, awareness and familiarity with navigation satellite and EO technologies, particularly within the public administration, is improving, but is still limited in Europe. The need to develop a commercial strategy for dissemination was also pointed out.

⁴⁶ Copernicus4Regions, 2012.

⁴⁷ ESA and NEREUS, 2012.

⁴⁸ MEDDTL, 2011.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

As shown by the US and other examples, the space economy is source of considerable growth potential. In Europe, huge investments and effort were made over the last 10 years to build a common space infrastructure. A return on the investment for the EU space programmes is possible only if substantial socio-economic benefits are achieved through the development of businesses in the downstream sector. So far, the performance of the European space downstream sector has fallen short of expectations, as compared to other space-faring nations.

A series of reasons can be put forward to explain this situation. First, **the European space policy started relatively late compared to its main competitors** – the US in particular. For example, the Copernicus programme will be fully operational by 2020 and it is only then that the full benefits of it will be available and assessable.

Moreover, the European approach has long been biased towards an overly institutional perspective that prioritized the upstream sector (the deployment of satellites) to serve the interest of the scientific community or of big companies. There was definitely **less concern for users downstream of the space value chain and investments for the distribution of data for non-scientific users** were initially not envisaged with the same diligence as investments in infrastructure. Yet, rapid and reliable access to data for all categories of users is critical for the downstream market.

Finally, **Europe has been slow to react to new business models based on the rapid and massive release of already processed space data** to inexperienced users, which has been having disruptive effects on different segments of the downstream space sector. In this context, actors like national space agencies and other (mainly institutional) actors are being forced to reconsider their traditional approaches and activities, by for example finding niches markets or exploiting specific strength in terms of quality or customisation.

Other context specific features of the EU market also contribute to explain the relative delay in developing downstream activities in the space sector. These include in particular the **fragmentation of the European market**, the persistence of a **business environment that is generally not conducive to the development of start-ups** (lower venture capital ready to be invested in risky projects) as compared to the US, and a far **less widespread use of industry – science partnerships**.

These features combined with a **weak and fragmented demand from public and private users**, explain why European companies in the downstream space market are generally small and domestically oriented. Differently, in the US, public-private collaboration between the government, that provided space imagery, and a number of IT giant companies, that made these data easily accessible to a large audience of potential users, triggered the development of the space imagery business. As a result, in the downstream sector, the US leadership rests on the effective management of large amount of data and information.

The European policy response to these different challenges has not been sufficient. Despite undeniable progress (e.g. the recent establishment of a unit within DG GROW to improve the EO data dissemination system), **the EU still lacks an integrated and coherent space industrial policy** addressing all industries along the space value chain. The data policy still suffers from shortcomings with issues related to intellectual property, privacy and security of data produced by national space agencies and contributing to the Copernicus programme. As for the distribution system, it does not yet provide a user friendly and equal access to space data made available through by Copernicus.

The **public sector** is the main customer of space data and satellite-based services. It **will play a crucial role in spreading the use of satellite data in Europe, but it is not sufficient to drive a demand** for commercial applications and services. Until citizens' awareness about the potential use of space data remains low, demand for mass market applications remains limited.

5.2. Recommendations

Ensuring the market uptake of space data is today a political priority. This study is relevant and timely to inform forward looking policies that would maximise the benefits of the EU space flagship programmes for industry and citizens alike. Different lines of action are possible at different levels, from strategic approaches to initiatives geared towards addressing technical issues, dealing with both supply and demand conditions.

On the supply side, **the priority is to make data easily accessible** to users through a comprehensive and coherent data access policy and an efficient distribution system. Examples of possible measures are:

- reinforcing the existing IT platform that supports Sentinel data distribution through big data and cloud solutions;
- granting access to the full set of users, i.e. public institutions, scientists and researchers, commercial and private users;
- providing pre-processed products usable by a diversified spectrum of users, including those lacking strong technical skills to manage the raw EO data;
- improving and harmonizing access to national space data at European level and develop national data distribution points that would make access equal across Member States.

It is equally important to stimulate the supply of innovative applications addressed to a public as wide as possible. For this, **the combined role of R&D and support to business development programmes** (e.g. incubation measures, promotion of venture capital) **are decisive**. Establishing a connection between the wealth of research generated through Horizon 2020, and the companies that could use these researches to develop commercial products should be encouraged as much as possible. In this respect, an appropriate dissemination strategy for the space-related research outcomes of Horizon 2020 could be envisaged to reach out to the business community. In general, supporting closer collaboration between universities and private companies for developing applications and services is recommended.

On the demand side, it is necessary to **stimulate or strengthen both the demand** by public administrations, which currently dominate the market, and that of the private sector (B2B or B2C). Strong demand drivers for public services are expected to be the recent destabilization of the neighbouring Mediterranean area, and the increased occurrence of natural disasters due to climate change. In this respect, the use of satellite data and services should be encouraged within public administrations to ensure a more effective response to citizens' security, safety and defence concerns.

Awareness raising activities need to be deployed effectively to tackle resistance to change the use of consolidated technologies. Targets are the public sector (at all level from local to national and European), the private sector and civil society. The role of the education system and universities in raising awareness and stimulating entrepreneurial interest in using space data should not be disregarded.

Specific measures that could strengthen the demand for space data by public authorities and / or amplify its effects on enterprises, are for example:

- increasing the **harmonization of procurement rules** to help enterprises (especially SMEs) have access to a larger European market of space data.
- carrying out a systematic **review of the existing EU regulations** in which the use of Copernicus data and of Galileo services could bring an added-value to identify needs and propose solutions; informing the EC services about the availability of possible suitable space data originating from EU programmes, and suggesting to use them could be useful.

In general, before proposing and introducing new instruments or additional regulatory requirements, it is recommended to examine first whether **“soft” measures**, which **build on existing measures and arrangements**, could achieve the desired goal anyway. At this stage, it would be advisable to recommend the use of space data as much as possible within the policy areas that fall within EU competence without making it mandatory. Similarly, Member States could encourage a larger use of satellite data and services within the different levels of their administrations. The market is indeed emerging, and it should be first made sure that capacities and awareness are consolidated before moving to more binding regulations, which could be difficult to implement for some Member States that lag behind in terms of infrastructure and capacities.

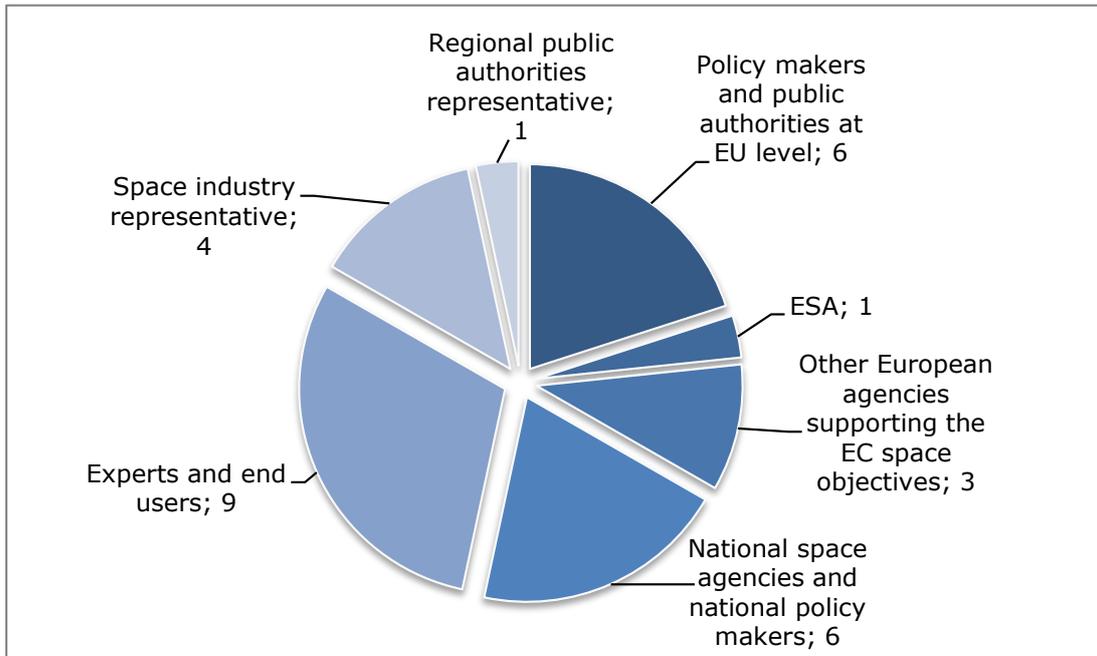
Overall, there is a need to scale up the strategic and political dimension of the challenge associated with the development of the downstream space market. **A long term explicit and common EU space industrial policy for the development of the downstream market should be formulated**, setting clear objectives and targets. In this regard, it is also important to make sure that the programmes’ services become available according to the time schedule planned and to avoid further delays as experienced by the Galileo programme. An **enhanced coordinating role of the EU** could better help reap the benefits of Member States and ESA systems that currently run separately or in parallel.

ANNEXES

ANNEX 1. LIST OF PEOPLE INTERVIEWED

A total of 30 people were interviewed. The distribution of interviewees by category is presented in the following chart, while the complete list of interviewees is provided in the following table.

Figure 5: Breakdown of interviewees by category



Source: Authors.

Table 11: List of interviewees

| CATEGORY | INTERVIEWEE | AFFILIATION | DATE OF INTERVIEW (day, month, year) |
|--|----------------------------|---|--------------------------------------|
| Policy makers and public authorities at EU level | Gilles Ollier | Head of sector DG Research & Innovation, European Commission | 10.07.2015 |
| | Jose Miguel Rubio Iglesias | Policy Officer DG Research & Innovation, European Commission | 10.07.2015 |
| | Alan Belward | Head of the Global Environment Monitoring Unit European Commission's Joint Research Centre | 08.09.2015 |
| | Andreas Veispak | Deputy Head of Unit DG Growth – European Commission | 15.09.2015 |
| | Thibaud Delourme | Policy Officer DG Growth – European Commission | 15.09.2015 |
| | Apostolia Karamali | Deputy head of unit, Space policy and research DG Growth – European Commission | 06.11.2015 |
| ESA | Josef Aschbacher | Head of the Earth Observation Programmes Directorate European Space Agency | 25.08.2015 |
| Other European agencies supporting the EC space objectives | Gian Gherardo Calini | Head of Market Development European GNSS Agency | 03.09.2015 |
| | Justyna Redelkiewicz | Market Development Officer European GNSS Agency | 03.09.2015 |
| | Christophe Morand | EEAS – Space and Security Crisis management planning directorate | 15.09.2015 |
| National space agencies and national policy makers | Helmut Staudenrausch | Team Leader Earth Observation German Aerospace Center | 11.09.2015 |
| | Mark Bacon | Head of European Space Policy UK Space Agency | 26.08.2015 |
| | Alain Podaire | Centre National d'Etudes Spatiales CNES | 11.09.2015 |
| | Jean-Christophe Schyns | Programme manager for the Belgian Federal Science Policy Office Belgian Earth Observation Platform | 28.09.2015 |
| | Marjan van Meerloo | Policy Officer Ministry of Economic Affairs – The Netherlands | 01.09.2015 |
| | Wencke van der Meulen | Policy Advisor Netherlands Space Office | 01.09.2015 |
| Experts and end users | Gherardo Chirici | University of Florence (IT) | 26.08.2015 |
| | Jocelyn Chanussot | Grenoble Institute of Technology (FR) | 14.08.2015 |
| | Arthur P. Cracknell | University of Dundee (UK) | 31.07.2015 |
| | Mehrez Zribi | Research Director CNRS (French National Centre for Scientific Research) | 27.08.2015 |

| CATEGORY | INTERVIEWEE | AFFILIATION | DATE OF INTERVIEW (day, month, year) |
|--|---------------------|---|--------------------------------------|
| | Antonio J. Plaza | Editor-in-Chief of the Transactions on Geoscience and Remote Sensing University of Extremadura (ES) | 31.07.2015 |
| | Lena Halounova | Chairman of the Bureau of the European Association of Remote Sensing Laboratories (EARSeL) | 04.08.2015 |
| | Simonetta Paloscia | National Research Council-Institute of Applied Physics | 29.07.2015 |
| | Massimo Antoninetti | Researcher and representative of IREA-CNR NEREUS | 17.09.2015 |
| | Anna Basoni | Research, Project manager IREA-CNR NEREUS | 17.09.2015 |
| Space industry representative | Geoff Sawyer | Secretary General EARSC | 15.09.2015 |
| | Axelles Pomies | Galileo Services Permanent Representative | 06.10.2015 |
| Regional public authorities and other end users representative | Roya Ayazi | NEREUS-Secretariat | 21.09.2015 |
| | Stefaan De Mey | Secretary General Eurisy | 15.09.2015 |
| | Teodora Secara | Programme coordinator Eurisy | 15.09.2015 |

Source: Authors.

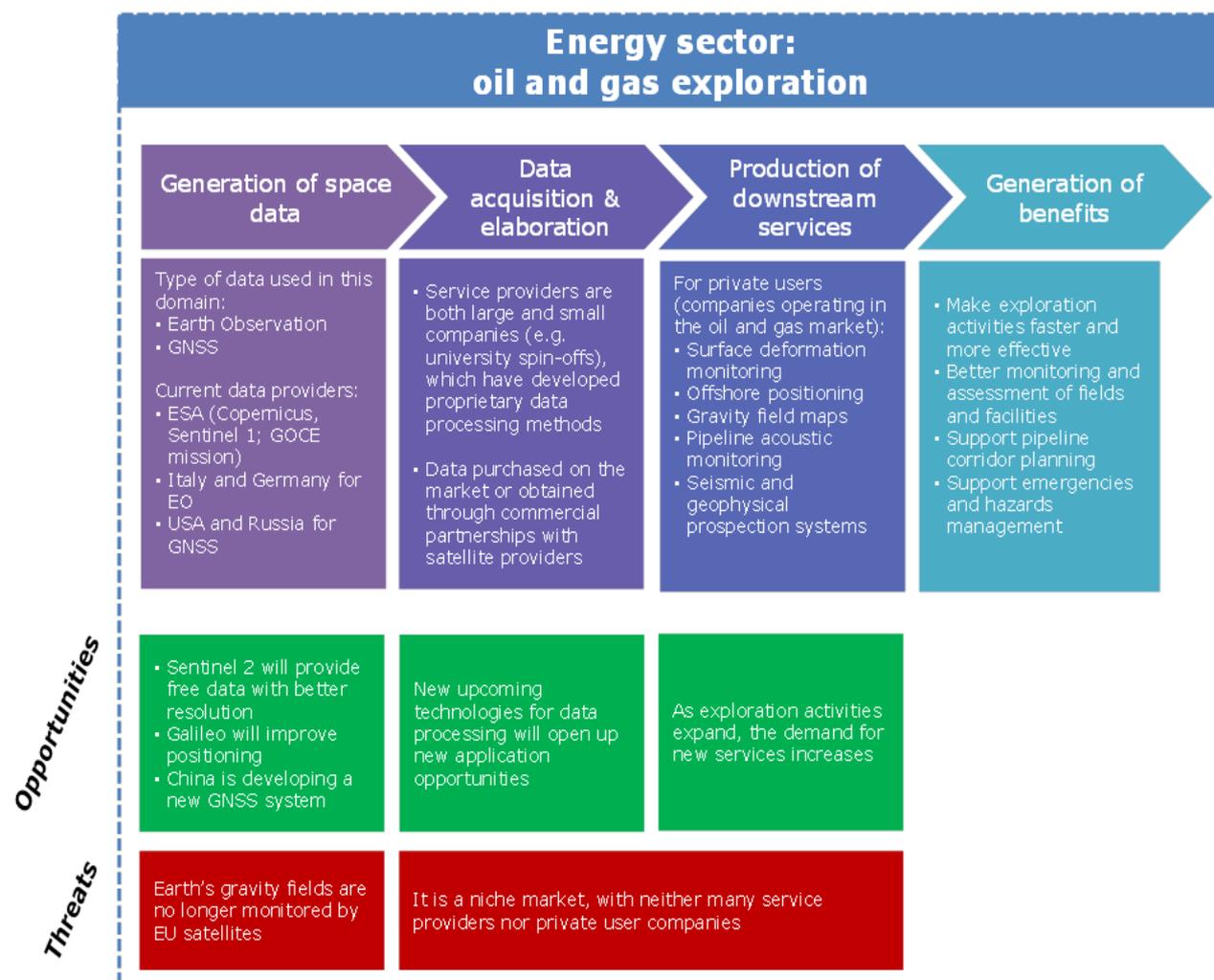
ANNEX 2. MINI CASE STUDIES

The following sectors have been selected for in-depth analysis because they show examples of applications based on satellite data for both the commercial and the institutional market.

1. **Energy.** This case explores the new trend in the oil and gas industry, which consists of promoting closer integration of multi-source satellite data with traditional on site geophysical surveys.
2. **Transport.** This case illustrates how space data can be employed to improve maritime security.
3. **Agriculture.** This is the sector that was reported to have the highest potential for the use of commercial applications of EO data. It describes the type of commercial services that have been developed, such as applications for to improving crop yields
4. **Environmental monitoring.** This case study shows the development of applications that monitor environmental parameters for improving public health.
5. **Disaster management.** Mostly driven by public sector demand, the services included in the analysis illustrate services that aim at improving the response to humanitarian crisis or environmental disasters.

ENERGY SECTOR: OIL AND GAS EXTRACTION

Figure 6: Energy sector flowchart



Source: Authors.

Background

Geospatial analysis is a critical tool to successful exploitation of energy resources, for knowing which sites are most promising for drilling and for making decisions faster. Consequently, in the last decade oil and gas companies started integrating satellite data into their workflows with other non-seismic technologies. Besides supporting oil and gas exploration activities, satellite imagery can help development operations, monitoring of producing fields, assessment of facilities, pipeline corridor planning, or emergencies and hazards management. For example:

- ESA's satellite gravity mission GOCE (Gravity field and steady-state Ocean Circulation Explorer) has collected useful data for computing maps of gravity anomalies in regional scale studies. This information can improve the modelling of the crust and lithosphere for a better understanding of the evolution of the thermal system in basins. This technology could help the geophysical exploration to highlight areas where hydrocarbons are likely to be trapped underground.
- The Italian COSMO-SkyMed, the German TerraSAR-X, and ESA's Sentinel-1 radar satellites are used for optimizing field operations by monitoring the surface

subsidence, uplift and displacements over producing reservoirs. This information can be used as input into geomechanical models to highlight reservoir boundaries and for estimating the volume, pressure and permeability changes over time. Moreover, this technology can be used to ensure that extraction activities adhere to environmental regulations and standards.

- When fully operative, the European Galileo system will be used to enhance the availability and reliability of positioning and the safety and productivity in remote areas (e.g. offshore platforms or uninhabited areas). This technology will provide autonomous navigation capabilities to Europe, as well as integration with the existing GPS (USA) and GLONASS (Russian) and the future BeiDou (Chinese) GNSS.

Example of commercial downstream services

Some examples of commercial satellite-based downstream services and products offered by European companies to the oil and gas industry are:

Monitoring of surface deformation: Tele-Rilevamento Europa (TRE)⁴⁹ is an Italian SME, with offices in Italy and Canada, which offers oil and gas companies satellite-based services for improving their business. TRE is the world leader in surface deformation monitoring services using the satellite Interferometric Synthetic Aperture Radar technology and has developed proprietary data processing methods. By analysing satellite images, they are able to measure surface deformation to millimetre accuracy. Figure 7 shows an example of ground displacement in Kazakhstan monitored with the RADARSAT satellite and the SqueeSAR™ technique. For instance, this information can be used for constraining subsurface deformation related to fluid injection/extraction from underground reservoirs⁵⁰.

Satellite positioning: Fugro⁵¹ is a large private company that has extended its products in the field of GNSS for offshore positioning applications. The inclusion of the Galileo satellites to the GPS, and GLONASS constellations offers their oil and gas customers an improved accuracy, confidence and reliability of the calculated position, the possibility to bridge periods of bad satellite's geometry for each of the separate GNSS, and independency from non-EU GNSS. Fugro has commercial partnerships with all the major satellite service providers and has developed proper experience and tools for turning data into information and solutions.

Gravity field maps: GReD⁵² is a small Italian University spin-off offering to oil and gas companies global gravity field maps estimated from satellite. The core of its business is its in-house developed algorithms and software to give state-of-the-art solutions according to the customers' needs. Figure 8 shows an example of a 3D modelling of the Moho beneath the Tibetan plateau and the Himalayan region generated using the gravimetric data collected by the ESA's GOCE mission. This information, related to sediment thickness, depth-to-basement, and type of crust, are fundamental input for oil and gas exploration (GReD).

Radar imaging: ARESYS⁵³ is an Italian SME historically serving the oil and gas market. Its expertise covers airborne and spaceborne radar technologies⁵⁴, along with pipeline acoustic

⁴⁹ <http://treuropa.com/>.

⁵⁰ <http://treuropa.com/oil-and-gas/oil-reservoirs/>.

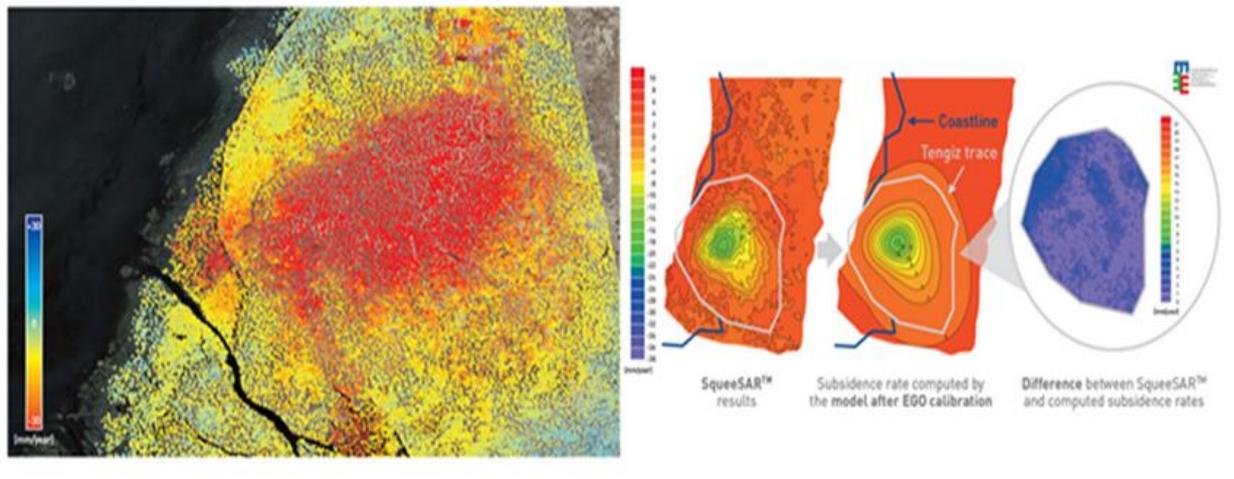
⁵¹ <http://www.fugro.com/>; <http://www.fugro.com/Widgets/MediaResourcesList/MediaResourceDownloadHandler.aspx?guid=81e062f1-f3db-6785-9f9d-ff1f0019aa6e>.

⁵² <http://www.g-red.eu/>.

⁵³ <http://www.aresys.it/>.

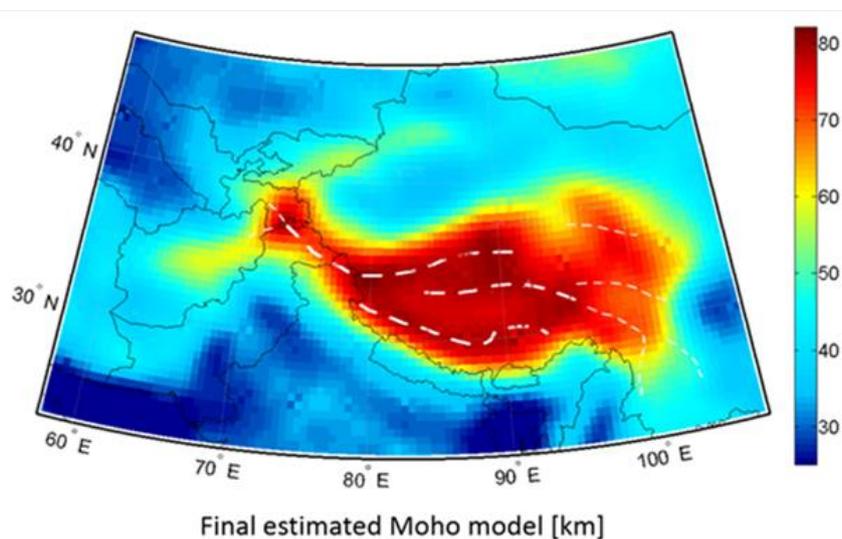
monitoring systems and seismic and geophysical prospection systems. Its mission is to support his customers with highly customized products and tools. ARESYS is part of the Copernicus Sentinel-1 industrial team since 2006 and has recently supported ESA (ENVISAT, Cryosat-2 and BIOMASS missions), the Italian Space Agency (COSMO-SkyMed mission) and the National Commission for Space Activities (SAOCOM mission).

Figure 7: Satellite-based map of ground displacement in Kazakstan used for monitoring oil fields



Source: Tele-Rilevamento Europa website (<http://treuropa.com/oil-and-gas/oil-reservoirs/>).

Figure 8: Satellite-based map of gravity field in Tibet used for oil and gas exploration activities



Source: GRd website (<http://www.g-red.eu/industries/natural-resources/oil-gas/>).

Market opportunities and threats

The market sector of space-based information services for the oil and gas industry is relatively new and is quickly growing. As the oil and gas companies further expand their exploration activities into outlying, remote and inaccessible areas, from sites deep in

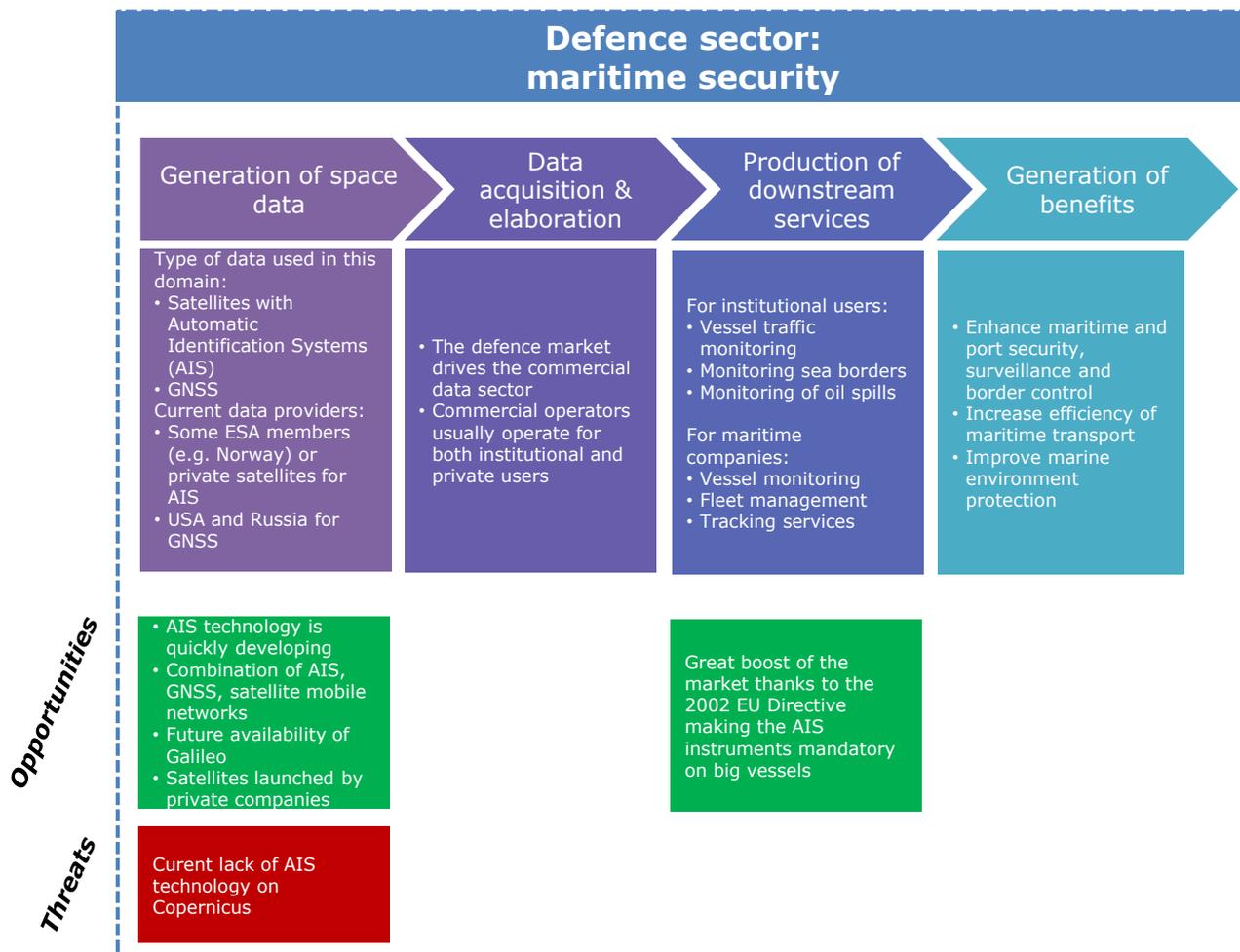
⁵⁴ Synthetic Aperture Radar (SAR), ground based SAR, RADARS and Ground Penetrating Radar (GPR).

the wilderness to fragile states, satellite data will play a larger role in their operations to reduce staff on the ground and costly surveys. Most of the major oil and gas companies, European companies included, are funding breakthrough research programmes for developing the next generation geophysical methods based on multispectral satellite imagery (e.g. Shell with University of Twente (Salati et al., 2014), Eni with Politecnico di Milano (Frassy et al., 2015)). Some independent oil and gas companies, included Tullow Oil plc (Ireland) and Heritage Oil plc (now part of Energy Investments Global Ltd.), are even testing these experimental technologies in new areas for reducing their exploration costs and risks. In the near future, these **novel technologies** that rely on satellite data **will likely open new downstream market opportunities for the European space industry**.

In past years, the lack of European satellites with payloads suitable for applications in the oil and gas field was an issue. With the availability of COSMO-SkyMed, TerraSAR-X and Sentinel-1 satellites, it is **now possible monitoring ground deformations with a high spatial resolution and short revisit time**. The new Copernicus Sentinel-2 satellite has filled the gap between the very-high spatial resolution of the French Pléiades and SPOT satellites and the low spatial resolution of the ESA's missions such as Envisat or PROBA-V. Moreover, Sentinel-2 also provides data with a better spatial and spectral resolution than the widely used United States' Landsat satellites. Galileo and EGNOS will give higher precision and reliability in positioning and navigation to the industry. Regarding the measurement of the gravity field, ESA's GOCE mission ended in November 2013. While the huge amount of data collected during the orbiting are still used, at present time there is no European continuity mission on this topic, thus the Earth's gravity field is no more monitored by European satellites.

DEFENCE SECTOR: MARITIME SECURITY

Figure 9: Defence sector flowchart



Source: Authors.

Background

Security, surveillance and border control are typical applications of satellite observation addressed to institutional users. A recent study by Euroconsult pointed out that defence users represented about 65 % of the commercial sales at global scale (Révillon, 2012). The US Defence (i.e. military users) represented about 60 % of revenues in 2014 for the market leader of commercial high-resolution satellite imagery DigitalGlobe, while industry verticals was only 19 % of its 2014 revenues (DigitalGlobe Investor, 2015). In Canada, the Department of National Defence is still an important customer for MacDonald Dettwiler and Associates Ltd (MDA). The renewal option signed in 2015 between MDA and the Government of Canada's Department of National Defence for the use of RADARSAT-2 satellite images valued at approximately 2.4 million CAD (MacDonald Dettwiler and Associates, 2015). Similarly, a study by Space tec Partners (2013), commissioned by the European Commission-Enterprise & Industry Directorate General for supporting the GMES related policy measures, showed that **"Growth in the commercial data sector is now being driven by wider global sales to defence users**, particularly by countries with high imagery intelligence requirements and limited viable proprietary solutions. In order to meet these needs, commercial operators are finding success in providing direct contracts to

end-users, providing secure imagery access to defence clients” and the Europe Union has only 15 % shares.

Besides military uses, some commercial applications addressed to corporate customers have been developed. However, these applications addressed to the monitoring of fleets, typically do not use traditional Earth Observation satellites but satellites carrying an Automatic Identification System (AIS), often complemented with GNSS and ground based equipment.

Example of downstream services addressed to institutional users

In the field of maritime security, the European Sixth Research Framework Programme and Seventh Research Framework Programme contributed in funding the transition of some research projects from pre-operational services to Copernicus operational services. This is the typical case of business-to-government or government-to-government services. Some examples of downstream services and products offered by European companies are:

- **Vessel traffic monitoring:** SafeSeaNet⁵⁵ is a vessel traffic monitoring and information system established to enhance maritime safety, port and maritime security, marine environment protection, and efficiency of maritime traffic and maritime transport (see Figure 10). The system uses the AIS messages transmitted by ships and has been developed and implemented under the leadership of the European Commission (Directorate-General for Mobility and Transport – DG MOVE).⁵⁶
- **Monitoring sea borders:** Maritime Security Services (MARISS)⁵⁷ delivers services that address maritime security in Northern and Western Atlantic waters, Baltic Sea and Mediterranean waters. The service is aimed to enhance capabilities of institutional users⁵⁸ to track vessels back and forward at sea borders and identify them as friends or suspects using Copernicus satellite imagery and AIS information.
- **Monitoring of oil spills:** CleanSeaNet⁵⁹ is a European satellite-based oil spill and vessel detection service, offering assistance to participating states in identifying and tracing oil pollution on the sea surface, monitoring accidental pollution during emergencies, and contributing to the identification of polluters. The service is based on the Canadian Space Agency’s RADARSAT-2 and the Italian Space Agency’s COSMO-SkyMed satellite images, and also on SafeSeaNet for vessel identification⁶⁰ (see Figure 11).

⁵⁵ European Maritime Safety Agency website (<http://www.emsa.europa.eu/>).

⁵⁶ Participating Countries are Cyprus, Greece, Bulgaria, Romania, Malta, Italy, Slovenia, Croatia, France, Spain, Portugal, Luxembourg, Belgium, Netherlands, Germany, Poland, Denmark, Ireland, United Kingdom, Lithuania, Latvia, Estonia, Finland, Sweden, Norway and Iceland. Austria, Hungary, Slovakia and Czech Republic are only data requester.

⁵⁷ <http://spatial.e-geos.it/mariss-gmes/index.html>.

⁵⁸ They include: Spanish Guardia Civil, Spanish Navy, French Navy, UK Royal Navy, Norwegian Coastal Administration, Finnish Navy, Italian Coast Guard, Hellenic Coast Guard, Portuguese Navy, Bundespolizei, Ports of Azores, and Ports of Madeira. Service providers include GMV for South Spanish Coast, ASTRIUM/CLS for Caribbean geographic area, Qinetiq for Western Atlantic, KSAT for Norwegian and Baltic Sea, DLR for the North Baltic sea, e-GEOS and Space Hellas for the Mediterranean area, Edisoft and Skysoft for the Portuguese area.

⁵⁹ <http://www.emsa.europa.eu/operations/cleanseanet/items.html?cid=122&id=2360>.

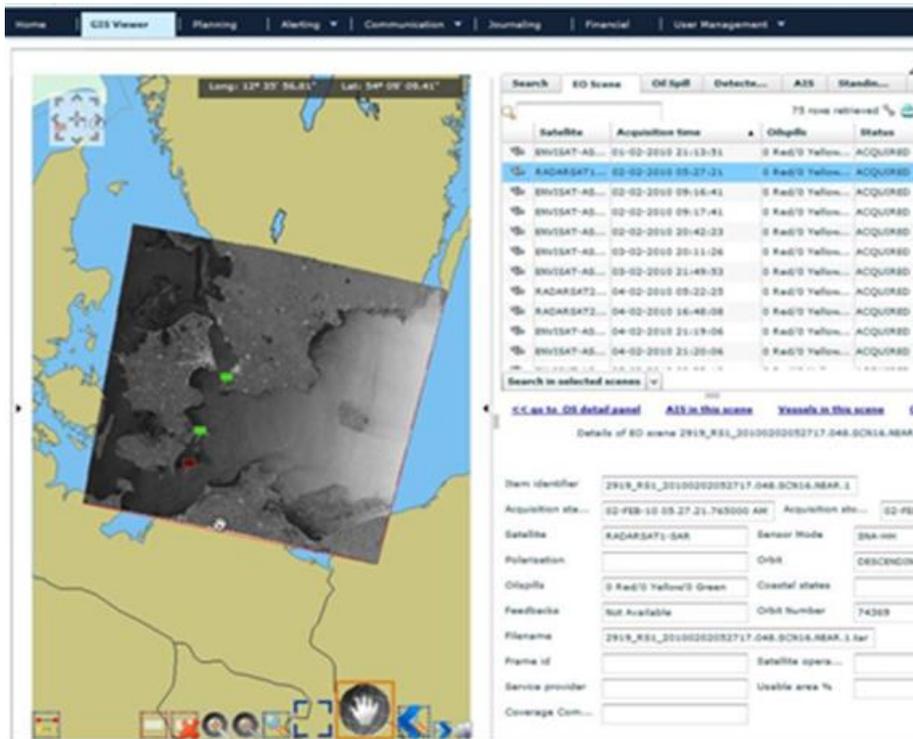
⁶⁰ http://www.emsa.europa.eu/images/stories/pics/csn_interface.jpg.

Figure 10: SafeSeaNet AIS-based vessel monitoring system



Source: European Maritime Safety Agency (<http://www.emsa.europa.eu/images/stories/comm/SSN-pic1.jpg>).

Figure 11: CleanSeaNet satellite-based oil spill monitoring service based on the Canadian and the Italian radar satellites



Source: CleanSeaNet (http://www.emsa.europa.eu/images/stories/pics/csn_interface.jpg).

Example of commercial downstream services

Some examples of commercial AIS-based downstream services and products offered by European companies for marine private traffic control are:

- **Vessel monitoring:** LUXspace⁶¹ belongs to the international network of companies within the OHB SE group⁶² and is located in Luxembourg. Since 2009, LUXspace offers global AIS data services (both terrestrial and satellite data) to institutional and commercial customers worldwide. Their key clients are institutional users in Europe, such as the European Maritime Safety Agency, European Fishery Control Agency, Frontex, national marine forces but also a number of commercial customers in the maritime sector. Figure 12 shows an example of global vessel mapping.
- **Fleet management:** TerraMar Networks⁶³ is an Irish provider of GNSS fleet management services. Their expertise spans a variety of industry sectors, including logistics and haulage, commercial maritime and offshore oil and gas. For its services, TerraMar Networks uses a mixture of GSM cellular networks, geostationary satellites, low Earth orbit satellites and both terrestrial and satellite AIS systems.
- **Tracking services:** Astra Paging Ltd⁶⁴ is a private limited liability company of Bulgaria, mainly focused on software development. It is one of the large international providers of AIS vessel tracking services, and its service operates the largest commercial AIS network in South Europe, processing data received from over 85,000 ships. Astra Paging customers are ship owners, managers, port operators, charterers, ship chandlers and insurance agents. Moreover, government agencies such as the Bulgarian Maritime Administration, Bulgarian Navy, or Border Police are also customers (see in Figure 13 an example of app for smartphones).

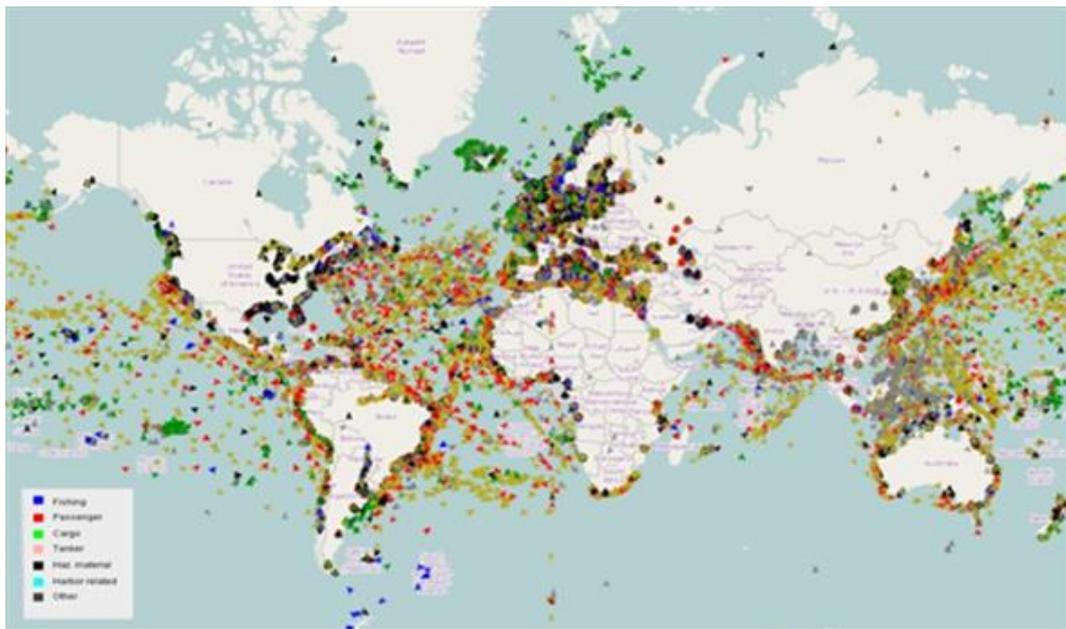
⁶¹ <http://www.luxspace.lu/index.php>.

⁶² The European company for Space Technology & Security, Telematics and Satellite Services (<http://www.ohb.de/index-english.html>).

⁶³ <http://www.terramarnetworks.com/>.

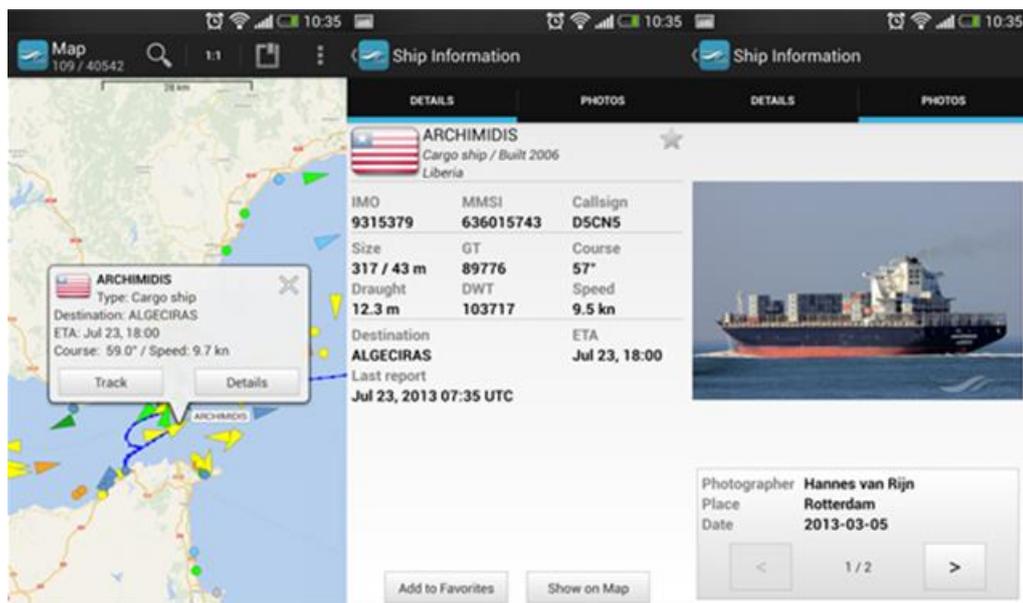
⁶⁴ <http://www.astrapaging.com/>.

Figure 12: Global vessel monitoring using AIS data



Source: LUXspace (<http://www.luxspace.lu/index.php/global-ais-dataservice.html>).

Figure 13: VT Explorer app for smartphones



Source: Astra Paging Ltd (<http://www.vtexplorer.com/vt-explorer-for-android.html>).

Market opportunities and threats

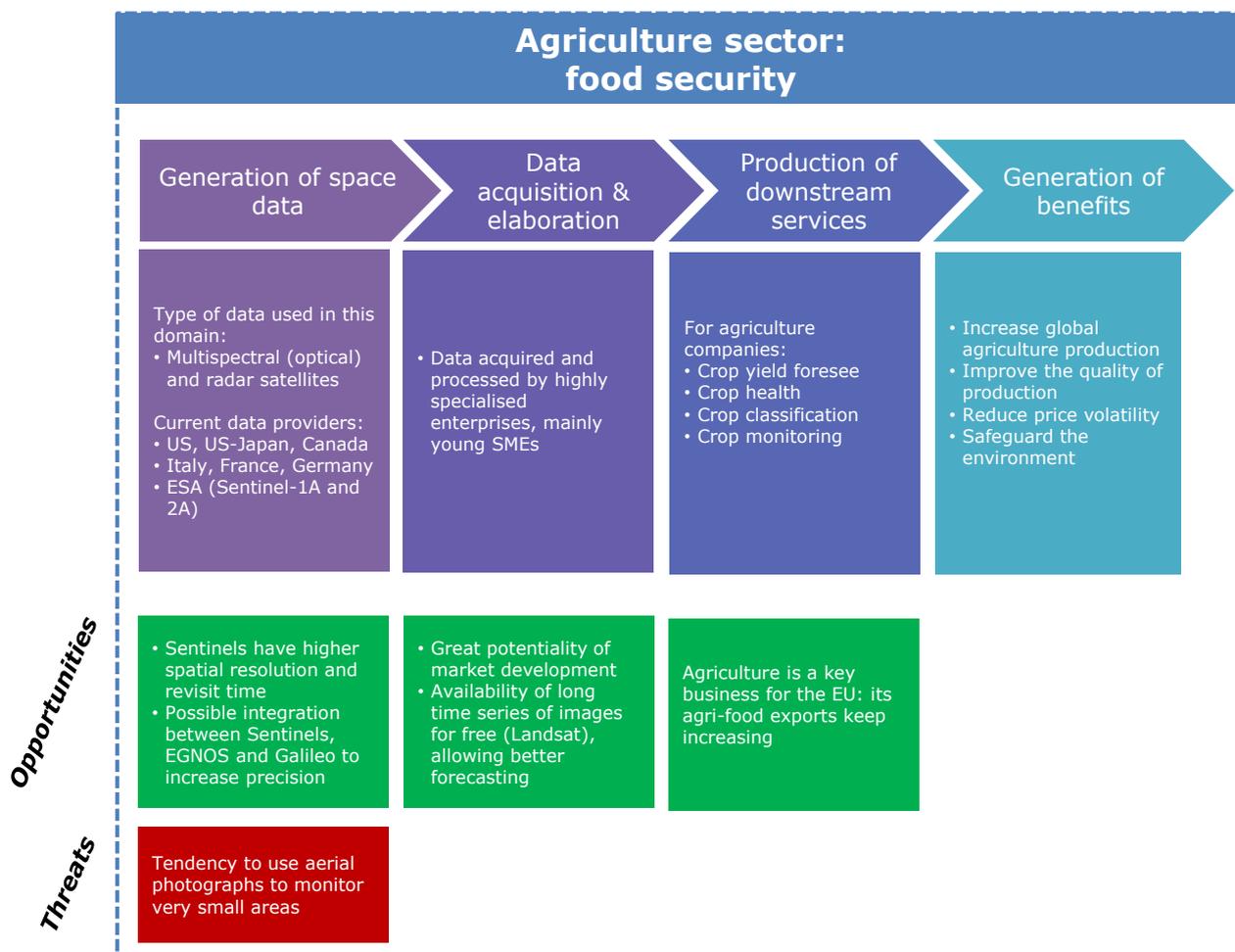
Terrestrial-based AIS networks provide real-time tracking of ships at several thousands of ports and coastal shipping routes worldwide. However, this technology is limited to coastal waters where the AIS signal can be recorded. Satellite-based AIS is a quickly developing technology for extending the monitoring of vessels tracks beyond coastal regions and every year several new AIS satellites are launched by private companies. The combination of satellite-based and terrestrial-based AIS, integrated with GNSS, GSM and satellite cellular networks gives a global maritime traffic monitoring capability, with new business opportunities addressed to the private market.

In the European context, the **directive 2002/59/CE**, related to the creation of a common monitoring and informative system of naval traffic, **determined a boost of the downstream market** by making the AIS instruments mandatory on vessels with a gross tonnage more than 300 tons, except for war ships, fishing ships and pleasure crafts with a size smaller than 45 meters (European Union, 2002). Although commercial services for vessel tracking typically do not use Earth observation data, they however use GNSS data. Consequently, **such kind of services will benefit from the availability of the Galileo and EGNOS systems**. The main limitation is the actual lack of AIS payloads in the Copernicus programme, even if the Norwegian Space Centre (an ESA Member State) has two dedicated missions. Thus, satellite-based AIS tracking services today offered by European companies rely on third-parties or private satellites. In the future some satellite AIS systems may become Copernicus contributing missions, or AIS instruments may be installed as additional payload on future European satellite missions. However there are currently no programmes going in that direction.

Finally, it is to be mentioned that, even if European private companies sell their services to corporate customers, governmental agencies and public authorities are still important clients for the downstream market of maritime security.

AGRICULTURE SECTOR: FOOD SECURITY

Figure 14: Agriculture sector flowchart



Source: Authors.

Background

With the rapid increasing in world population (United Nations, 2015), there is the need for increasing the global agricultural production. According to the last report of the United Nations' Food and Agriculture Organization on the state of food insecurity in the world "about 795 million people are undernourished globally" (Food and Agriculture Organization, 2015). Food is a limited resource and its production is strictly related to the health of our environment: it depends on fertile soil, availability of freshwater and favourable climate conditions. At the same time, agriculture has a major impact on the environment: farms and pastures can cause erosion, desertification, chemicals pollution and water shortages. Therefore, all these risks need to be monitored and managed.

Agriculture is a key business for the European Union and its agro-food exports to third countries are continuous increasing. In this context, satellite systems have the capability to support sustainable agriculture by supplying reliable information of the agricultural resources, their health and biological stages. Besides, Earth observation satellites could be used for optimizing (and minimizing) the use of chemicals (pesticides and fertilizers) and irrigation, overall increasing not only the quantity but also the quality of the European production.

Well before the era of spaceborne Earth observation systems, scientists were using aerial photography to carry out crop inventories and soil survey mapping. In the early 1970s the US began funding research programmes to stimulate the use of remote sensing technologies in agriculture, and in 1972 the possibility of estimating wheat yield from space over wide areas became a reality with the Landsat programme (Nellis et al., 2009). Since then, Landsat satellites are providing continuous data for agricultural monitoring which are used worldwide. Other main sources of space data were the French SPOT satellites and the U.S./Japanese Terra (ASTER) satellite for local studies, while the U.S. NOAA AVHRR satellites and the U.S./Japanese Terra (MODIS) satellite were mainly used for large regional and global studies. Regarding the radar technology, the European ERS satellites and the Canadian RADARSAT satellites have been for long time the main source of data, and only in recent years the Italian COSMO-SkyMed constellation and the German TerraSAR-X satellite added new powerful tools. **With the availability of the first Sentinel satellites (Sentinel-1 and Sentinel-2) Europe is going to play a major role.** When fully operational, the radar Sentinel-1 will provide information such as surface moisture or illegal deforestation, and the optical Sentinel-2 will complement with information on crop types, vegetation stress or land use changes with a medium/high spatial resolution and a high revisit time.

Example of commercial downstream services

Some examples of commercial downstream services and products offered by European companies for food security are:

Crop yield foresee: CloudEO⁶⁵ is a German SME offering to its customers services based on satellite data for crop yield potential evaluation. This information can then be used as a basis for pre-season field management decisions or soil sample planning according to crop yield potential zones. Moreover, using multi-temporal satellite observations CloudEO⁶⁶ is able to give their customers a regular update on biomass development and vegetation status, very useful information for general crop monitoring and in-season management decisions like fertilizer and pesticide application.

- **Crop classification:** Rezatec⁶⁷ is a UK company established in 2012 to help farmers and fast-moving consumer goods companies better to manage their land-based assets by making use of Earth observation imagery. Rezatec aggregates a multitude of data sources, including satellite optical and radar data, to provide their customers decision support tools for agribusinesses. For example, their services include crop measurement and monitoring for yield improvement and cost reduction, crop planning for better use of resources on a season per season basis, and forecasting for optimizing logistics and storage for food processors (see Figure 15).
- **Crop health:** Ceptu⁶⁸ is a new Danish start-up founded in 2014 to bridge the gap between research and practical application of farming technology. Its FieldSense app for smartphones will combine images collected by the Copernicus satellites Sentinel-2A and Sentinel-2B with crop health models to generate health maps for individual fields (Figure 16). Ceptu service will bring farmers an easily tool for monitoring the health of their crops and to make informed decisions about how to tackle crop health issues.

⁶⁵ www.cloudeo-ag.com.

⁶⁶ <http://store.cloudeo-ag.com/green-spin-relative-crop-yield>.

⁶⁷ <http://www.rezatec.com>.

⁶⁸ <http://www.ceptu.com>.

- **Crop monitoring:** Vista GmbH is a German value adding company working in the field of hydrological and agricultural applications. The main application areas in which Vista is active are yield estimation of agricultural crops, modelling of evapotranspiration, runoff and ground water recharge, advanced land use classification, observations of snow cover and water bodies, precipitation and soil moisture observation for flood modelling and forecast (see some examples in Figures 17 and 18).

Figure 15: Example of the crop classification using Earth observation data



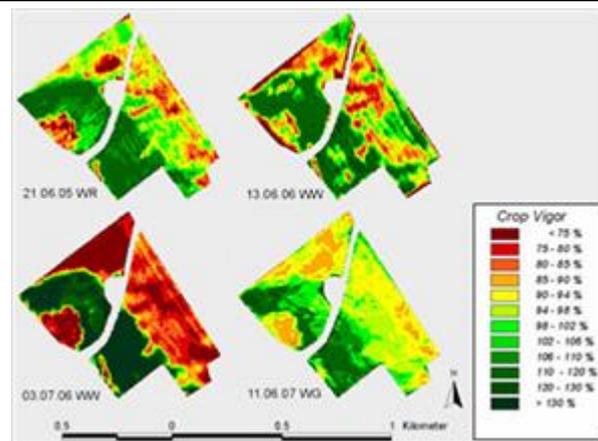
Source: Rezatec (<http://www.rezatec.com>).

Figure 16: Example of the FieldSense app for smartphones that will give farmers weekly updates on crop health status



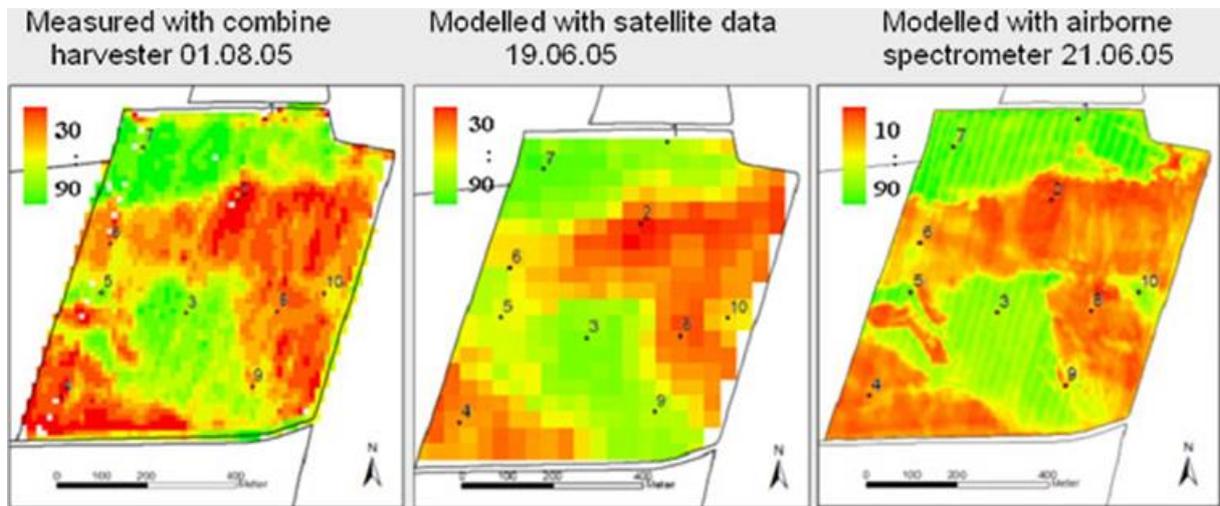
Source: Copernicus Master (http://www.copernicus-masters.com/index.php?kat=winners.html&anzeige=winner_cloudeo2014.html).

Figure 17: Development of the same patterns in the ripening phase for one field over several years and three crop types (winter rape seed, winter wheat, and winter barley)



Source: Vista (http://www.vista-geo.de/vista/eng/landwirtschaft/precisions_farming.php).

Figure 18: Yield estimation for winter wheat six weeks before harvest using airborne and satellite data in comparison to the yield map as measured with a combine harvester



Source: Vista (<http://www.vista-geo.de/vista/eng/landwirtschaft/ertragsvorhersage.php>).

Market opportunities and threats

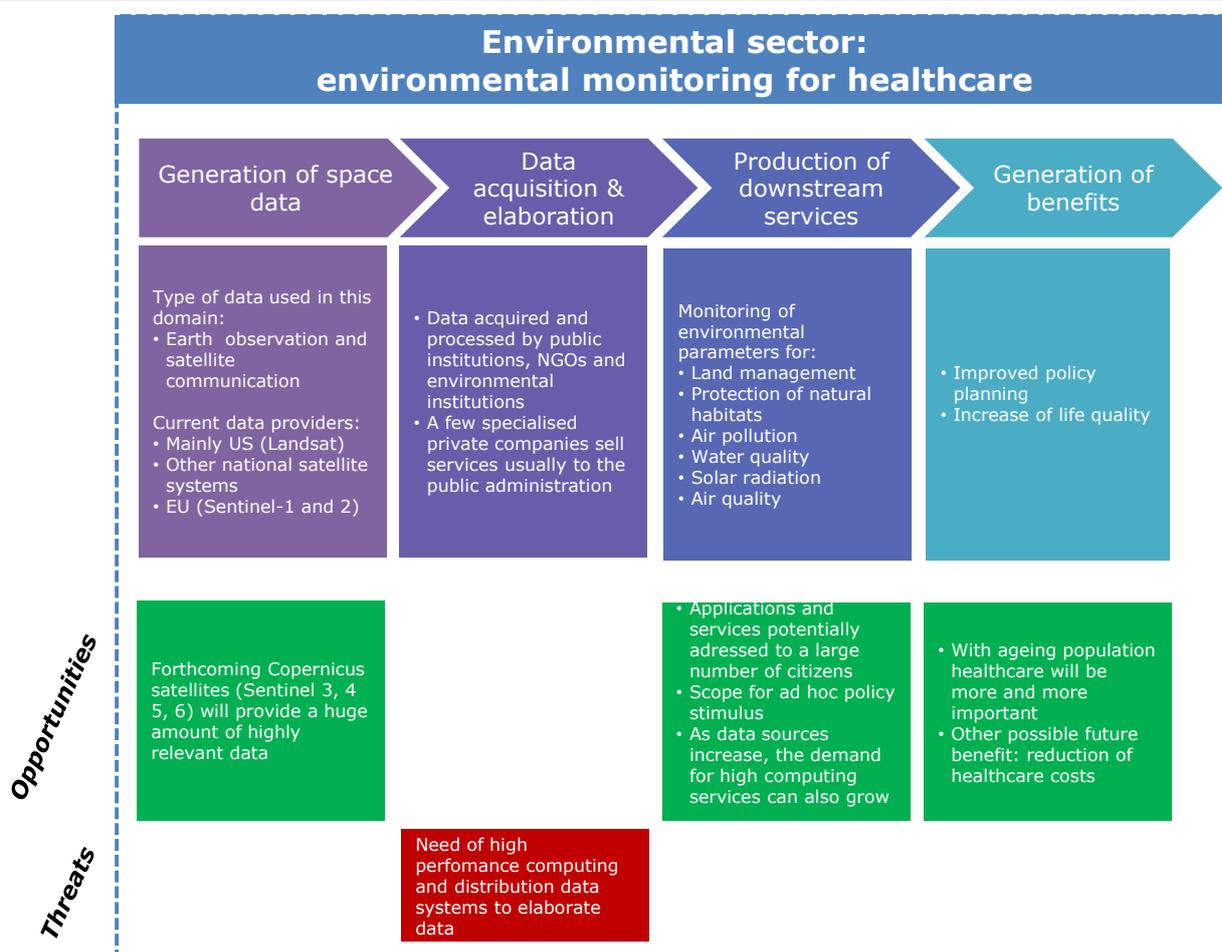
In the next decades, **agro-food could become the main private market for space technologies in the European Union**, with great potentialities for further developing the European SMEs offering downstream services to farmers. For long time data have been provided by US satellites, whose technical specifications were tailored to meet the needs of United States' croplands, as a trade-off between spatial resolution (related to the minimum size of the fields observed), satellite's swath (the width a satellite can observe during one orbital passage) and revisit time (the time span between two consecutive passages). Consequently, the 30-meters spatial resolution of Landsat data imaged every 16 days was enough for monitoring the 340 million acres of the United States used for agriculture (United States Department of Agriculture-Economic Research Service, 2006), especially in a country where 65 % of holdings have an agricultural area greater than 50 hectares (Lowder et al., 2015). However, figures in the European Union are different. Not only the surface covered by cropland is smaller (about 263 million acres) (Eurostat, 2013), but farms are remarkably different: 70 % of the member states' holdings have an agricultural area of less than 5 hectares (Eurostat database⁶⁹). Therefore, Landsat data were not optimal for monitoring the patchy land of the European Union.

Copernicus is a game changer. The superior spatial resolution and higher revisit time of Sentinel-2 satellites, compared to Landsat, are tailored for monitoring the cropland agriculture of the European Union's member states. Currently small EU countries still rely on aerial photographs for land monitoring, but the integration of Sentinel-2 data with Sentinel-1, Galileo and EGNOS, will breathe new life into precision agriculture, making Earth observation suitable for the European small crop fields too.

⁶⁹ <http://ec.europa.eu/eurostat/web/agriculture/data/main-tables>.

ENVIRONMENTAL SECTOR: ENVIRONMENTAL MONITORING FOR HEALTHCARE

Figure 19: Environmental sector flowchart



Source: Authors

Background

When thinking about health care and space industry, one's thoughts are on satellite communication systems. They provide cost-effective and accessible solutions for remote medical diagnosis and remote medical care, not only in developing countries but also to the European ageing population. Today Earth observation satellites can also play an important role in this sector, by enabling the monitoring of chemical, physical, and biological parameters at local, regional and global scales. Satellites data can be used for monitoring a large number of environmental parameters influencing our quality of life. **This is the typical case of public interest's application domain, but there is also room for a private market, potentially addressed to a large number of citizens.**

The European Copernicus programme will collect a huge amount of data for monitoring the health of our planet. For example:

- Sentinel-1 satellites will help managing the marine environment and its resources, giving timely maps of sea-ice conditions for safe passage in the Arctic waters or offering information on wind and waves, imaging the entire Earth every six days (when both satellites 1A and 1B will be operational);

- Sentinel-2 satellites will deliver information on plant's health, water bodies or land imaged in 13 different wavelengths and with a five days revisit time (when both satellites will be operational);
- the forthcoming Sentinel-3 satellite will measure the Earth's topography, its surface temperature and ocean colour, in support of ocean forecasting systems and for environmental and climate monitoring;
- the next Sentinel-4 and -5 missions will be dedicated to monitoring the composition of the atmosphere in support of European policies. Services based on Sentinel-4 and -5 will include the monitoring of air quality, stratospheric ozone, solar radiation, and climate monitoring;
- Sentinel-6 is expected to give high-precision observations of the topography of the global ocean every 10 days. This information is extremely useful for the study of ocean currents, wind speed and wave height, both for maritime safety and for protecting the coastal zones.

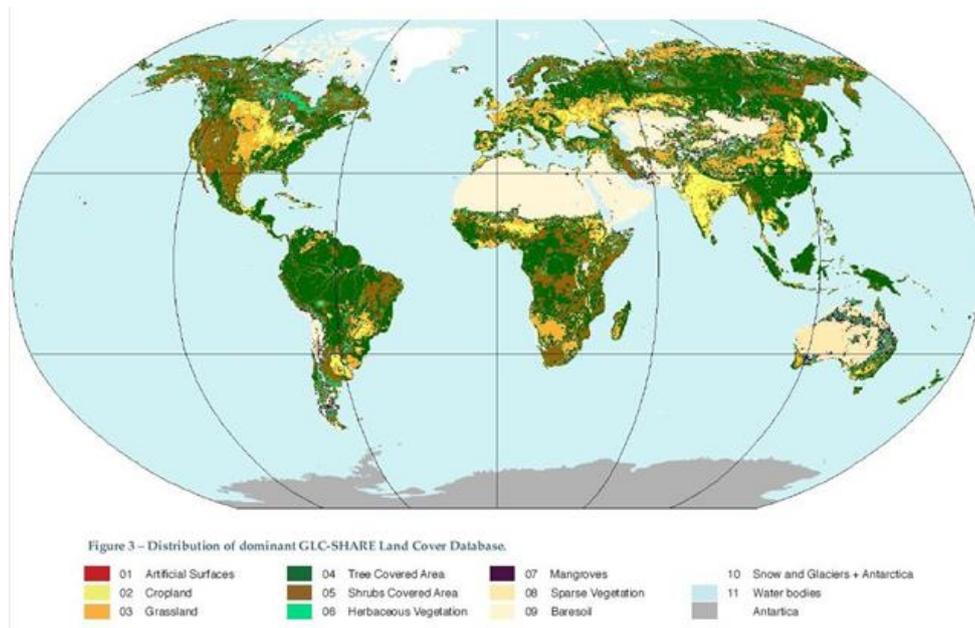
Example of downstream services addressed to institutional users

Environment is the main application field where remote sensing has been used. Besides, the monitoring of the environmental changes and dynamics is one of the Government's prerogatives. Some examples of services and products offered by NGOs at global scale are:

- **Land management:** The Food and Agriculture Organization (FAO) of the United Nations delivers the "Global Land Cover-SHARE" database (see Figure 20)⁷⁰. This product collects scattered and unharmonised land cover information of the Earth's surface from around the world into one centralized database. Applications of the database include assessment, monitoring and reporting of the distribution of the major land cover classes, land suitability evaluation, land accounting, environmental accounting, climate change impact assessments in productivity and yields, land use planning and sustainable development addressing food security and environmental threats.
- **Protection of natural habitats:** satellite imagery makes it possible understanding the cause of changes in land use and land cover around the world at different spatial scales. NGOs such as the World Wildlife Fund (WWF) use satellite-based maps in their study and reports to inform Governments and citizens about the consequences of practices such as deforestation, expansion of agriculture or land fragmentation on natural habitats (see an example of thematic map in Figure 21).
- **Air pollution:** The Regional Environmental Center (REC) for Central and Eastern Europe provides assistance in solving environmental problems in Central and Eastern Europe by promoting cooperation among governments, NGOs, businesses and other environmental stakeholders. REC was established in 1990 by the United States, Hungary and the European Commission as a not-for-profit international organisation. Its satellite assisted management of air quality has been developed as a toolkit for institutional users for managing air quality information (e.g. on PM10).

⁷⁰ http://www.glcnet.org/databases/lc_glcshare_en.jsp.

Figure 20: The Global Land Cover-SHARE database provided by the Food and Agriculture Organization of the United Nations



Source: FAO (http://www.glcn.org/databases/img/glcshare_map_large.jpg).

Figure 21: Percentage of land area formally protected, by terrestrial ecoregion



Source: WWF (2014).

Example of commercial downstream services

- Water quality:** EOMAP GmbH & Co. KG⁷¹ is an independent German company selling Earth observation services for monitoring aquatic environments. EOMAP products are focused on the monitoring of water quality parameters such as turbidity, suspended matter, chlorophyll-a and harmful algae blooms using satellite data. This information for both inland and coastal waters is essential for identifying long-term trends and highlighting emerging problems over large areas (Figure 22).

⁷¹ <http://www.eomap.com/>.

- **Solar radiation:** Flyby⁷² is an Italian private company offering commercial products based on optical satellite images in several fields. Among its services, HappySun is an innovative app for smartphones that provides real-time information about UV solar radiation intensity (Figure 23). The service can help tourists and citizens to protect themselves from solar radiation by monitoring the local environmental conditions based on geolocation from GNSS and images coming from different ESA's Earth observation satellites which provide data regarding the characteristics of atmosphere, water and soil.
- **Air quality:** ObsAIRve is an EU-funded public-private consortium made of the German private companies T-Systems International GmbH⁷³ and GAF AG⁷⁴, and the public entities German Aerospace Center⁷⁵ and Environment Agency⁷⁶. ObsAIRve offers a pilot service (see Figure 24) making use of data provided by the European Earth observation satellites and in situ monitoring stations for providing up-to-date air quality information for Europe (measurement values as well as forecast model data). The goal is to provide European citizens an air quality service that shows easy and comprehensible information for their safety and security.
- **High performance computing:** Terradue UK Ltd⁷⁷ is a SME supporting researchers in many Earth Sciences domains such as geosciences, marine ecosystems, oceans and coastal zones, and climate change. The company's activities focus on the use of web services, web protocols, Grid and Cloud APIs, to support distributed spatial data management and high performance computing applications in collaborative digital environments. Terradue offers a service for the management and distribution of very large spatial data sets complemented with data inventory, query and processing systems, carried out collaboratively with open source projects. Customers and partners are space agencies, state/local governments, applied science labs, academic research organizations, international standardization committees, open source software communities and private sector companies.

Market opportunities and threats

Despite the European Commission has funded several research projects within the Seventh Research Framework Programme, the European private market of satellite-based services for health care is still an underdeveloped area. However, this specific market sector has potential to grow in future, as the increasing life expectancy of the European population will bring about new information and service needs.

Some ad hoc policy stimulus could contribute to stimulate this specific market sector. For instance, policies of the health care systems of the European Union's member states could support the developing of new (private) downstream services, with the final long-term objective of reducing public healthcare costs through a better management of the causes of chronic diseases.

⁷² <http://www.flyby.it>.

⁷³ www.t-systems.com.

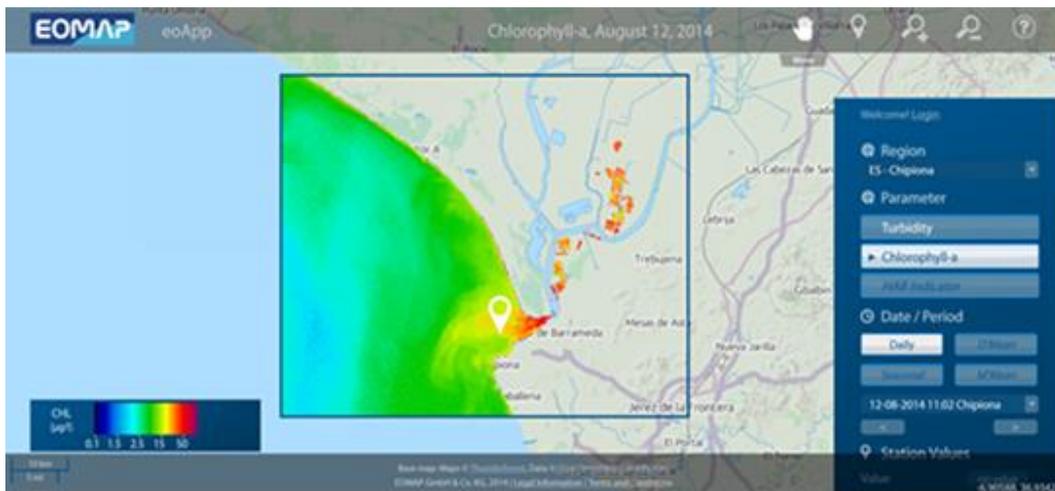
⁷⁴ www.gaf.de.

⁷⁵ www.dlr.de.

⁷⁶ www.umweltbundesamt.at/en/.

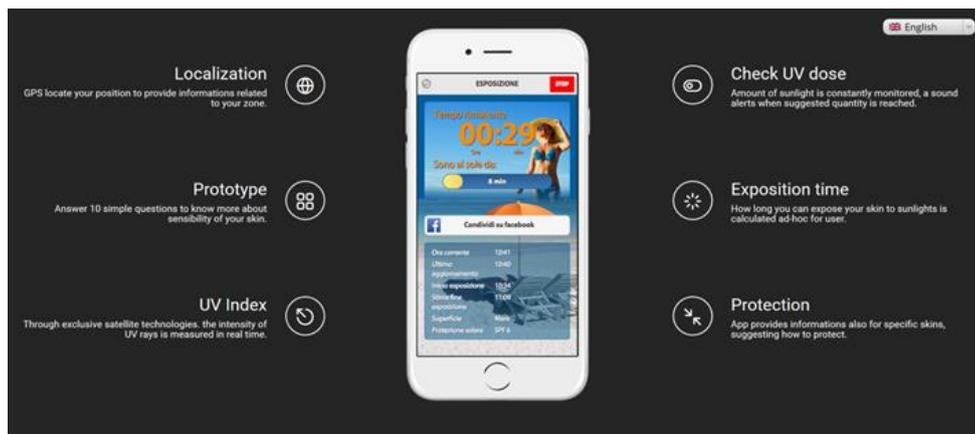
⁷⁷ <https://www.terradue.com/>.

Figure 22: eoApp® WQ Monitoring Service. Example of chlorophyll-a retrieval using satellite observations



Source: EOMAP (<http://eoapp.eomap.com/>).

Figure 23: HappySun app for smartphones



Source: Flyby (<http://www.happysun.it/en.html>).

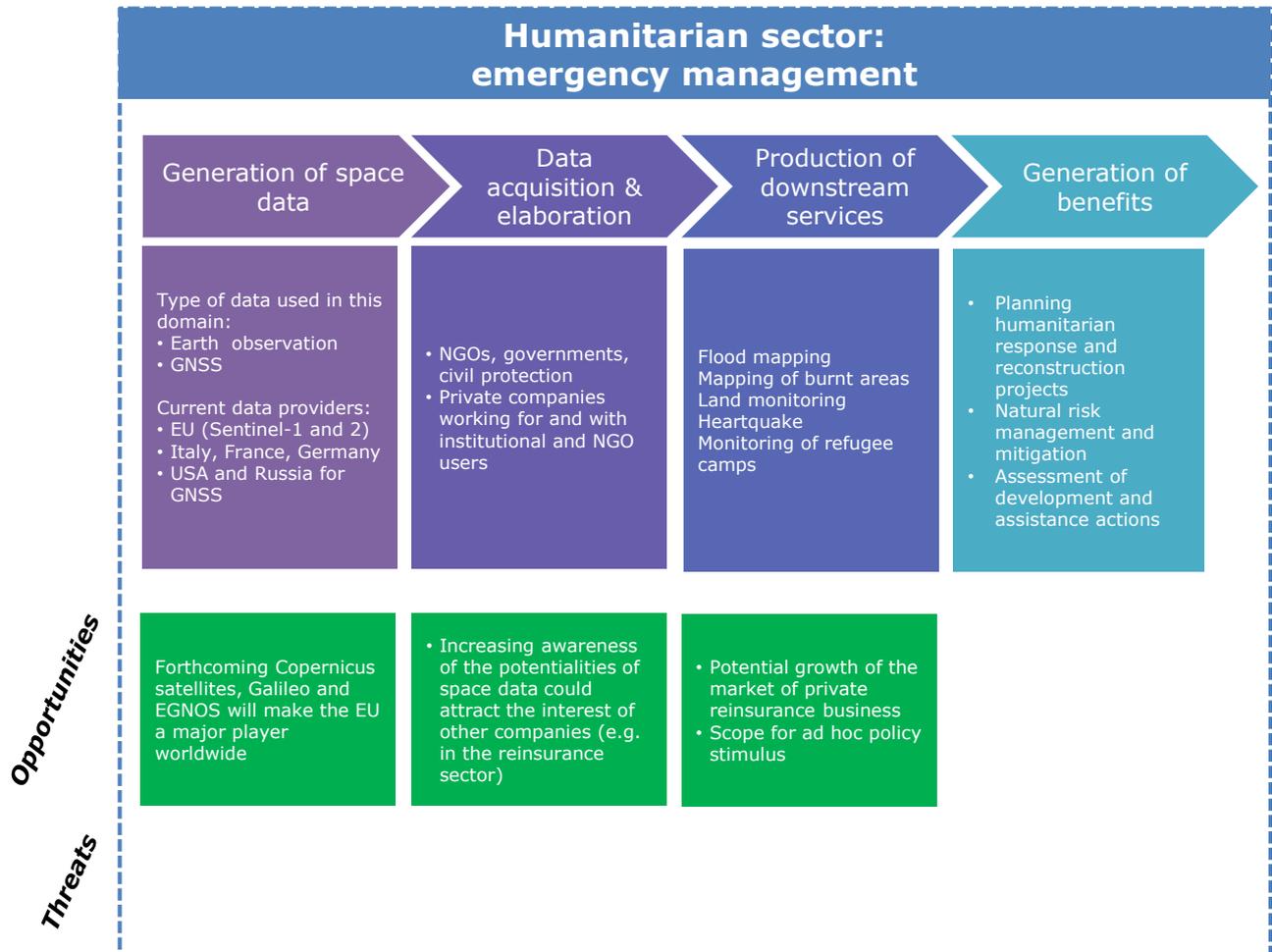
Figure 24: ObsAIRve app for smartphones



Source: iTunes (https://itunes.apple.com/de/app/obsairve/id490939811?mt=8&iqn-mpt=uo_%3D4).

HUMANITARIAN SECTOR: EMERGENCY MANAGEMENT

Figure 25: Humanitarian sector flowchart



Source: Authors.

Background

In the last few decades the number and impacts of natural disasters in the European Union and worldwide have increased: storms, extreme temperature events, forest fires, droughts, flood, snow avalanches, landslides, earthquakes, and volcanoes. In 2011 the European Environmental Agency concluded that "There is some evidence that climate change is contributing to increasing the frequency and intensity of weather related natural hazards. It is projected that these effects of climate change could intensify in the future". With reference to industrial accidents and their relationship with natural hazards, the Green Paper on the Insurance of Natural and Man-made Disasters stated that "natural hazards and disasters, for example, lightning, low temperature or earthquakes, may trigger man-made ('natech' - Natural Hazard Triggering Technological Disasters) disasters such as atmospheric releases, liquid spills or fires (i.e., the 2011 Fukushima nuclear disaster, Japan). Such compound 'natech' disasters can occur more often due to the increased frequency of extreme natural events and the increased complexity and interdependency of industrial systems" (European Commission, 2013). Moreover, like natural disasters, 'natech' disasters could also have large-scale and cross-border impacts.

In this context, space technologies (both Earth observation and GNSS) are unique and powerful tool more frequently used for planning humanitarian response actions, planning within post-crisis reconstruction projects, planning within natural risk management, planning and managing within development projects, or assessing the effectiveness and efficiency of assistance and development actions. With its Copernicus, Galileo and EGNOS constellations, in the next two decades **Europe is going to become a major player not only in the downstream market but also in the midstream**. During emergencies, all the available satellite data are collected and assimilated into straightforward maps. Therefore, NGOs and non-EU Governments will greatly benefit from the availability of Copernicus data, free and open.

Example of services addressed to institutional users and NGOs

- **Flood mapping:** ITHACA⁷⁸ is an Italian non-profit association devoted to support humanitarian activities in response to natural disasters by means of Earth observation systems. In collaboration with the Polytechnic University of Turin, ITHACA undertakes comprehensive operational and research activities in the field of analysis, evaluation and mitigation of damages caused by natural or manmade catastrophes and supports the United Nations' World Food Programme by providing highly detailed satellite maps for helping its humanitarian operations (see Figure 26);
- **Mapping of burnt areas:** S'ervice Régional de Traitement d'Image et de Télédétection (SERTIT) is a technology transfer center of the University of Strasbourg⁷⁹. The center participates in emergencies worldwide, through its rapid mapping service during crises caused by natural or industrial disasters. SERTIT is capable of mobilizing expert teams 24/7, 365 days a year, to deliver crisis mapping within 6 hours based on satellite images covering emergency events and their consequences. With respect to international aid, SERTIT supports humanitarian missions, epidemiological surveillance, development aid, reconstruction, and territorial management (see Figure 27).
- **Land monitoring:** The Remote Sensing Applications Center (ReSAC)⁸⁰ is a Bulgarian non-profit organization involved in fast-track mapping on the emergency response and land monitoring. In the beginning supported by the United Nations' Food and Agriculture Organisation, ReSAC's mission is to facilitate local, national and international authorities, as well as private enterprises, to introduce Earth observation-based products into agricultural and environmental management, land cover and land use mapping, soil and forest inventory, water resources, environmental hazards, disaster management and urban planning (see Figure 28).
- **Monitoring of refugee camps:** The Center for Satellite Based Crisis Information (ZKI)⁸¹ is a service of the German Remotes Sensing Data Center at the German Aerospace Center. It provides a 24/7 service for the rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide. In case of humanitarian crises, ZKI assists relief efforts in cooperation with international partner organisations and provides user specified information and map products, such as

⁷⁸ <http://www.ithacaweb.org/>.

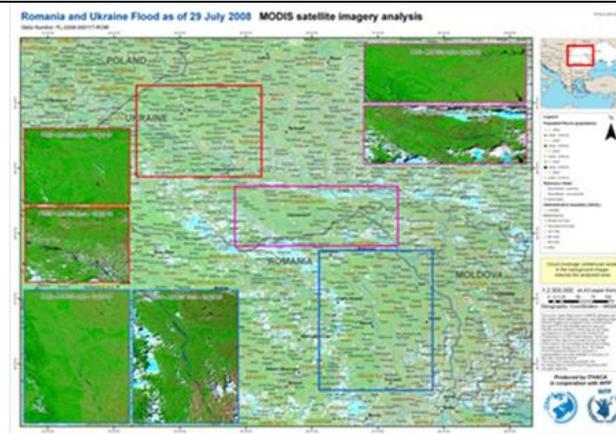
⁷⁹ <http://sertit.u-strasbg.fr/>.

⁸⁰ http://www.resac-bg.org/index_en.html.

⁸¹ <http://www.zki.dlr.de/>.

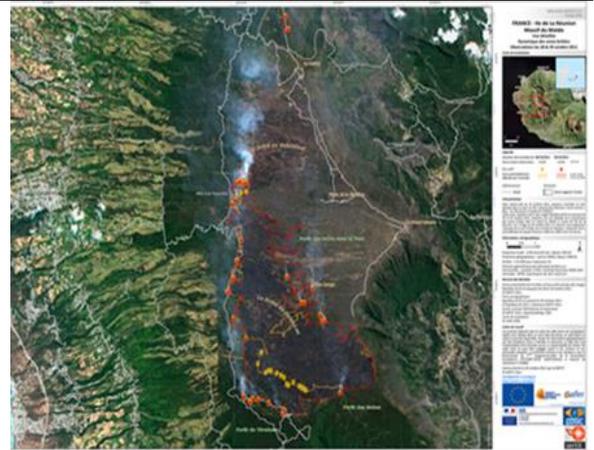
refugee camp and situation maps, used for logistic support and operation planning (see Figure 29).

Figure 26: Satellite-based map of flood occurred in Romania and Ukraine in July 2008



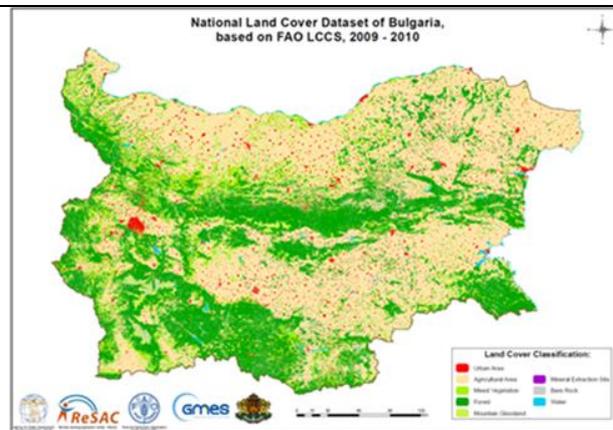
Source: ITHACA
(<http://www.ithacaweb.org/maps/romania/>).

Figure 27: Satellite-based map of burnt areas occurred in Maito Massif (Reunion Island) in October 2011



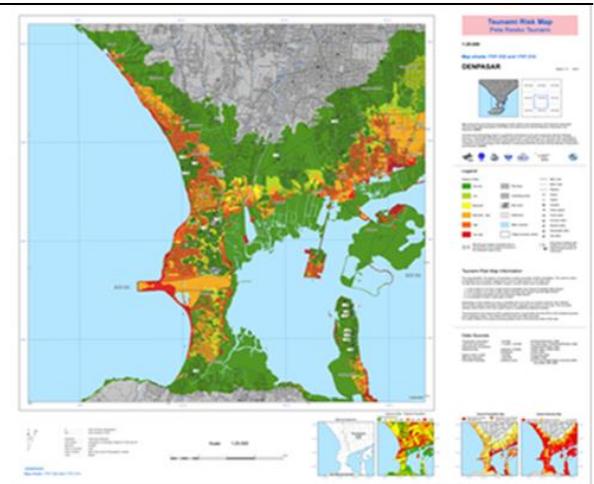
Source: SERTIT (http://sertit.u-strasbg.fr/applications_en.html).

Figure 28: Satellite-based land cover map of Bulgaria



Source: Bulgarian Spatial Data Infrastructure
(http://bsdi.asde.bg.org/data/Lccs/pdf/lccs_RL_2010_v02_EN.pdf).

Figure 29: Map illustrating the risks in case of a tsunami in Indonesia



Source: ZKI (<http://www.zki.dlr.de/image/939>).

Market opportunities and threats

Emergency management may seem the typical case of business-to-government or government-to-government services. In fact, at present time the main customers of Earth observation-based services are government agencies and NGOs. Consequently, today **public funds and donors drive the market**.

However, natural and manmade disasters also affect the private insurance business. While from a technical point of view there are no limits or constraints in using satellites for timely

helping insurers to assess the impact of hazards and extreme events, **the use of Earth observation data in the European insurance industry is still in the early stages**. An example is PERILS AG, a Swiss insurance company aimed at improving the availability of catastrophe insurance market data. PERILS offers industry exposure and event loss data and an associated industry loss index service for Europe windstorm, UK flood and Italy earthquake and flood. In 2012, within ESA's activities to develop the industrial use of Earth observation-based services, a consortium of insurance companies including PERILS, Swiss Re, Munich Re, Allianz, Willis and Guy Carpenter, has tested the use of real-time flood extent information based on data from a constellation of six European and Canadian remote sensing satellites⁸². Nevertheless, it was a sporadic case study and it is possible this specific market sector needs some ad hoc stimulus for developing the use of Earth observation and GNSS products for its business.

⁸² http://www.esa.int/Our_Activities/Observing_the_Earth/Insurance_industry_adopts_Earth_observation_for_assessing_floods.

ANNEX 3. A SYNTHESIS NOTE ON THE US MARKET AND POLICY CONTEXT OF SATELLITE DATA AND INFORMATION

The US space program has historically placed a high value on the development of a commercial space sector; this is reflected by the 2010 US Space policy, which lists as one of the five basic principles: "A robust and competitive commercial space sector is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship." Undoubtedly, the development of the US commercial sector is the primary focus; US private companies benefit from privileged access to public sector contracts, and enjoy the support of government entities such as the Office of Space Commercialization⁸³. However, this principle has resulted over the years in a set of policies of open, unrestricted and free access to US space data, with no discrimination users (public or private US users, or international users), hence playing a vital role in the establishment of the USD 314 billion global space market (Space Foundation, 2014). This note summarizes some of the aspects of the US GNSS and Earth Observation programs, that more directly provide a benchmark of the potential impacts of the Galileo and Copernicus programs on the European Space Market.

The Navstar Global Positioning System

History and essential technical characteristics

The Navstar Global Positioning System (GPS) is the Global Navigation Satellite System (GNSS) operated by the government of the United States of America. Initially known as Defence Navigation Satellite System (DNSS), it was conceived in the early 1970s as a military program, in support of the positioning needs of all branches of the US military (Pace et al., 1995). The US Air Force was designated in 1973 as the lead agency in the development of the constellation; the first set of 11 satellites (GPS Block I) was launched between 1978 and 1985, followed by 56 satellites of the second series (Block II) from 1989 onwards (several series of Block II satellites have been produced, with improved characteristics). The expected life of the current generation of GPS satellites is 7.5 years, and the constellation requires 24 satellites for nominal performance; 24 or more satellites have been constantly in orbit since 1993; 31 are in orbit and healthy at the time of writing⁸⁴.

GPS provides two types of service:

- Standard Positioning Service (SPS) is the service available to all GPS users on a continuous, worldwide basis with no direct charge. SPS is provided on a single frequency (L1) and contains a Coarse Acquisition (C/A) code and navigation ancillary information. Until year 2000 the C/A code was intentionally degraded (Selective Availability), reducing the positional accuracy of civil GPS receivers to about 100 metres.

⁸³ <http://www.space.commerce.gov/> The Office of Space Commercialization is part of the US department of commerce, and has the mission of fostering the conditions for the economic growth and technological advancement of the U.S. commercial space industry.

⁸⁴ [www.gps.gov.](http://www.gps.gov/)

- Precise Positioning System (PPS) is the service available to military and federal government GPS users. PPS is provided on two frequencies (L1 and L2), that broadcast a precision (P) code.

Modernization

Modernization of the GPS constellation started with improved Block IIR-M⁸⁵ and Block IIF⁸⁶ series satellites launched since 2005, and will continue with the forthcoming Block III satellites⁸⁷ (begins launch in 2016). The modernization will substantially change the GPS service:

- second civil signal available on band L2, which will allow civil GPS receivers to achieve the same positioning precision of military receivers;
- new military code (M) for improved jam resistance;
- third civil signal available on band L5, restricted to aerial navigation;
- fourth civil signal on band L1, designed to allow interoperability with Galileo receivers⁸⁸.

Relevant policies for the civilian use of GPS

While the initial development of GPS was entirely focused on military applications, the possibility of civilian access to the positioning services, albeit with some limitations, was discussed since the early 1980s (Easton, 2013). President Ronald Reagan announced in 1983⁸⁹ that GPS signal would have been opened to civilian receivers, once the constellation had reached operational status. In 1987, the US Coast Guard was designated as the government body in charge of the implementation of GPS for civil use (Pace et al., 1995). Since 1993, GPS signal has been accessible, free of charge, for international users, and it is expected to continue for the foreseeable future (2010 National Space Policy of the United States). The growing importance of GPS for the US economy was led to its designation as 'dual use' (military and civil) system in 1996 via a presidential order of President Bill Clinton⁹⁰; furthermore, the Clinton 1996 policy prescribed that the Selective Availability (SA), i.e. the degradation of C/A signal needed for SPS of civil receivers, would be discontinued after allowing an adjustment period. SA, which had been in place since 1991⁹¹, was turned off in 2000, and never reactivated. As a significant recognition of the vital importance of GPS for the US and global economy, the US government announced in 2007 that the newest (Block III) generation of GPS satellites, planned to be launched starting in 2017), will not have SA capability, "thereby eliminating a source of uncertainty in GPS performance that has been of concern to civil GPS users worldwide"⁹².

⁸⁵ Air Force Factsheet, GPS IIR/IIR-M satellite <http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=18671>.

⁸⁶ Air Force Factsheet, GPS IIF satellite <http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=18670>.

⁸⁷ Air Force Factsheet, GPS III satellite <http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=18830>.

⁸⁸ EU-US Cooperation on Satellite Navigation, Working group C, Combined Performances for Open GPS/Galileo receivers, 2010, <http://www.gps.gov/policy/cooperation/europe/2010/working-group-c/combined-open-GPS-Galileo.pdf>.

⁸⁹ NSDD102 - US response to Soviet Destruction of KAL Airliner, 05 Sep 83, declassified text available at <http://fas.org/irp/offdocs/nsdd/index.html>, last accessed October 19, 2015.

⁹⁰ PDD NTSC-6 - "U.S. Global Positioning System Policy", 28 March 1996 <http://clinton2.nara.gov/WH/EOP/OSTP/html/gps-factsheet.html>, last accessed October 19, 2015.

⁹¹ Notice Advisory to NAVSTAR Users 121-92282 DTG 011354Z JUL 91.

⁹² Statement of the Press Secretary, September 18, 2007 <http://georgewbush-whitehouse.archives.gov/news/releases/2007/09/20070918-2.html>, last accessed October 19, 2015.

The management structure of GPS is currently defined by the 2004 US Space Based Positioning, Navigation and Timing (PNT) Policy, complemented by the 2010 National Space Policy, which provides an additional framework for the operation and continuation of the GPS programme. According to the 2004 PNT policy, the Department of Transportation is responsible for civil GPS applications.

Maintaining and enhancing PNT systems is one of the “foundational activities and capabilities” of the 2010 policy, which states that “The United States must maintain its leadership in the service, provision, and use of global navigation satellite systems (GNSS)”. This overarching goal is articulated in four fundamental activities:

- “provide continuous worldwide access, for peaceful civil uses, to the Global Positioning System (GPS) and its government-provided augmentations, free of direct user charges”;
- “engage with foreign GNSS providers to encourage compatibility and interoperability, promote transparency in civil service provision, and enable market access for U.S. industry”;
- “operate and maintain the GPS constellation to satisfy civil and national security needs, consistent with published performance standards and interface specifications. Foreign positioning, navigation, and timing (PNT) services may be used to augment and strengthen the resiliency of GPS”;
- “invest in domestic capabilities and support international activities to detect, mitigate, and increase resiliency to harmful interference to GPS, and identify and implement, as necessary and appropriate, redundant and back-up systems or approaches for critical infrastructure, key resources, and mission-essential functions”.

Economic impact of GPS

A commercial GPS market started in the mid-1980s with equipment for surveying – a logical entry point at a time when the limited number of available satellites did not allow for acquisition from any moving platform (Pace et al., 1995). The revenue from surveying equipment allowed for significant investment by US firms, that expanded by the 1990s into new markets such as aerial and terrestrial navigation (Pace et al., 1995). The rapid growth of the commercial GPS sector can be fully appreciated by considering that during the 1990 Gulf War 90 % of the receivers used by the US military were commercial receivers (Rip and Lusch, 1994). The landmark 1996 change in GPS policy, (GPS becoming a dual purpose military/civilian programme, and improved accuracy for civilian users) was a recognition that the GPS commercial sector was relevant enough to trump any remaining security concerns (Lachow, 1995).

The US government is investing, in recent years, over USD 1 billion per year in the GPS programme, including operations, research and development, and deployment of new satellites. This budget is mostly allocated to the Department of Defence (Fiscal Year 2015: USD 1.03 billion; Fiscal Year 2014: USD 1.21 billion, Fiscal Year 2013: USD 1.23 billion), with the civil funding allocated to the Department of Transportation⁹³ (Fiscal Year 2015: USD 115 million; Fiscal Year 2014: USD 97 million; Fiscal Year 2013: USD 120 million). NPD consulting (Pham, 2011) conducted an extensive study of the economic benefit of commercial GPS use in the US, estimating annual GPS sales averaging USD 33.5 billion

⁹³ Space Based Positioning Navigation and Timing Executive Committee, 2011, Civil GPS overview, <http://www.gps.gov/policy/funding/2011-civilfundingpaper.pdf>.

/year, generating an additional economic benefit of USD 67 billion/year due to increased productivity and reduced costs (Table 12). While a relatively low number of workers were estimated to be directly involved in the GPS manufacturing industry (130'000 employees), 3.2 million jobs in the US rely on GPS use in the downstream industry. Further growth is anticipated as positioning is increasingly embedded in the multiple devices that are collectively defined as the "internet of things" (West, 2014).

Table 12: Annual benefits to all commercial GPS Users in the U.S. Economy

| | Annual GPS Equipment Spending (USD billion) | Estimated Annual Benefits (USD billion) |
|--|---|---|
| Precision agriculture (crop farming) | 0.5 | 19.9 – 33.2 |
| Engineering Construction (heavy & civil and surveying/mapping) | 1.1 | 9.2 – 23.0 |
| Transportation (commercial surface transportation) | 3.2 | 10.3 – 15.1 |
| Sub-total (3 industries examined) | 4.8 | 39.4 – 71.3 |
| Other commercial GPS users | 3.5 | 28.2 – 51.1 |
| Total commercial GPS users in the U.S. economy | 8.3 | 67.6 – 122.4 |

Source: Pham, 2011.

Earth Observation Programs

This section focuses on the two programs, MODIS Terra/Aqua and Landsat, which are comparable with the Sentinel-3 and Sentinel-2 components of the Copernicus programme, both in terms of instrument characteristics, and in terms of potential commercial applications. Similarly to ESA and the EU, the US civil federal agencies are not currently operating any high resolution Earth Observation Systems, relying instead on collaboration and data purchases from commercial remote sensing operators⁹⁴.

Coarse resolution environmental monitoring: EOS Aqua/Terra

The Terra and Aqua satellites (launched in 1999 and 2002 respectively) were conceived in the early 1990s as the main components of NASA's Earth Observing System (EOS), with government investment peaking at around 1 USD billion in 1999 in the pre-launch phase (Lawler, 2004). The MODIS instrument⁹⁵, carried on both satellites, belongs to the same coarse space resolution class as the OLCI imager on-board Sentinel 3-A and 3-B, and like OLCI is an instrument designed both for Ocean and Land monitoring (Tucker and Yager, 2011; Donlon et al., 2012). NASA operates the satellites, and generates a set of systematic thematic products in support of NASA's Earth Science Objectives⁹⁶; calls for proposals are released at three years intervals, soliciting proposals that cover the basic research and

⁹⁴ U.S. Commercial Remote Sensing Space Policy, 2003

⁹⁵ MODIS design, specifications and components are provided at <http://modis.gsfc.nasa.gov/about/index.php>.

⁹⁶ <http://science.nasa.gov/earth-science/>.

development needed to generate these thematic products (Justice et al., 2002; Salomonson et al., 2002). The selected Principal Investigators become part of the relevant Science Team, which is responsible for the quality, and integrity of the thematic products. Funding available for the science team have fluctuated over the years; the latest solicitation⁹⁷ had an annual budget of 10.5 USD million, covering about 50 proposals.

Moderate resolution environmental monitoring: the Landsat Program

Landsat 8, successfully launched in 2012, is the last satellite of the Landsat series, initiated with Landsat-1 in 1972. The Landsat satellites have carried a variety of multispectral coarse resolution instruments (with resolution ranging from 15 to 80 meters), that have systematically observed the Earth since 1972⁹⁸. NASA operates the satellites, while the United States Geological Survey (USGS) is in charge of data distribution. Landsat data access has changed widely throughout its history: the mission was privatized in 1984⁹⁹, based on the assumption that the market for remote sensing products was sufficiently mature to sustain the mission, but instead the demand for Landsat shrank, with fewer and fewer users requesting increasingly expensive data (Eisenbeis, 1995; Folger, 2014). The policy was reversed in 1992, and funding was allocated for a NASA operated Landsat-7¹⁰⁰; by 2001 the commercial operator (EOSAT) returned control of Landsat-4 and Landsat-5 to the US government. In 2008 USGS discontinued the distribution of Landsat data on media at the marginal cost of dissemination (ranging at the time from 15 to 4 000 USD for scene, switching exclusively to free web dissemination¹⁰¹ (Woodcock et al., 2008). The number of Landsat scenes distributed per month grew as a result exponentially, from less than 300 per month, to over 100'000 a month immediately after the change in policy, and over 250'000 a month by early 2011 (Wulder et al., 2012). The 2014 National Plan for Civil Earth Observation¹⁰² calls for a 25 year program of sustained Landsat observations, fully compatible with the existing 42 year data record. Landsat data is largely distributed at L1T level (radiometrically corrected, standard terrain corrected), with more recent prototypes of distribution of higher level products¹⁰³, that could lower the entry barrier for data use, especially by SME.

US Data Policy

The US policies on data access recognize that Earth Observation data have both public and private use. The government invests in the satellite systems to fulfil various mission purposes (from planning and monitoring of natural resources, to climate and climate change monitoring), but the same data can be used by commercial entities to pursue economic opportunities (Hertzfeld and Williamson, 1997). The current data distribution policies build on the pre-existing legislation: (1) the NASA Act of 1958 mandates that observations from space have to be openly and freely disseminated¹⁰⁴; (2) as a general principle, government policy prescribes that data collected by federal agencies is

⁹⁷ Solicitation NNH13ZDA001N-TERAQ, released Feb 14 2013.

⁹⁸ For a complete history of the Landsat mission, and for the technical details of the instruments carried onboard Landsat1 through 8, see <http://landsat.gsfc.nasa.gov>.

⁹⁹ Land Remote-Sensing Commercialization Act of 1984, Public Law 98- 365.

¹⁰⁰ Land Remote Sensing Policy Act of 1992, Public Law 102-555.

¹⁰¹ USGS Policy on Fees and Landsat data Products, http://remotesensing.usgs.gov/landsat_fees.php.

¹⁰² OSTP. (2014). National Plan for Civil Earth Observations http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/2014_national_plan_for_civil_earth_observations.pdf.

¹⁰³ <https://landsat.usgs.gov/WELD.php>.

¹⁰⁴ National Aeronautics and Space Act of 1958, Public Law 85-568.

disseminated at no more than the cost of dissemination¹⁰⁵, hence preventing federal agencies to charge data users for any cost associated with the acquisition of the datasets (Hertzfeld and Williamson,1997); (3) the US legislation prevents government documents (“government works”) from being protected by copyright law¹⁰⁶. Key points of the current NASA data access policy¹⁰⁷ are:

- “NASA commits to the full and open sharing of Earth science data obtained from NASA Earth observing satellites”;
- “there will be no period of exclusive access to NASA Earth science data. Following a post-launch checkout period, all data will be made available to the user community”;
- “NASA will enforce a principle of non-discriminatory data access so that all users will be treated equally”;
- “NASA will make available all NASA-generated standard products along with the source code for algorithm software, coefficients, and ancillary data used to generate these products”.

The NASA data policy is clear, concise and unambiguous¹⁰⁸, and allows commercial entities (in fact, any entity regardless of affiliation) to have the same level of access granted, for instance, to federally sponsored programs, effectively enabling the commercial remote sensing sector to rely on these data to provide value added services. In particular:

- the data are not copyrighted, therefore users are free to use, redistribute, or sell both the original data, and any derived value added product;
- code and algorithms used to generate NASA datasets are also shared, and are free from copyright, and therefore can be re-used in commercial, for-profit work;
- any investment in data infrastructure (e.g. data preprocessing, archiving and distribution) that is designed to meet government needs, will benefit all users equally;
- the fact that there is no wait period means that datasets cannot be withheld from the public, therefore guaranteeing timely access to all users.

It is important to notice that, setting aside some technical aspects of the data transfer, the ingestion of the whole Landsat archive in the Google Earth Engine cloud¹⁰⁹ did not deviate from the NASA distribution policy: any other entity could download systematically and redistribute any amount of NASA satellite data.

Economic impacts

The MODIS mission was primarily designed in support of climate change studies (Lawler, 2004), and the scale of the observations (global, daily, coarse spatial resolution) makes them relevant mostly for applications at the national and continental scale, thus

¹⁰⁵ Executive Office of the President, Office of Management and Budget, Circular No. A-130, Washington DC, 28 November 2000. https://www.whitehouse.gov/omb/circulars_a130_a130trans4/.

¹⁰⁶ Copyright Act of 1976, PL 94-553.

¹⁰⁷ NASA Data and Information Policy, <http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/>.

¹⁰⁸ In comparison, the most recent ESA data policy for ERS, Envisat and Earth Explorer recognizes the need of open and free access to create the conditions for private investment, but includes a number of exceptions on the type (data up to level 2) and amount of data freely and promptly available, excluding for example full dataset or “large volumes” of data (with no clear definition of “large volume”) https://earth.esa.int/c/document_library/get_file?folderId=296006&name=DLFE-3602.pdf.

¹⁰⁹ <https://earthengine.google.org/#intro>.

primarily limited to the science or government sector. As an example, MODIS data, thanks to the open access policy and to their systematic availability, are used internationally for crop monitoring and yield forecasting, with a significant reduction on the volatility of commodity prices, with an estimated commercial value of USD 556 million per year (Abbot et al., 2013). MODIS also provides real time wildfire detections (Giglio et al., 2003), that are a key component of the geospatial support to firefighting operations (Federal Geographic Data Committee, 2008) – no direct estimates of the benefit of satellite data is available, but the total cost of fire suppression is close to USD 1.2 billion per year in the US alone (USDA, 2015). Insurance and reinsurance for agricultural risks, fires and flooding is also an emerging market for moderate resolution data (de Leeuw et al., 2014).

The overall cost for the design, construction and launch of Landsat 8 was approximately USD 850 million, with operations costing an additional USD 30 million per year¹¹⁰. Following the 2008 free distribution policy, and the ongoing debate in Congress regarding funding for the forthcoming Landsat 9 mission (Folger, 2014), the economic impact of Landsat was systematically studied. The National Geospatial Advisory Committee (NGAC 2014) analysed sixteen economic sectors where the use of Landsat data leads to productivity savings, for an annual benefit of over USD 400 million. The sectors included in the NGAC studies are mostly related to federal and state government (i.e. mapping, wildfire suppression, water monitoring), but interestingly one of the study cases (E&J Gallo Winery, largest exporter of California wine) reported that water management in the winery is entirely supported by Landsat 8 data, with estimated benefit of USD 5 million / year. This represents a typical example of service that is provided by commercial entities, when free and timely access to satellite data is guaranteed.

With an alternative approach, Loomis et al., (2014) evaluated the annual aggregate economic benefits of Landsat by through the Contingency Evaluating Method, i.e. estimating how much users would be willing to pay for the data that they are downloading (for free) from USGS. The total benefit was estimated at USD 1.8 billion/year for US users, and USD 0.4 billion/year for international users. The average benefit or private business who are established Landsat users was estimated to be USD 1 057 per Landsat scene, which is an indicator of the added value of the services provided by the commercial sector.

¹¹⁰ Space news, June 9 2014, <http://spacenews.com/40841nasa-official-a-landsat-8-clone-would-cost-more-than-650-million/>.

Box 7: The Direct Readout Community



The Direct Readout Community is an interesting example of new market developing thanks to open access data policies. The Terra and Aqua satellites broadcast MODIS data in unencrypted format; local receiving stations are supported by NASA's Direct Readout Lab (<http://directreadout.sci.gsfc.nasa.gov/>).

Over 200 receiving stations are now operating (see map): some privately owned, some public and some attached to educational institutions. Improved real time monitoring in support of decision making (e.g. crop monitoring and yield forecast) and emergency preparedness (e.g. flooding and wildfire monitoring) carries significant societal benefits. Furthermore, the Direct Readout community opened up new market for companies, especially SME, that market and install receiving stations, support publicly owned stations by providing custom computer code, or operate stations providing real time services to public and private sector users.

Source: Authors.

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NOTES

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