Chapter 7
Benefit Assessment of the Application of Satellite Earth Observation for Society and Policy: Assessing the Socioeconomic Impacts of the Development of Downstream Space-Based Earth Observation Applications

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7.1 Introduction

Space provides a unique viewpoint for understanding our living planet and providing benefits for society. Satellite Earth observations can benefit many areas of society, including environment and resources management, agriculture and food security, transport, air quality and health, risk management, and security.

Since the start of the SPOT program, the French government has encouraged the use of satellite Earth observations for public policy needs and downstream applications. In response, the French National Centre for Space Studies (CNES) initiated an iterative dialog with policy makers, scientific communities, and industrial partners in order to support feasibility and demonstration studies as well as improve data accessibility, tools, and expertise.

Today, *NewSpace*[1] highlights the crucial role that space-based assets can play to meet population needs. It provides new opportunities for Earth observation to contribute to economic growth and jobs creation.

[1] *NewSpace* is a dynamic for the commercialization of low Earth orbit (LEO) satellites. Serving the ISS with commercial SpaceX or Blue Origin launches is a first step, which could be followed by the emergence of many new Earth observation service providers and massive Earth observation data flows.

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In the context of financial constraints, the need to underline the return on investment (ROI) of government funding to the space sector has increased. Accounting for the return focuses on the applications and services downstream. In order to maximize return, CNES now considers ex ante identification of the socioeconomic benefits of Earth observation for public policy users and space-based service providers as a requirement for all projects engaged in the frame of the French Programme d'Investissement d'Avenir (PIA).

7.2 Assessing the Benefits of Satellite Earth Observation for Public Policies: A Focus on Environmental and Maritime Policies

Convincing policy makers to make increased and more effective use of space-based Earth observation data and products requires robust benefit and cost assessments that compare Earth observation solutions to existing frameworks. A clear understanding of the value chain and actors is critical. Quantitatively assessing the benefits of space-based Earth observation is challenging because different multi-discipline approaches are needed for each case.

Several other issues also have to be addressed in order to motivate policy makers to invest in space-based Earth observation: space asset continuity, data and product accessibility, reliability, performance, and affordability are all relevant concerns.

Facilitating access to space Earth observation data is a key issue. Efforts are ongoing to facilitate access to scientific data hubs, e.g., ForM@Ter,[2] AERIS (collating Ether and ICARE),[3] and Aviso.[4] Copernicus Sentinel data and processing facilities are also made accessible via Plateforme d'Exploitation des Produits Sentinel (PEPS).[5] SPOT World Heritage data are made accessible through Theia.[6]

Convinced that space Earth observation could be a promising tool for the implementation and control of public policies, the French Ministry of Environment (MEDDE) and Ministry of Overseas Territories (DGOM) have intensified their relationship with CNES to facilitate the integration of satellite Earth observation information and their decision-making systems.

[2]ForM@Ter: http://poleterresolide.fr/.

[3]AERIS: http://pole-ether.fr and http://www.icare.univ-lille1.fr.

[4]AVISO: https://aviso-data-center.cnes.fr/.

[5]PEPS: https://peps.cnes.fr.

[6]Theia: https://theia.cnes.fr/.

7.2.1 MEDDE PlanSat: Satellite Earth Observation Contribution Toward Environmental Policy

The relationship between CNES and MEDDE was initiated at the beginning of the SPOT program to raise awareness about the potential of Earth observation data and to facilitate its integration into environmental policy. Thanks to SPOT's multi-scale, long-term information series and high temporal resolution, rapid mapping, and change detection information can also be provided to risk management actors (civil security and health departments). Such value-added products can also be used to anticipate damages. It is expected that this Earth observation information can provide policy makers with major benefits.

Anticipating Copernicus data availability, MEDDE elaborated PlanSat[7] to identify space Earth observation contributions for directorates in charge of Prevention and Risks (DGPR), Energy and Climate (DGEC), Infrastructures-Transport and Maritime (DGITM), Town and Country Planning-Lodging and Nature (DGALN), Fishery and Aquaculture (DPMA) and Civil Aviation (DGAC). In 2011, MEDDE and CNES signed a master agreement to implement actions.

Quantifying the benefits of using space Earth observation within a domain is a significant undertaking. The method used by MEDDE and CNES to assess the benefits of the implementation and control of public policies was based on the concept of demonstration-comparison-feedback, with and without space Earth Observation assets. Assessments were undertaken for various monitoring and control issues in policy areas such as soil-use, infrastructure monitoring, coastal erosion, and natural hazard management.

Quantitative assessments of the benefit of space Earth observation necessitates the clarification of value chains in each domain and determination of the "value" of space-based Earth observation information within each segment of the chain. Input from space Earth observation experts, economists, social sciences experts, and policy makers is mandatory. CNES has also initiated discussions on space Earth observation value in the frame of a new group that gathers social sciences experts. Long-term sharing of common definitions and methods are conducted by CNES, MEDDE, and industrial partners within Le Comité de Concertation Etat Industrie sur l'Espace (COSPACE) in cooperation with Commissariat Général à l'Investissement (CGI)[8] and Direction Générale des Entreprises (DGE).[9]

[7]PlanSat is the MEDDE master plan that identifies space-based Earth observation benefits and needs for each directorate: http://www.developpement-durable.gouv.fr/Le-plan-d-applications.html.

[8]CGI is funding space technology transfer for industrial production capacities in the frame of PIA.

[9]DGE supports the development of the upstream and downstream space sectors.

7.2.2 DGOM: Satellite Earth Observation for Overseas Challenges

For territories overseas, France must implement and control public policies in various domains, including health, transportation, town and country planning, agriculture, natural risks and crisis management, environmental and maritime surveillance, illegal fishing, pollution surveillance, and security.

Needs are specific, depending on the geographical situation and on the geo-political challenges of the overseas territories located in the tropics, Arctic, or Antarctic. The Direction Générale des Outre-Mer (DGOM) is in charge of coordinating the efforts of the different ministries involved in the implementation and control of public policies overseas.

The benefit assessment of space Earth observation was conducted within the frame of a demonstration-comparison-feedback process. The relationship between DGOM and CNES was initiated in response to illegal fishing in French Guyana. CNES facilitated access to expertise at Collecte Localization Satellites (CLS) and supported a feasibility study for which satellite optical and radar sensors were combined to provide maritime security authorities with adapted products for information and decision-making. In 2013, convinced that satellite Earth observation was a promising tool, DGOM and CNES decided to cooperate on a long-term basis and a master agreement was signed.

Sargassum algae surveillance is one of the concrete actions for which a benefit assessment is ongoing. MEDDE, DGOM, and the Ministry of Health collaborated to establish an appropriate response to the health, environmental, and economic problems caused by the decomposition of algae around the beaches of Martinique and Guadeloupe. In the frame of their master agreement, DGOM asked CNES to evaluate the possibility and cost of implementing a space-based Sargassum algae surveillance system. A feasibility study was initiated with the objective of evaluating the ability of satellite Earth observation to detect Sargassum algae and to evaluate the suitability of Sentinel tasking for an operational service. The CLS facilities VIGISAT[10] and Mobydrift[11] were run using free satellite Earth observation data from Landsat-8 (optical) and Sentinel-1 (radar). Discussions were initiated with Direction de l'Environnement et de l'Aménagement du Littoral (DEAL) Martinique and Guadeloupe to understand the operational constraints and information needs, in order to provide them with adapted information products.

Thanks to this study, the dynamic of the Sargassum algae drift along Martinique and Guadeloupe was characterized. A service based on a satellite system combining optical and radar sensors was dimensioned and the running costs estimated. An iterative dialog with future users is ongoing in order to optimize service quality and costs.

[10]A maritime surveillance Geographic Information System (GIS) for visualizing information products.

[11]A drifting model.

The Chamber of Commerce of Guadeloupe estimates fishery and tourism economic losses related to algal blooms to be about EUR 5 million (USD 8 million) in the first quarter of 2015 alone (Valo 2016). The health impacts of SO_2 vapor coming from Sargassum algae decomposition is difficult to estimate, but will increase global damage and economic losses. These are key elements for assessing the benefits of using space-based Earth observation information in early warning information systems for Sargassum algae.

7.3 Assessing the Downstream Economy of Space-Based Earth Observation: Challenges, Methods and First Results

Growing demand for satellite Earth observation from policy makers contributes to the justification for the development of next-generation Earth observation satellites. Growing demand for value-added products will contribute to the development of downstream service providers. Policy makers and administrations will be able to procure adapted products and services, initiating a virtuous economic loop.

A healthy space-based Earth observation service provider ecosystem can be considered an indicator of the benefits of public investment in space. Its contribution to the global economy and employment is to be evaluated.

With increasing awareness of the potential economic benefits of space-based Earth observation and the downstream service provider industry, governments have been investing in business development programs, for example, the UK Catapult and French *Boosters* initiatives. However, assessing the impact of these investments is a challenge, as no common methodology has been identified by the space sector or economists. For this reason, CNES motivated DGE to join discussions in the frame of the OECD Space Forum. CNES has also initiated several actions to assess the French space-based Earth observation sector, evaluating financial value, and the impact of government investment toward downstream services.

7.3.1 Towards a Methodology for Assessing the Economy of the Downstream Space-Based Earth Observation Sector

The economy of the upstream space industry is surveyed regularly. Market reports are available addressing the launcher, satellite, and ground segments, but such reports do not exist for the downstream space-based Earth observation sector.

Determining any impact requires a clear view of the domain to be evaluated. So, the first question is what to count as part of the space Earth observation downstream sector.

This introduces some further questions:

1. What is the perimeter of the downstream space Earth observation sector? The delineation between upstream and downstream is not clear, nor accepted by the traditional actors. Moreover, new players coming from the ICT sector do not present themselves as space Earth observation service providers but just as service providers.
2. What is the service taxonomy to be used? There is no common classification for space-based Earth observation services. Reading through catalogs of space-based Earth observation service promoters and/or providers shows that taxonomies of service vary depending on the community addressed (scientific, agencies, industry, etc.).
3. For a given service, how should the importance of the space Earth observation data contribution be evaluated alongside other sources of information? Service offerings are increasingly a combination of many sources of information. Insider knowledge is often required to appreciate the exact contribution.
4. Is the service operational or not, and is it delivered on a commercial basis?
5. How should public organizations be considered when they could have commercial activities?

Discussions are ongoing in the frame of the OECD Space Forum, which contributes to common definitions. Segmentation into three space segments was proposed, setting up perimeters related to space activities, products, and services (Fig. 7.1).

As a member of the OECD Space Forum, CNES has supported several studies in order to assess the impact of public investment on the development of the downstream space-based Earth observation sector. This work has been conducted in the frame of COSPACE, in coordination with Groupement des Industries Françaises Aéronautiques et Spatiales (GIFAS) and DGE.

The first issue was to establish awareness of the French downstream space-based Earth observation sector. A mapping of French organizations with activities that are either linked with, or directly using, space Earth observation was established (Magellium 2014). Following analysis, a segmentation of actors was proposed and French space-based Earth observation service providers were identified. Secondly, an estimate of the financial value for this sector in France was established.

This approach promotes raised awareness of the financial soundness of the sector and establishes a useful reference. Revisiting these studies regularly will make the assessment of the impact of public investment in the downstream space-based Earth observation sector possible.

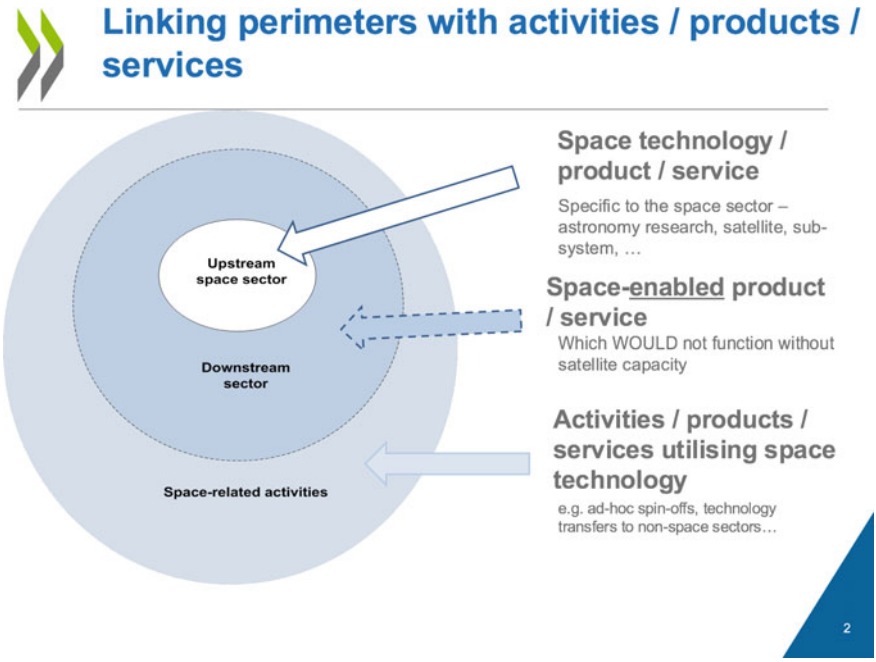

Fig. 7.1 OECD Space Forum segmentation of the space sector

7.3.2 Mapping French Satellite-Based Earth Observation Service Providers

Within COSPACE, CNES has initiated discussions around elaborating requirements for a study into mapping French space-based Earth observation service providers. A study, funded by CNES, was performed by Magellium in 2014 to test the following hypotheses:

- Societies with activities and jobs in France should be considered;
- A turnover of EUR 1 million is an effective threshold to divide up very small enterprises and industrial actors;
- Both commercial and noncommercial organizations should be identified;
- Segmentation of actors by sector of activity (software providers, data providers, service providers, etc.) is a requirement; and,
- "Real" service providers and their market segment should be precise.

CNES completed this study with an estimate of the financial value in 2015 (Fig. 7.2).

With a global picture of around 122 entities, downstream space-based Earth observation is well developed in France. The EUR 1 million threshold enables the identification of about 41 key actors with commercial activities in France. The 51

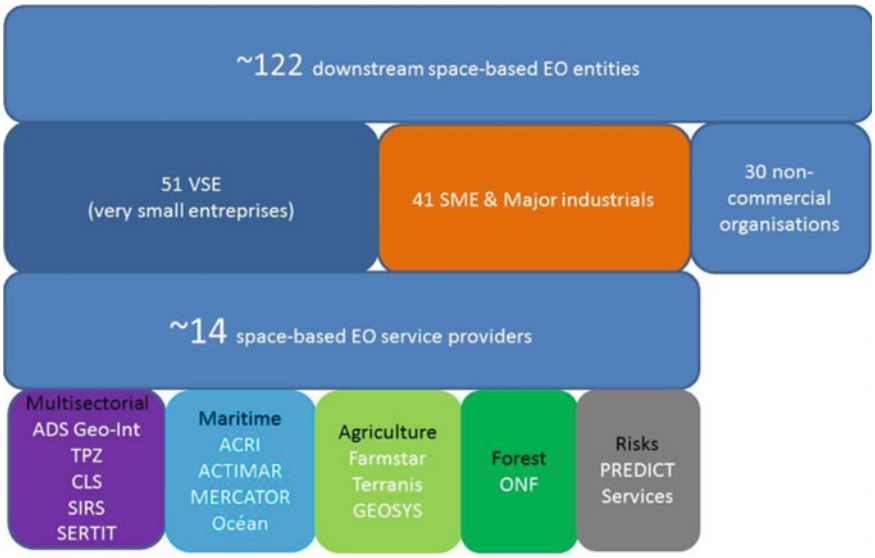

Fig. 7.2 Mapping downstream space-based Earth observation service providers in France (CNES 2015)

very small enterprises (one-expert, small consultancy offices, start-ups), spread France-wide, can be considered as a pool of resources that may grow with rising demand.

The study highlighted an ecosystem of about 14 providers serving policy makers and commercial users in traditional sectors such as agriculture, maritime, and disaster risks.

The landscape is expected to evolve considering the *Boosters* initiative and the arrival of new players from the digital economy, as well as the possible contributions of new systems such as UAVs and airborne Earth observation.

7.4 Lessons Learned and Perspectives

Just as governments are asked by taxpayers to provide the cost-effectiveness of their investments, space agencies must provide feedback on the benefits of using space and on the financial soundness of the ecosystems they develop. If the development of space assets to understand our living planet is, and remains, the main issue, providing taxpayers with an assessment of the benefits for public policies and the development of commercial space-based services is now part of the framework of Earth observation space programs.

Raising awareness of the capabilities of space-based Earth observation: assessing the benefit of a space-based Earth observation strategy begins with the

utilization of space-based Earth observation data and products. Raising the awareness of public authorities and other potential Earth observation users remains a challenge. Promoting the capabilities of satellites is important, but not sufficient. Promoters of space-based Earth observation have to answer questions about service and cost benefits for users. Pertinent answers can only be given after an iterative cross-sensitization process that raises the awareness of both sides. Long-term cooperation in the frame of master agreements has proven its efficiency, providing both partners with a framework they can refer to in order to align actions, evaluate progress, and coordinate efforts.

Increasing the accessibility of space data: this is a key issue. Free and open data access will motivate users, especially, if the data are reliable and delivered continuously. Capacity building for potential users should be organized.

Assessing the value of space-based Earth observation data: studies should be conducted to identify the value of space-based Earth observation data. Supporting feasibility and demonstration studies with a user-driven approach is an important issue. Comparisons with existing tools/alternate methods should be organized in order to assess/quantify the benefits of using space-based Earth observation. This could be made possible by gathering policy makers and multidisciplinary experts from the Earth observation industry, social sciences, and economists. In support of the objective of providing stakeholders with quantitative information, long-term relationships should be organized.

Developing a common definition of space sector segmentation: the space manufacturing sector is well-structured and related economic surveys are conducted on a regular basis, but the same is not true for the downstream Earth observation sector. Work conducted within the OECD Space Forum will contribute to common definitions of space sector segmentation between upstream, downstream, and space-related segments. Comparisons between countries will then be possible.

Measuring the impact on the space-based Earth observation services ecosystem: involvement of policy makers in decisions related to the development of new satellites is a key indicator of the impact of space-based Earth observation services on their work. The Copernicus program is a major achievement of dialogue and partnership between policy makers, space agencies, scientific communities, and industrial partners. A public demand for geospatial information has been structured. The motivation of policy makers to use Sentinel data for public policies within the core services[12] is a key indicator and a trigger to develop an ecosystem of space-based Earth observation downstream services.

The French *Boosters* initiative aims to develop the use of space tools. By benefiting from the digital economy leverage, this initiative paves the way toward the development of flourishing new commercial services.

[12]Land monitoring, marine monitoring, atmosphere monitoring, emergency management, security, and climate change.

Regularly mapping the state of the art, CNES has organized itself to provide stakeholders with pertinent surveys of the downstream space-based Earth observation sector.

Providing opportunities for satellite Earth observation through the *NewSpace* context: new actors are entering the space sector as it has been identified as a promising economic domain. Coming from the digital economy, these actors are investing (or motivating venture capitalists to invest) in satellite Earth observation constellations, overthrowing the established order. Between 2014 and 2016, approximately 15 space Earth observation constellation projects were announced. Space agencies' free and open access data policies are facilitating the use of space Earth observation data for all. The challenge of using space-based Earth observation data has shifted from data accessibility to data dissemination and services. In these domains, new ICT players are leading the way. With their mastery of cloud-based hosting and big data analytics, new space actors are challenging traditional Earth observation service providers by democratizing the use of space and embedding space-based Earth observation information with other sources of information, making it difficult to evaluate the contribution and value of space-based Earth observation. As many services are turned into digital apps, the benefit assessment of space-based Earth observation will face new challenges.

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Author Biography

Murielle Lafaye is a foresight and economic impact expert at France's Centre National d'Études Spatiales (CNES) in the new Directorate of Innovation, Applications, and Science. Murielle has 18 years of experience in space-based downstream services development for various societal benefit areas (SBAs), such as health, agriculture, natural hazards and risk management, and overseas challenges. In her position at the Directorate of Strategy and Programs, Murielle was the point of contact with French ministries responsible for overseeing the overseas departments and territories of France, health, agriculture, and the digital economy. Her dual background in program management and business development involved her in the definition and implementation of the "Boosters" initiative to facilitate access to space data and accelerate space business within the frame of the digital economy. Fond of anticipating societal needs and space-based

services, Murielle is the coinventor of the CNES patent on tele-epidemiology. She has promoted the use of space for health in the frame of WHO, the Committee on Earth Observation Satellites (CEOS), and the Group on Earth Observations (GEO) as co-chair of the health SBA. In her new position, Murielle develops comprehensive scenarios to anticipate new trends for innovation and the space economy, in cooperation with policy makers, social scientists, digital economy stakeholders, and the space community in the frame of international organizations, the European Space Agency (ESA), and the OECD Space Forum.