EUROPEAN COMMISSION

EUSPA

Conceptual Framework for the assessment of the benefits from the EU Space Programme

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1 Introduction

1.1 Objective of this document

The design, deployment and implementation of the EU Space Programme, including the provision of EU space services supported by the different components of the Programme, are associated with a range of economic and societal benefits, generated not only for the industry developing systems, components and services upstream and downstream, but thanks to the use of space services in a plethora of space-enabled application sectors, which generate benefits for their users as well as positive spill over effects, including on the environment, public safety and many other dimensions.

As recommended by the European Court of Auditors (ECA), **to estimate economic and societal <u>benefits</u> of the EU Space Programme** more consistently, **a conceptual framework is needed**[1]. The design of such framework, designed to enable harmonising different assessments of benefits of the programmes themselves, should involve in the process other stakeholders such as the OECD, the ESA and Member States.

The objective of this document is **to present the conceptual framework for the assessment of the benefits from the EU Space Programme**, developed to answer to ECA recommendations, including the necessary elements for the application of the conceptual framework by space economy practitioners.

The conceptual framework has been developed under the coordination of the European Commission and the European Agency for Space Programme, implementing the comments from the Joint Research Centre, Eurostat, the European Space Agency, the Organisation for Economic Co-operation and Development (OECD), EU Member States, international institutions such as the US Bureau of Economic Affairs and other space practitioners.

1.2 The EU Space Programme

Over the past 20 years, the European Union has been committed to creating an EU Space Programme and infrastructure that is competitive, innovative and that delivers real benefits to citizens and business alike. The EU Space Programme is implemented in close cooperation with the EU Member States, the European Union Agency for the Space Programme (EUSPA), the European Space Agency (ESA), EUMETSAT and many other stakeholders with the aim to deliver unique services in satellite navigation, Earth observation and telecommunications, and strengthening both the upstream and downstream sectors.

The EU Space Programme is composed by the following **flagship components**: **Galileo**, the European civil global navigation satellite system (GNSS) featuring a range of services to serve a multitude of applications and users; **EGNOS**, the European Geostationary Navigation Overlay Service: Europe's regional satellite-based augmentation system (SBAS) that is used to improve the performance of GNSS and **Copernicus**, the European Earth Observation (EO) system supporting the management of the environment, helping to mitigate the effects of climate change and ensuring safety and civil security.

[1] ECA (2021). Special Report EU space programmes Galileo and Copernicus: services launched, but the uptake needs a further boost. Special Report No 07/2021: EU space programmes Galileo and Copernicus (europa.eu)

Further, additional components include **GOVSATCOM**, a satellite communications service under civil and governmental control[2]; and **SSA²** (Space Situational Awareness), providing comprehensive knowledge and understanding about space hazards[3]. In 2023, the European Union announced a third flagship European space project: **IRIS**, Europe's new Infrastructure for Resilience, Interconnection and Security by Satellites.[4] Below a more detailed description of each **component** is provided[5]:

- **Copernicus**: the European Union's Earth Observation (EO) programme which monitors our Earth for the benefit of all European citizens. The programme provides information services based on Earth observation data from satellites and data from Earth and it supports the management of the environment, helps to mitigate the effects of climate change and ensures safety and civil security across Europe.
- **Galileo:** a Global Navigation Satellite System (GNSS) under civil control and based on a constellation of satellites and a network of ground stations. It offers positioning, navigation, and timing services, as well as integrates the needs and requirements of security to numerous EU economic sectors such as transport and agriculture to border management and search and rescue[6].
- **EGNOS:** the European Geostationary Navigation Overlay Service Europe's a reliable navigation signal that improves the navigation services to aviation, maritime and land-based users in over 30+ countries.
- **GOVSATCOM:** the purpose of this programme is to provide secure and cost-efficient communications capabilities to security and safety critical missions as well as operations managed by the European Union and its Member States, including national security actors and EU Agencies and institutions. It aims to protect critical infrastructures, support surveillance and crisis management, as well as enable high-speed broadband everywhere in Europe.
- **SSA (Space Situational Awareness):** an essential component of the EU Space Programme. By providing comprehensive knowledge and understanding about space hazards, SSA plays a key role in ensuring the safety and security of the European economies, societies and citizens who rely on space-based capabilities and applications such as communication, navigation, and observation applications. SSA mitigates the risk of a collision between space assets – including EU ones – and other spacecraft and debris.
- **IRIS²**: this programme, whose infrastructure will be based upon, integrate, and complement the infrastructure developed for the purposes of the of the GOVSATCOM component, aims to protect critical infrastructures, support surveillance and crisis management, enable high-speed broadband to best anticipate future challenges, as well the access to secure and cost-effective satellite communications services, for governmental communications and commercial use. It will provide connectivity to whole Europe, including areas that do not currently benefit from broadband Internet, and the whole of Africa[7].

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[2] EU Space Programme (europa.eu) and Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021, establishing the Union Space Programme and the European Union Agency for the Space Programme

[3] Ibid.

[4] EU Space Programme (europa.eu) and Regulation (EU) 2023/588 of the European Parliament and of the Council of 15 March 2023 establishing the Union Secure Connectivity Programme for the period 2023-2027

[5] EU Space Programme (europa.eu) and https://defence-industry-space.ec.europa.eu/eu-space-policy/iris2_en

[6] Information on Galileo services can be accessed on the Galileo Service Centre website https://www.gsc-europa.eu/galileo/services

[7] https://defence-industry-space.ec.europa.eu/eu-space-policy/iris2_en and Regulation (EU) 2023/588 of the European Parliament and of the Council of 15 March 2023 establishing the Union Secure Connectivity Programme for the period 2023-2027.

1.3 Benefit generation across the space economy, end users and the society

Based on the definition provided by the OECD[8], the **space economy** consists of the full range of space-related activities that create value to human beings. Value can be created by activities of exploration, research, as well as understanding of, management, and use of space. Hence, its scope "*includes all public and private actors involved in developing, providing, and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society*"[9]. The OECD categorises the space economy into three sectors:

- **Upstream:** the scientific and technological foundations of space programmes (including for example fundamental and applied research; scientific and engineering support; dedicated ancillary services (e.g., insurance); supply of materials and components; design and manufacturing of space equipment and subsystems; integration and supply of full systems; space launch);
- **Downstream**: from the space infrastructure operations to "down-to-earth" products and services that directly rely on space data and signals to operate and function. These include, in the OECD definitions, operations of space and ground systems; supply of devices and products supporting consumer markets (e.g., GNSS-enabled devices, set-top boxes, selected GIS); supply of services supporting consumer markets (such as satellite television broadcast);
- **Space derived activities:** these are derived or induced from space activities but are not dependent on them to function. Such activities include, but are not limited to, technology transfers to various sectors, including automotive, medical, etc. sectors, as well as the use of space enabled services.

This conceptual framework refers to the categorisation of the OECD in its **full and most comprehensive scope**, in particular when it comes to downstream and space derived activities, to enable capturing not only the benefits produced for the suppliers active in the space economy, but also those generated among users and the society. To this end, the conceptual framework refers to the concept of **space-enabled** (downstream) **applications** as relevant part of the space derived activities.

Although the concept of space-enabled applications has been widely referred to in the EU space policy and Programme, a universal definition for space-enabled applications does not exist. We propose to adopt the following in this conceptual framework:

*"**Space-enabled applications** are applications that use data and information from space-based systems for their functionality to serve a specific purpose, directly or in combination with other data, software or hardware,[10]"*

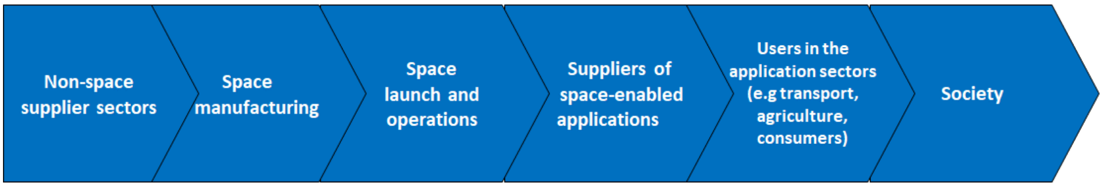
[8] OECD Handbook on Measuring the Space Economy, 2nd Edition

[9] OECD Handbook on Measuring the Space Economy, 1st and 2nd Edition.

[10] The relevant information depends on the specific space system enabling the application. As selected examples, GNSS-enabled applications typically make use of position, velocity and timing information, while Earth Observation-enabled applications leverage observations of the Earth's surface and atmosphere via space remote sensing instruments.

In synthesis, any conceptual framework aiming to fully capture the benefits of EU (or other) space programmes *should take into full account the scope of the space economy, including the landscape of space-enabled applications and their impacts produced on users in the relevant application sectors* (as selected examples, smartphone users, farmers, transport operators and drivers), *as well as on the society as a whole*, as depicted in the figure below.

Figure 1: Conceptual framework: relevant ecosystem for space impacts and benefits



1.3.1 Benefits for suppliers

The EU Space Programme, similar to other space programmes, is implemented through a mix of different activities, with different objectives and modes of implementation. Within each programme component (see the list above), activities are classified into four distinct, but partly concurrent, phases, namely[11]:

1. **Definition phase**: defining the programme component and its technical parameters,
2. **Development and validation phase**: developing and validating the assets required to deliver the service(s) of the component.
3. **Deployment phase**: the manufacture and deployment of space- and ground-based assets to the required scale, and
4. **Exploitation phase**: the development of equipment and capabilities to allow the wider economy to use and benefit from the services provided by the EU Space Programme.

Suppliers in the space economy are important stakeholders across all phases, from contributing to the **definition phase** through feasibility studies and costs assessments, through contracting in the **development and validation** phase, where the agreed system designs are developed and tested. The **deployment phase** involves sizeable industrial contracts (procured through ESA) to build the infrastructure required in space and on the ground for the programme component to deliver the defined space service. The vast majority of these activities are undertaken by the upstream space industry and academia. The **exploitation phase** is more geared towards the downstream industry, which generates the link between end users and assets thanks to the provision of space-enabled applications.

The space economy benefits from the existence of the EU Space Programme through the **direct funding** it provides to direct contractors and to the wider supply chain, whereby **R&D** is undertaken, and **jobs** and **GVA** are **supported**.

Additionally, the organisations in the space economy benefit from a long-standing and committed EU Space Programme as this allows organisations to plan R&D efforts with the confidence that the infrastructure their offering relies on will be available for a long period of time. Thus, demand from the EU Space Programme helps catalyse investment in space technologies both for use within the programme and through **spillovers** to the rest of the economy (terrestrial or space). These spillovers

[11] See e.g., Briefing European Parliamentary Research Service (europa.eu)

include **market creation** benefits for downstream **suppliers of space-enabled applications**, as the uptake of EU space services can increase the overall size of the downstream market.

1.3.2 Benefits for downstream users, the public sector and the society

The suppliers in the space economy serve a range of users upstream and downstream, up to final consumers, with all users benefitting from the operation of the relevant space applications. Therefore, the following elements are also relevant for the conceptualization of the benefits from space programmes:

- **Users in the application segments**: the space-related products and services often get embedded into products, systems, and processes, **adopted by "non-space" users** (smartphone apps leveraging GNSS data, insurance processes leveraging Earth Observation imagery for risk assessment, governmental users requiring secure communication, …);
- **Citizens and society**: the **applications of space, through their use and operation, ultimately affect "non-users",** i.e., citizens and the society. As examples, GNSS-enabled navigation solutions contribute to the reduction of emissions, the time drivers saved in traffic jams, whereas safety-of-life applications in several transport modes contribute to saving lives. Similarly, Earth Observation services and data help achieve societal benefits, e.g., helping meeting air pollution targets, or providing immediate information when disasters occur.
- **Public sector**: civil servants of space faring nations, as well as the European Commission and its Agencies in the EU, are employed to operate the systems and the related activities. In Europe, governments may employ civil servants specifically to manage the Member State's relations with the EU Space Programme. As a consequence, benefits e.g., in terms of employment are enjoyed in the public sector.

Looking to the example of the European Union, the aspects above are well recognised in its Space Policy[12], whose role is indeed to use space for the achievement of EU's political priorities, including fighting climate change (European Green Deal[13]), stimulating technological advances and innovation (a Europe fit for the digital age[14]), and providing, more in general, socio-economic benefits to citizens (Promoting our European way of life[15]), as well as reinforcing Europe's role at geopolitical level (a Stronger Europe in the World[16]).

As the benefits for users and the society are produced by the use of space services and data in downstream application sectors[17], a thorough understanding of the space-enabled applications is fundamental. The application segments for the main components of the EU Space Programme are covered in the next section.

[12] https://defence-industry-space.ec.europa.eu/eu-space-policy_en

[13] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[14] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_en

[15] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/promoting-our-european-way-life_en

[16] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/stronger-europe-world_en

[17] For example, environmental externalities from the reduction of pollution can be achieved thanks to space solutions enabling to optimise and reduce the use of pesticides.

1.3.3 Relevant applications and segments of EU Space services

The EU Space Programme is a major enabler in the downstream space-enabled application market. It is important to stress that the socio-economic benefits of the services, considered per se, is equal to zero, unless such services are put at use for a specific purpose or **application**. As such, applications represent an essential element of the conceptual framework. As explained in the previous sections, the economy and the society increasingly rely on space-enabled applications, which is reflected in their growing diversity. To manage the complexity caused by the high number of applications, it is advisable to categorise such applications into verticals, or **market segments**, in which the applications are clustered based on homogeneous groups of target uses and/or intended users.

By looking to, describing and analysing how space services and data are leveraged on by the solutions of suppliers, which are in turn adopted by users to achieve operational objectives and generate impacts, **investigating applications** has the advantage of **enabling to explore pervasively** the generation of **benefits,** both in terms of **generation of markets** for downstream suppliers, positive **impacts for users,** and **externalities for the society.**

Possible downsides, connected to such accuracy and pervasiveness, include the associated **resourcing.** Moreover, since the approach relies on the investigation of real-world cases of use, achieving **exhaustiveness is challenging**, since technical and market innovation continuously leads to new ways of embedding and use space data and services.

To help address those challenges, existing downstream market segmentations and taxonomies of applications are extremely valuable. The figure below shows, as an illustrative example, the EU conceptualization defined in the GNSS and EO Market Report, issue 2, in terms of key application segment for Galileo and EGNOS, as well as Copernicus[18].

Table 1: Application segments of the EU Space Programme for EGNOS & Galileo and Copernicus

	EGNOS and Galileo	Copernicus
Agriculture	x	x
Aviation and drones	x	x
Climate, environment and biodiversity	x	x
Consumer solutions, tourism and health	x	x
Emergency management and humanitarian aid	x	x
Energy and raw materials	x	x
Fisheries and aquaculture	x	x
Forestry	x	x
Infrastructure	x	x
Insurance and finance	x	x
Maritime and inland waterways	x	x
Rail	x	x
Road and automotive	x	x
Urban development and cultural heritage	x	x
Space	x	

Note: updated information on the relevance of EU Space Programme for the relevant application segments can be found at: https://www.euspa.europa.eu/european-space/euspace-market/gnss-market/eo-gnss-market-report

Further examples at application level are provided in Annex 6 for the relevant sub-segments and application areas of EGNOS and Galileo and Copernicus.

[18] By covering only GNSS and EO, the conceptualisation is not exhaustive for all the components of the EU space programme. Moreover, it is not exhaustive in terms of application domains, since technical and market innovation continuously leads to new ways of embedding and use space data and services. Moreover, only applications where the use of solutions involves financial transactions are covered by the taxonomy, which excludes some of the applications used by governmental organisations.

1.4 The need for a conceptual framework to evaluate the benefit of the EU Space Programme

As explained in the section above, the provision of EU space services is associated with a range of economic and societal benefits, deriving not only from the upstream and the downstream segments of space, but also from the use of space in a plethora of space-enabled application sectors, which generates benefits for the users, well as positive impacts on the environment, public safety and many other dimensions.

At the same time, the deployment and operation of the EU satellite systems entails significant and long-term costs for the EU budget. From the start of the programmes until the end of 2020, total EU expenditure for Copernicus, Galileo and EGNOS amounted to more than €18 billion[19].

As recommended by the European Court of Auditors, **to estimate economic and societal benefits of the EU Space Programme more consistently, a conceptual framework is needed**[20]. The design of such framework, designed to enable harmonising different assessments of benefits of the programmes themselves, should involve in the process other stakeholders such as the OECD, the ESA and Member States. The **programme components in scope** include Galileo, EGNOS and Copernicus, in line with the focus of ECA Special Report. The conceptual framework could also be applied, through dedicated extensions to capture the related specificities, to the other components of the EU Space Programme, including GOVSATCOM, IRIS^2 and SSA.

While different definitions exist, a conceptual framework is considered here as an intellectual structure [framework] for an idea [concept] or set of ideas or principles that exists for a purpose[21]. In this case, we define a conceptual framework for measuring the benefits of space programmes *as a structure of ideas or principles to appraise the benefits of space programmes not only across the whole spectrum of the space economy, but also considering the socioeconomic impact that space-enabled applications produce on the users and on the society as a whole*.

In the absence of an established conceptual framework and taking into account that the information required to conduct space-related impact assessments is generally not readily available[22], **it has proven challenging to date to consistently estimate benefits from space services, as well as to compare them to other economic sectors or devise a cost-benefit analysis of the space programmes**.

This resonates with the challenges and areas for further development of the two key reference documents of this conceptual framework, the OECD Handbook on Measuring the Space Economy (2nd edition) and the Better Regulation Toolbox[23]:

- The **OECD Handbook** provides a comprehensive review of the existing approaches for the assessment of impacts from space activities and the space economy. However, it also acknowledges that space economy impact assessment remains a challenging field. Overall, the

[19] ECA (2021). Special Report EU space programmes Galileo and Copernicus: services launched, but the uptake needs a further boost. Special Report No 07/2021: EU space programmes Galileo and Copernicus (europa.eu)

[20] Ibid.

[21] See explication of the purpose in Section 1.2.

[22] OECD Handbook on measuring the space economy, 2nd edition.

[23] A comprehensive review of relevant literature is included in Annex 5.

results of many impact assessments conducted in the sector tend not to be robust over time, comparable with other sectors or across countries. The information required to conduct space economy impact assessments is generally not readily available and is often gathered on a case-by-case basis. Information is particularly scarce with regards to the non-market effects of space activities. As a result, space economy impact assessments, tend to be highly subjective and lack coherence with other areas. Accordingly, the OECD Handbook recommends developing overall results-oriented evaluation frameworks supported by adequate resources, reinforce efforts in the collection of space economy statistics to improve impact assessments and document and share methodologies widely.

- The **Better Regulation guidelines** and **toolbox**[24], set out requirements for policy cycles that aim to help design EU policies, laws and programmes. This includes (but is not limited to) establishing regulatory instruments such as evaluations, fitness checks, impact assessments, and input from stakeholders. These instruments are used to create policy initiatives that achieve their stated objectives, including by measuring ex-ante and ex-post policies or programmes in terms of relevance, coherence, complementarity, EU added value and, importantly, efficiency and effectiveness. The Better Regulation Toolbox also specify methodologies for analysing impacts (including benefits and costs) in impact assessments, evaluations, and fitness checks[25]. However, the guidelines and toolbox alone do not specify the methods to be adopted for specific sectors, so to ensure the comparability of different studies.

By creating an explicit foundation from which further work expands upon, the conceptual framework for estimating the benefits of the EU Space Programme seeks to address the challenges and implement the recommendations outlined in its key references, including by defining a consistent methodology for appraising such benefits, ensuring compatibility across time. The use of the conceptual framework, leveraging the elements outlined in the OECD Handbook on Measuring the Space Economy, and in complement with the 'Better Regulation' Guidelines and Toolbox, aims to ensure efficiency and consistency across the entire EU Space policy cycle, as well as sound assessment of the return on the investment.

1.5 Key elements of a conceptual framework for estimating space benefits

Conceptual frameworks are created under the belief that the "provision of enhanced information will improve decision-making" or allow objective assessment of outcomes. Conceptual frameworks are widely used both implicitly and explicitly by organisations of all types. Each successful conceptual framework is highly specific to its context: the scope of what is being measured, the methodology of how this is carried out, the stakeholders who validate results, and the steps to achieve them are all fundamentally tied to the subject of a given framework.

When referring to a "conceptual framework for estimating the benefits of EU space programmes", as defined in ECA Special Report[26], the notion of a conceptual framework implies the definition of the

[24] The Better Regulation guidelines include the EU impact assessment guidelines (which describe *when*, *why*, and *how* an impact assessment should be prepared) as well as the Better Regulation toolbox, offering guidance, tips, and best practices for implementing the Better Regulation guidelines.

[25] See Better Regulation Toolbox 2023, Chapter 8, in particular Tools #56, #57, #60, #63, and #68.

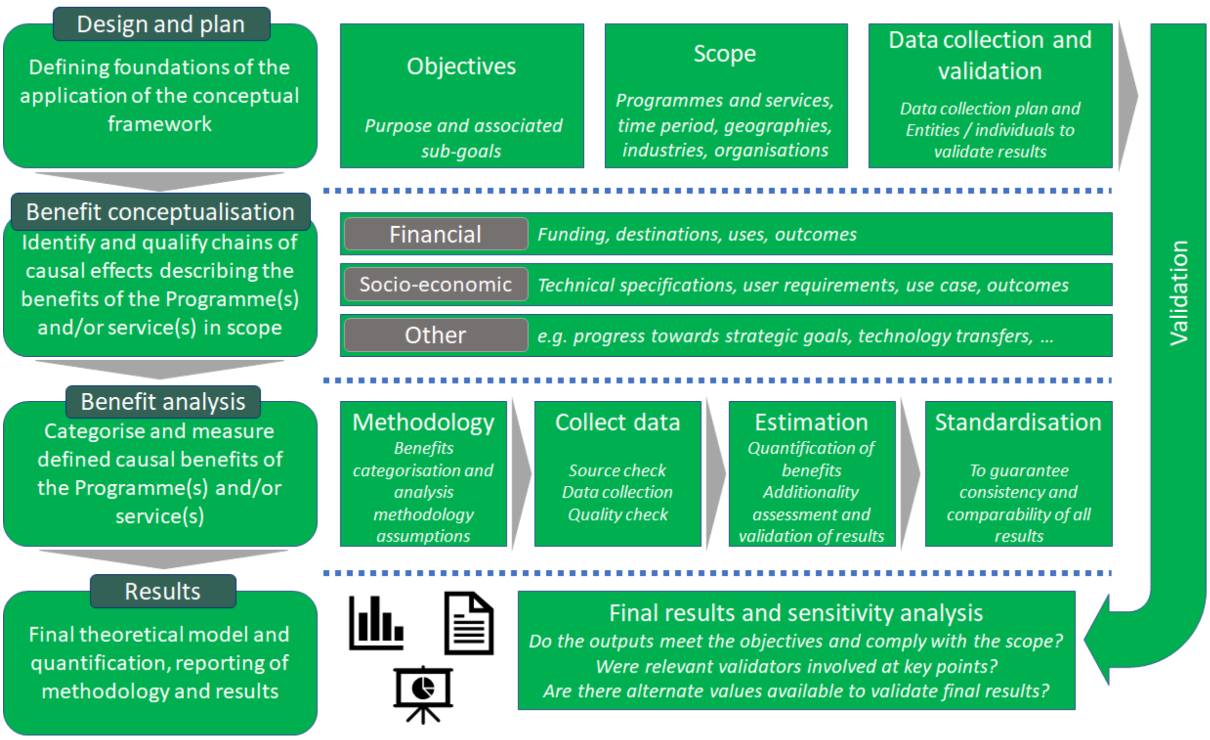
[26] European Court of Auditors, Special Report No 07/2021: EU space programmes Galileo and Copernicus

interrelations (**or chains of causal effects**) that connect the launch and operation of the **EU Space Programme components** (and the services that are supported by these components) with the impacts and **benefits** that these generate, on the **space economy and beyond**.

From a more methodological perspective, the process of laying down, adopting and then applying the conceptual framework to estimate benefits entails a series of steps and elements, which are also depicted in the figure below:

- **Design and plan,** defining the foundations of the conceptual framework, including the definition of the objectives, the scope (including but not limited to the relevant space programme components and services, the geographical scope and the time period of the analysis) and the data collection and validation plan of the framework.
- **Benefit conceptualisation,** identifying the main <u>interrelations (i.e., chains of causal effects)</u> that serve to identify the impacts and benefits of the EU Space Programme;
- **Benefit analysis,** categorising and measuring the benefits of the programme based on the defined methodology, data input collection, valuation and standardization;
- **Results,** outlining the assessment and sizing of the <u>benefits</u> produced by the Space Programme and/or service under analysis.

Figure 2: Key elements of the conceptual framework



Each of these elements represent key pillars of the conceptual framework itself and how they can be used to implement the framework for a specific objective are further detailed in the next section.

1.6 How to use the conceptual framework

The conceptual framework is designed to be used by practitioners to assess and determine the benefits of the EU or other space programmes, either adopting a comprehensive approach or focusing on specific programme components, services or applications.

As mentioned above, it has proven challenging to date to consistently estimate benefits from space services, as well as to compare them to other economic sectors or devise a cost-benefit analysis of the space programmes, largely due to the fact that the information required to conduct assessments of benefits from space programmes and activities is generally not readily available.

While the conceptual framework is designed to address allow for higher transparency and comparability of results on benefit assessment, users are expected to apply its principles with common sense and based on available resources.

Of particular importance, depending on available resources, is the **level of exhaustiveness** targeted. In particular, due to the constant evolution of space services and innovation at application level, achieving full exhaustiveness is currently hardly feasible.

To ensure a sound and coherent implementation of the framework, the following suggestions are presented for implementing the framework:

- Clearly outline the **design and plan** (described more into details in Section 2 below), in particular when it comes to the definition of the objectives of the specific implementation of the framework: the defined scope and the ambition of the data collection plan.
- Before moving to the quantification, prioritise the **achievement of a qualitative understanding** of **how benefits** are generated, as this is indispensable to ensure the soundness and validity of quantitative results. The proposed approach based on **chains of causal effects**, outlined in Section 3, provides a valuable resource to develop such qualitative understanding, through a streamlined and modular logic structure.
- Move on to the **quantification of the benefits**. Once the chains of causal effects are outlined, the logic elements identified and their relationship explained, it is possible to implement the modelling approaches suggested in this framework to express them in quantitative terms, as explained in Section 4. While doing this, it should be considered that **models are always a simplification of the reality**, and **different levels of complexity in the quantification methodology and of accuracy in the quantifications are possible,** depending on the ambition of the objectives, the sought exhaustiveness, as well as available resources and timeframe. Independently from the complexity of the methodologies adopted, a rigorous approach in the assessment, for example related to the determination of counterfactuals and avoidance of double counting, should always be adopted.
- **Report on the results,** thoroughly documenting not only the outputs, but also the approach and sources, to enable effective validation and achieve the necessary transparency. This enables to ensure the soundness of the results and their comparability. Results should always be validated before disclosing them as final, with sensitivity analyses strongly advised for quantification elements exhibiting low underlying data reliability and/or high impact on the estimated benefits.

2 Design and plan

This section outlines the **key elements required to design and plan** the implementation of the Conceptual Framework to estimate the benefits of a space programme (including the EU Space Programme), specific components, or related services, for all or selected applications. These elements, refer to the objectives of the application of the framework, the scope, and the validators of the logic and outputs.

2.1 Objectives

A framework for estimating the economic and societal benefits of the EU Space Programme must capture within its methodology, principles, and interrelations, the specificities of space in terms of being woven into the fabric of modern technology and hence the life of people across the globe.

Due precisely to this wide impact, which encompasses nations, space agencies, industries, and individuals across the globe, the value of alignment on such a framework is high. With a common framework for measurement, socioeconomic benefits across the entire space industry, the users and the society can be reliably tracked, compared, and better understood.

More specifically, the Conceptual Framework can be used for the following purposes:

1. **Ex-post** [i.e., historical] assessment of the benefits / impacts of the EU Space Programme;
2. **Ex-ante** [i.e., forward-looking] analysis of future impacts as well as possible alternatives and policy questions for the EU Space Programme evolution;
3. **Put benefits in perspective**, relative to the costs of the EU Space Programme;
4. Additionally, to provide a **reference guideline for the assessment of benefits** related to space-related initiatives, programmes, economic activities, or policies.

2.2 Scope

An effectively defined scope delimits the boundaries of the assessment, such as the industries and users that *could be* scrutinised as part of the conceptual framework, and the further decision on which of these *are to actually be included*. The scope will be a compromise between the level of ambition and the budgetary envelope decided for the assessment to which this conceptual framework is applied.

In the context of the EU Space Programme conceptual framework, important examples of scope definition include the timeline covered in the analysis, geographies, and entities to include as stakeholders. Other important examples include which EU Space Programme components, and for what part of their lifetimes and which technical capabilities they possess, are to be included in the framework. In order to be comprehensive, the conceptual framework development should be defined in such a way as to allow application to different components of the EU Space Programme (specifically Galileo, EGNOS, Copernicus, GOVSATCOM, SSA and IRIS[2]) and related services, as only this will ensure the conceptual framework is widely applied and becomes an industry norm[27].

At the same time, the conceptual framework, taking into account the intended objective of its application, must be scalable in order to enable the assessment of the following levels:

- **A space programme as a whole**, as it can be the case for the application of the framework to the entire EU Space Programme;
- **One or more components of a space programme**, for example Galileo, EGNOS or Copernicus. The Conceptual Framework should define clearly whether all these use cases are in scope, or any are omitted for any reason. Note: *being the objective of this document to be a public reference point for space benefits assessments, it is proposed to focus on civil applications, including for governmental use, excluding dual-use, and military related ones[28].*
- One or **more services or data types** or features included within a specific component, for example the Open Service or the High Accuracy Service of Galileo, the Copernicus Land Monitoring Service, or the data provided by one of the Sentinels;

Based on the levels above, the scope in terms of relevant applications is also to be defined based on the objective. At the wider level, all relevant segments of application and the related detailed applications should be included. Vice versa, for specific assignments the framework should be applicable to specific segments or even more narrowly to selected **space-enabled applications**, since understanding how the EU Space Programme is used on Earth is essential for estimating the impact thereof.

Taking also into account the specific application of the framework, the scope of the conceptual framework should also be defined in terms of:

- **Geographic scope:** The Conceptual Framework should primarily ensure that its geographic scope permits an estimated allocation of all the socio-economic benefits [upstream, downstream, users] accruing to the EU. In general, it is appropriate to mirror the scope of costs in the scope of benefits, even though when indirect benefits are considered, a global approach could be adopted [29]. In the case of EU Space Programme components and services, different geographic scopes may be appropriate for the purpose of estimating the EU return-on-investment of each component or service. Based on the availability of the necessary data, a wider or more specific geographic focus could also be applied, e.g., to assess benefits for a specific country or to assess global benefits[30].
- **Time period of analysis**: The time period depends on the specific application of the conceptual framework. A starting point is typically the date of the initial feasibility of each of the programme, components and/or services in scope (i.e., the final go/no-go decision point). In the case of assessing the EU Space Programme or relevant subsets, the end points may be determined taking into account the EU funding cycle and, as examples, conclude at the end of the current Multiannual Financial Framework (MFF), at the end of a subsequent MFF, at mid-points to support interim evaluations, or when the infrastructure commissioned to date has

[27] To see how these seemingly simple examples can be contentious, attention should be paid to the widely used space economy definition provided in the OECD handbook that is an imperfect match to other definitions (especially for US space economy). Such discrepancies can cause significant divergences in results and make it difficult to reconcile the findings of different reports based on frameworks with different scopes.

[28] This is due to the specificities of benefit assessment related to non-civilian applications. Subject to specific adjustments to consider such specificities, the conceptual framework might also be applied to non-civilian services and applications.

[29] Options therefore include EU, EU plus states allied to EU Space Programmes (Norway and Switzerland), EU plus Member States of ESA not in the EU (Norway, Switzerland, and UK). A global perspective could possibly be applied for indirect benefits (consideration especially pertinent when considering environmental impact)

[30] In case of partially missing data, proxies could be uses (e.g., GDP, population, etc.) to calculate benefits for which data is available only at wider geographical scope.

reached end-of-life or other specific considerations. The decision on an appropriate timeline for evaluation needs to factor any legacy benefits into the analysis. Benefit may continue to arise far into the future (e.g., from R&D funding), so it is necessary to consider any final values within the analysis.

- **Beneficiaries of EU Space Programme**: The EU Space Programme delivers goods and services that benefit a wide range of economic agents. To ensure the impact analyses resulting from the application of the conceptual framework are comprehensive, it is necessary to identify all those economic agents. In the space domain, there are generally four groups of beneficiaries: academic researchers, the space industry (upstream and downstream), users, and non-users or the population as a whole. Users are further divided into commercial entities that make use of space products or services in their production function, government entities (including super-governmental entities), non-governmental organisations, and the general public (e.g., users of car navigation systems). Academic researchers and the space industry benefit directly from the programme as they receive contracts or funding, while users generally benefit indirectly from the existence of the services provided. Non-users are the beneficiaries that enjoy positive externalities from other agents' use of the outputs of the EU Space Programme and might include drivers that experience less traffic because other road users change their routes in response to live traffic data. The general public benefits from positive environmental externalities from pollution reduction or biodiversity efforts underpinned by space. *It is proposed that all these actors are in scope*[31].

2.3 Data collection and validation plan

The credibility of models rests on the quality of the data and the validity of results. When a specific implementation of the conceptual framework is envisaged, plans for the collection of data and validation of its outcomes, including the identification of relevant stakeholders, should also be defined. The **data collection plan** should detail:

- Which **data should be collected**, taking into account the objectives of the implementation of the conceptual framework, the scope and the data requirements of the steps to estimate the different benefits (see Section 4.2).
- **How the data** will be collected, taking into account a series of factors, including timeframe available, data availability and quality, available resources and the targeted exhaustiveness and accuracy of results. Relevant suggestions and guidelines for data collection are included in the OECD Handbook on Measuring the Space Economy[32] as well as in the better regulation toolbox[33] .
- **Which process will be put in place** to collect the data, including but not limited to aspects such as the definition of who will collect the data, the data acquisition, storage and elaboration processes, the timeframe and dependencies, etc.

The following elements have to be considered for **validation**, along with the relevant stakeholders:

[31] *For the identification of the downstream industry and users, a potential source is the EUSPA EO and GNSS Market Report* https://www.euspa.europa.eu/european-space/euspace-market/gnss-market/eo-gnss-market-report . Several other sources include thematic analyses and taxonomies of use domains, use cases and users. A non-exhaustive list of other sources includes the European Association of Remote Sensing Companies (EARSC), Eurisy, and several commercial providers of space downstream market intelligence.

[32] Notably, for using industry surveys.

[33] See for example Tool #67. Data identification for evaluation and impact assessment.

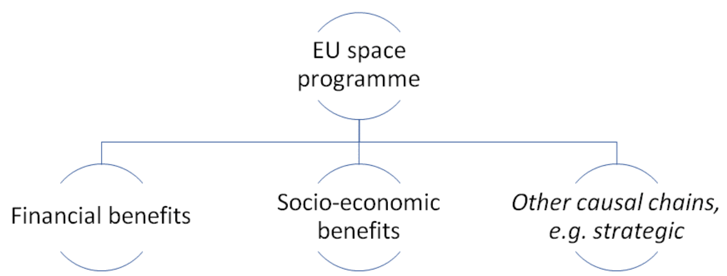
- **Full methodology** applied: the full methodology adopted, from the general logic to the more specific choices, for example related to modelling and quantification.
- **Theory of change:** the assessment of how the given intervention on the space programme and/or relevant subsets, is expected to lead to specific changes. Relevant stakeholders for validation of the theory of change include the programme management, think tanks, the upstream and downstream industry, users, and relevant authorities.
- **Chains of causal effects:** the specific pathways leading from the changes produced by the space programme (and/or relevant subsets) lead to the generation of benefits. Relevant stakeholders for validation include socio-economic assessment experts, the upstream and downstream industry, and users and authorities.
- **Data inputs and assumptions and related limitations:** the data used, the approach to data collection, the estimated soundness and reliability of the data inputs, as well as the assumptions developed to cope with the absence of data, as well as the related limitations and what impact they may have on the results obtained. Relevant stakeholders for validation include data providers, research institutes, industry experts and users.
- **Quantification of outputs:** the results of the quantifications (i.e., the estimation of the benefits) produced and the underlying methodology. All stakeholders involved can be relevant validators of the quantification of outputs.

3 Benefit conceptualisation

The objective of the benefit conceptualisation of the conceptual framework, is to outline and explain the conceptualisation of the benefits from the EU Space Programme, into different categories of benefits which, together, enable a comprehensive appraisal of its socio-economic benefits.

To quantify benefits, it is necessary to understand them first. To this end, and in line with the principle of the Better Regulation Toolbox, the connection between the definition, development, deployment and operation of the Space Programme components and the impacts and benefits that these generate should be developed through **chains of causal effects** (in other terms, detailed chains of cause-and-effect relationship). These can in turn be categorised into financial, socio-economic, and other chains of causal effects.

Figure 3: Key categories of benefits



The chains of causal effects, which together enable to appraise the total socio-economic benefits of the EU Space programme, are outlined in the following sub-sections.

3.1 Chains of causal effects

As mentioned in Sections 1 and 1.5, the notion of a conceptual framework implies the definition of the interrelations connecting the launch and operation of the Space Programme components with the impacts and benefits that these generate. **Chains of causal effects** support this understanding, also setting the limits of what can be measured and what inputs can be considered.

Causal effects define the links between an intervention and the consequence (i.e., the effect) attributable to it[34]. In the context of the assessment and measurement of the benefits from the EU Space Programme, this entails the assessment of how the investment in the Programme, and the technical offerings from the operation of the related components propagate through the economy and society and generate socioeconomic benefits.

[34] See the EU Better Regulation Toolbox, Tool #68.

Moreover, the identification and definition of chains of causal effects are also important for a conceptual framework, as they allow the comparison and cross-checks of how the inputs, activities, and impacts included in the framework's focus relate to one another[35].

The propagation of impacts from inputs through to tangible effects that can be measured is a crucial step to ensure that no effects are missed, and to ensure that there is a valid logical map that explains how impacts are created[36]. Within the conceptual framework of the benefits of EU Space Programmes, three different types of chains of causal effects can be identified[37]:

- **Financial chains of causal effects**, articulating the channels through which financial outlay on the components of the EU Space Programme impacts companies, organisations, and the economy;
- **Socio-economic chains of causal effects**, elaborating how the application and use of data and services provided by EU Space Programme components translates into user utility and positive externalities.
- **Other chains of causal effects**, including, but not limited to, strategic benefits arising e.g., from European autonomy, in particular in the field of technology, and benefits from technology transfers.

3.2 Financial chains of causal effects

Financial chains of causal effects articulate the channels through which financial outlay on the components of the EU Space Programme impacts companies, organisations, and the economy. Benefits of financial chains of causal effects are divided into two broad categories, namely:

1. Those associated with the financial outlay and which support employment and economic activity in the contracting organisations and trickling through to their supply chains. This includes private companies, third sector organisations, and the EU itself. The financial outlay is used both to procure infrastructure and facilities, and to upskill the industry through R&D investments. The benefits occur as a **direct** result of the investment.
2. Those associated with the dynamic impact of the funding, including through knowledge and market spillovers, that arise because organisations funded by the programme generate knowledge and expertise that can be leveraged in the broader market. These **spillover** impacts occur as a result of both procurement of the system(s) and through R&D investment by upskilling industry or demonstration of flight heritage, among other mechanisms.

The financial chains of causal effects may therefore sensibly be split according to the objective of the funding, with two relevant categories to consider: R&D funding, and procurement of goods and services (including from EU agencies).

[35] For example, they can identify whether different space programme services are complementary or rivalrous, or whether impacts are being double counted. On top of this, chains of causal effects can link how the technological services offered by space programmes can benefit the society through better service provision via applications in various industries across the economy.

[36] This step is consistent with the 'Better Regulation' principles of 'comprehensive approach' that mandates that 'considerations should cover all relevant economic, social and environmental impacts, all interested parties and every phase in the policy cycle' – defining chains of causal effects ensures that all relevant impacts are identified and included.

[37] Note: when calculating total benefits, overlaps between benefits, e.g., from financial chains of causal effects and socio-economic of causal effects, need to be addressed to remove double counting. The approach to be adopted is described in Section 4.3.

3.2.1 Funding amounts, sources, and spend destinations

To understand the financial chains of causal effects and the impact of funding, the first step is to capture the full set of Space Programme-relevant funding. In the case of the EU Space Programme, this needs to be sourced from the EU's Multiannual Financial Framework (MFF) and must consider funding lines of the 2021-2027 MFF, covering both procurement and R&D. Note, this list of funding lines is not exhaustive and subject to change as new MFFs are passed.[38]

Within the MFF, **Cluster 1.0.4 Space** is obviously in scope, but challenges remain in analysing and categorising the funding stream, as well as disentangling the different components of the EU Space Programme and the objectives of funding. This will likely also require investigation of the budgets and financial reports of the European Space Agency (ESA), EU agencies (e.g., EUSPA), Copernicus entrusted entities, and other organisations, to ensure the delegated funding from the EU is traced and its objectives and impact can be understood.

Another key funding line in the 2021-2027 MFF is **Cluster 1.0.1 Horizon Europe**, which disperses R&D funding across a wide range of projects and topics. Space (Cluster 4, Destination 5) is the most obvious funding line to be considered from Horizon Europe but given the proliferation of space goods and services across the economy, additional funding lines, e.g., in transport and logistics or environmental resilience, must be evaluated to ensure the full range of space-relevant R&D from Horizon is considered. Additional clusters in Horizon Europe and its successor programmes therefore need to be identified to obtain a full picture of the spending associated with the EU Space Programme.

Having identified and catalogued the full funding of the space programme and the objective of each line of funding, the next step is to map this to a list of funding recipients, referred to as "spend destinations". This is to ensure that any leakage from the EU economy is considered appropriately (if e.g., launch services are purchased from outside the EU then the impact of the funding does not accrue in the EU).

This requires desk-based research to ensure the picture is as accurate and complete as possible. This process would benefit from engagement with the entities involved in the implementation of the EU Space Programme, for validation purposes. Horizon and its predecessors publish detailed databases of grant funding recipients, which would allow the analyst to gain a full picture of where the funding goes[39].

3.2.2 Assessment of funding uses and counterfactual

With the knowledge of the full amount of EU Space Programme expenditure, the specific funding sources, and their destinations, the next step is to analyse in more detail how the funding has been spent. At the company level, this is expected to differ significantly between R&D funding and procurement contracts, and it is important to understand both.

The spending of the funding may be categorised into four different groups, namely: R&D staff, equipment, raw materials or intermediate inputs, and delivery staff. Some of the funding is also expected to generate profit for the company.

[38] Note the MFF includes a wide array of budget lines that have some degree of space programme relevance. For that reason, detailed analysis is required to attribute budget to the space programme, and a detailed explanation and log required to justify decisions. These should also be validated with institutional staff to ensure overlap between perception and reality.

[39] This information is available in the tools, e.g., CORDIS, which are part of the Research and Innovation community platform of the European Commission.

With raw materials or intermediate inputs, it is important to consider whether any of those inputs are imported from outside the European Union, as any such procurement represents leakage from the EU economy and therefore needs to be properly accounted for in the benefits estimation.

Another absolutely critical component of the analysis is the counterfactual, i.e., the situation that would prevail in the absence of the EU Space Programme, and specifically its funding. Only impact **additional** to the counterfactual should be considered in the analysis. Additionality can be broken down into several components:

1. **Deadweight:** where the EU Space Programme replaces other funding on space-related activities (e.g., from ESA or national programmes). This would imply that a proportion of the gross investment made into the EU Space Programme would have otherwise been invested in space through alternative channels and the impact of the funding is therefore less than the gross value.
2. **Displacement:** where the increase in economic activity as a result of funding from the EU Space Programme *displaces* other economic activities. If so, competing activities may suffer a reduction in economic output, which must be considered in the assessment.
3. **Transfers:** if funds are transferred between economic agents without resulting in economic activity these should not be considered in the benefits estimation. If distributional effects arise and need consideration, then transfers ought to be considered as both costs and benefits in the estimation, thus cancelling each other out.
4. **Substitution:** where the EU Space Programme places requirements on the personnel that can be involved in specific activities (e.g., EU eyes, security clearance), which could lead to job losses for staff that are unable to meet such requirements.
5. **Leakage:** where EU Space Programme funding is channelled out of the EU economy, e.g., because inputs are required that cannot be delivered by EU firms. Such inputs may include certain raw materials and intermediate inputs, or specific services such as launch.

All these considerations are necessary to ensure only the additional impact of the EU Space Programme is considered, and that effects that would have occurred in its absence, through alternative channels, are properly accounted for.

3.2.3 Impact on spend destinations

In broad terms, the spending on the EU Space Programme is directed at three different destinations, supporting employment and acquisition of infrastructure and equipment. Each destination has its own objectives of funding and different associated impacts. These are:

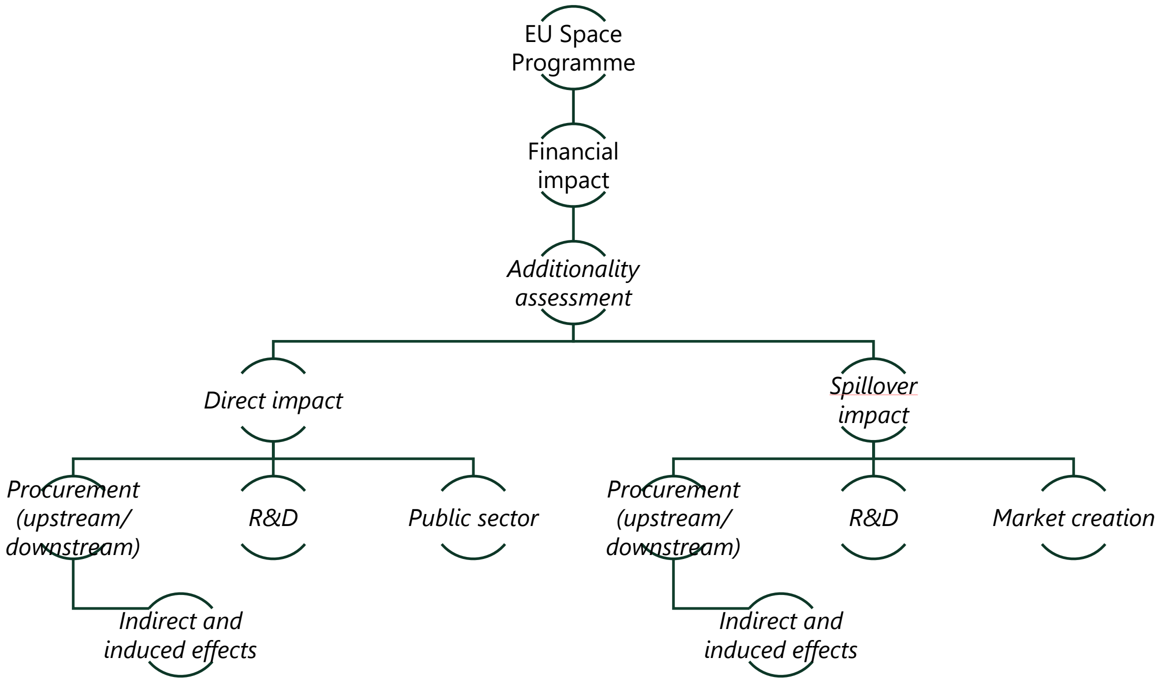
1. **Space manufacturing, launch, and operations**: procurement of the system (in space and ground segment) is generally delivered by firms in the *upstream* industry. These companies may also receive funding from R&D programmes to develop the skills and expertise required to build the system.
2. **Space-enabled applications and applications sectors**: the space applications industry uses the data and signals from space in the products and services they market. These companies predominantly receive R&D-related funding for product and service development. This results in impact on the workforce and IP held by the organisations, dynamic impact through improved competitiveness and resulting improvements in market shares and additional revenue to EU

organisations. Additionally, some specific services are procured by users in the space applications sectors for the improvement of the systems. The line between this downstream end of the space economy and space-enabled applications activities in other parts of the economy is inherently blurred, and it is very likely that R&D funding is provided to end-user organisations. For simplicity, this set of organisations is considered part of the downstream.

3. **Public sector activities**: the third and final destination of funding is internal to the EU system, where civil servants in the European Commission and its Agencies (most notably the European Union Agency for the Space Programme) are employed to operate the system and its related activities. In addition, governments of EU Member States may employ civil servants specifically to manage the Member State's relations with the EU Space Programme.

Figure 4 shows a graphical representation of the financial chains of causal effects and outlines conceptually what types of benefits need to be considered in the analysis. Each block is discussed in more detail in the subsequent sections.

Figure 4: Financial chains of causal effects at EU Space programme level



Direct impact

Direct impacts are those that can be linked directly with the expenditure of the EU Space Programme, where **procurement** contracts or **R&D** grants support employment and gross value-added (GVA) in the organisations that deliver infrastructure and services. The impact trickles through the supply chain and support activities in the organisations supplying to direct contractors or grantees.

Direct impacts are found in both upstream and downstream organisations, where upstream organisations typically concentrate on the delivery of infrastructure and systems while downstream organisations have a greater emphasis on R&D funding-derived activities. Both upstream and downstream organisations rely on a specialised supply chain of organisations within and outside the space economy. When procurement contracts increase the demand for goods and services from contractors and grantees then additional demand is generated in the supply chain for those companies to enable delivery. These supply chain effects are described as **indirect and induced effects.**

To capture the full impact of the EU Space Programme it is also necessary to consider the activities undertaken by the **public sector** as part of the programme. The EU employs staff at Commission and Agency levels and at contributing organisations. Moreover, Member States may undertake activities specific to the EU Space Programme that support employment. It is unlikely that the public sector generates profit through financial spending, so the benefits are likely confined to employment.

Additionality needs to be assessed at all stages of the assessment, with particular emphasis placed on **deadweight**, **displacement**, and **leakage**.

Spillover impact

Both procurement and R&D funding lead to **spillover** impact. **Spillover** impact arises where companies can leverage the expertise, IP, and experience gained from procurement or R&D activities. Such spillovers may arise because the contract or grant has:

1. Resulted in the development of market leading technology.
2. Increased the manufacturing capacity of the contractor.
3. Acted as a 'seal of approval' for the company, because delivery of a major component, subsystem, or system to the EU Space Programmes proves flight heritage, meaning prospective customers consider the product less risky than that of a competitor.

R&D funding supports European space organisations, including its SMEs, in the development of space-based products and services to help the companies improve competitiveness and capture a larger share of the international market. R&D funding through the EU Space Programme can be tailored to a specific purpose or be entirely open to the challenges identified by the industry.

Some of the R&D funding goes to organisations outside of the space industry that make use of space products or services as an end-user. Such organisations benefit from the direct impact on employment and income, as well as potential benefits to their operational efficiencies. Direct benefits are considered a financial benefit while operational efficiencies are classified as **socio-economic benefits** (covered in the next section).

Additionality needs to be assessed at all stages of the assessment of spillover impact, with particular emphasis placed on **deadweight**, **displacement**, and **leakage**.

Additional spillover impact arises because of **market creation** activities undertaken by the European Union (e.g., through EUSPA), where government investment to increase the adoption of space services, and especially those from EU assets, increase the overall size of the downstream market. This effect is interspersed with the more nebulous impact of the EU Space Programme on the availability of space signals and associated existence of the downstream market. For this assessment, it is imperative to analyse the market very carefully, and only attribute to EU assets what is truly additional activity – beyond that which would exist if the EU assets had not been launched.[40]

[40] The HMT Green Book offers detailed guidance on how to undertake such analysis, available here: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government/the-green-book-2020

3.3 Socio-economic chains of causal effects

Socio-economic chains of causal effects articulate how the application and use of data and services provided by EU Space components translates into user utility and positive externalities. The following categories of socio-economic chains of causal effects can be identified based on the type of benefit generated.

1. Those associated with the *user utility* of using the space-enabled products, data, or services. These benefits include savings in terms of costs for consumers (e.g., travel cost reduction) or productivity improvements for businesses (reduction of the use of agricultural inputs for farmers, increase of yield, etc.).
2. The ones determined by *positive externalities* from the use of space, for which no monetary compensation is provided. Example of positive externalities include, among others, environmental benefits (reduction of air and noise pollution, etc.) and safety-related benefits, including the prevention of fatalities, injuries, or accidents[41].

To identify how the space programmes actually generate real-world impacts for potential beneficiaries, it is necessary to identify a comprehensive list of ways on how the technical offerings of the EU space programme components are utilised and what impact this use has, as also who the main users and beneficiaries are. The value chain that is envisioned includes researchers, the upstream industry, the downstream industry, all users, and non-users benefitting indirectly from the offerings.

However, value chains differ significantly between both EU Space Programme components and market segment, or group of applications considered. In the case of the EU space programme framework, it is anticipated that the value chain will need to be presented in **multiple dimensions** to capture specifics across the market and align with previous efforts to create such a value chain definition.

Taking into account those multiple dimensions, **logical chains of causal effects** should be defined, explaining how the relevant services impact the users in the applications of interest. This in turn implies a series of steps, including the assessment of the level of adoption of the application, the definition of the role and contribution of the EU space services within the application, the apportionment of the benefits of the relevant service and the determination and quantification of socio-economic benefits.

3.3.1 Services of the space programme and technical performance

Each of the components of the EU Space programme comprises one or more services, offering different features and addressing different types of users. The **technical performance** of each of the services[42] and data types, is the starting point enabling the potential generation of benefits, as soon as such services and data are adopted and used. A **non-exhaustive** representation of the current services is provided in the table below.

[41] Externalities are relevant and should be estimated independently from their internalization in the economic system. As an example, any reduction of CO_2 emissions enabled by the use of space applications, does produce beneficial impacts on the environment due to reduced contribution to climate change – independently from the market internalization of these CO2 emissions (for example through carbon credits).

[42] E.g., in terms of, horizontal and vertical accuracy, coverage, availability, time to first fix and time of convergence, etc. for satellite navigation services; type of measurement, resolution, revisit time etc. for EO data

Table 2: Services of the EU Space Programme

Programme	Services
Galileo[43]	**Open Service (OS):** Galileo open and free of charge service set up for positioning and timing services. In the future, the Galileo Open Service will also provide Navigation Message Authentication, which will allow the computation of the user position using authenticated data extracted from the navigation message.
	Open Service Navigation Message Authentication (OSNMA): Free access service complementing the OS by delivering authenticated data, assuring users that the received Galileo navigation message is coming from the system itself and has not been modified.
	High Accuracy Service (HAS): A service complementing the OS by providing an additional navigation signal and added-value services in a different frequency band. The HAS signal can be encrypted to control the access to the Galileo HAS services.
	Public Regulated Service (PRS): service restricted to government-authorised users, for sensitive applications that require a high level of service continuity.
	Search and Rescue Service (SAR): Europe's contribution to COSPAS-SARSAT, an international satellite-based search and rescue distress alert detection system.
	Signal Authentication Service (SAS): a service based on the encrypted codes contained in the signals, intended mainly for satellite navigation applications for professional or commercial use
EGNOS[44]	**EGNOS Safety of Life (SoL):** the service provides the most stringent level of signal-in-space performance to all Safety of Life user communities.
	EGNOS Open Service: improves positioning accuracy by correcting error sources affecting GNSS signals intended for a wide range of applications in various domains.
	EDAS: the EGNOS Data Access Service (EDAS) offers ground-based access to EGNOS data through the Internet on a controlled access basis.
Copernicus services[45]	**Atmosphere**: the Copernicus Atmosphere Monitoring Service (CAMS) provides continuous data and information on the Earth's atmospheric composition, in terms of the current situation, forecasts and data records.
	Marine: the Copernicus Marine Environment Monitoring Service (CMEMS) provides regular and systematic reference information on the state, variability and dynamics of the ocean and marine ecosystems.
	Land: the Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover and its changes, land use, vegetation state, the water cycle and energy variables of the Earth's surface to a broad range of users in Europe and across the world.
	Climate change: the Copernicus Climate Change Service (C3S) supports society by providing authoritative information about the past, present, and future climate in Europe and the rest of the world.
	Security: the Copernicus service for Security applications aims to support European Union policies by providing information in response to Europe's security challenges. It improves crisis prevention, preparedness, and response in three key areas: border surveillance, maritime surveillance, and support to EU External Action.
	Emergency: provides all actors involved in the management of natural disasters, man-made emergency situations, and humanitarian crises with timely and accurate geo-spatial information It consists of a mapping component and an early warning component.
Copernicus data[46]	**Sentinel 1:** constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather.
	Sentinel 2: polar-orbiting, multispectral optical, HR imaging. Global coverage in 10 days, in daylight. More frequent possible for emergencies
	Sentinel 3: two-satellite programme for ocean and land observation, to provide continuity to the Envisat missions.
	Sentinel 4: ultraviolet Visible Near-infrared (UVN) spectrometer and data from thermal Infrared Sounder (IRS), on the MTG-Sounder (MTG-S) satellite, to monitor key air quality trace gases and aerosols.
	Sentinel 5: passive grating imaging spectrometer to globally monitor key air quality trace gases and aerosols.
	Sentinel 6: radar altimeter and a microwave radiometer data for high accuracy and high precision sea-surface height measurements.

[43] Evolution studies are ongoing to prepare the first batch of the Galileo second-generation satellites. While on the service level, many activities are ongoing to develop additional services for Galileo, in line with Article 45 of the EU Space Programme Regulation (Regulation (EU) 2021/696). These include an Emergency Warning Satellite Service (EWSS), a timing service and an extension of the SAR Return Link Service capabilities. Up to date information on Galileo services can be found at: https://www.gsc-europa.eu/galileo/services

[44] New services are being deployed, namely a new generation of EGNOS is currently under development. This generation (EGNOS V3) will introduce new services based on multiple frequencies of multiple constellations (GPS, Galileo). Up to date information on EGNOS services can be found at: https://egnos-user-support.essp-sas.eu/

[45] Up to date information on Copernicus services can be found at: https://www.copernicus.eu/en/copernicus-services

[46] Up to date information on Copernicus data can be found at: https://www.copernicus.eu/en/access-data and https://sentinels.copernicus.eu/web/sentinel/home. Note: there is an overlap possible of impacts and benefits from the use of Copernicus Services and Copernicus data, insofar the Services use Sentinel data, together with in-situ data. However, the use of Sentinel data can produce benefits also thanks to its implementation in other services, including those offered by private players.

Programme	Services
GOVSATCOM/IRIS²	Secure, guaranteed, reliable and cost-effective access to SatCom capacities and services for governmental users.

3.3.2 Applications of interest and user requirements

The services and data offered by the components of the EU Space Programme are adopted and ultimately generate benefits, insofar they enable users to satisfy their needs, and more specifically meet the user requirements.

The identification of how the technical offering of the space programmes generates real-world impacts for potential beneficiaries requires the identification of a comprehensive list of ways the technical offering is utilised and the impact this use has.

A **first part** of this consists in the **identification of the relevant space-enabled applications** of the EU Space services. The identification starts from the intended use of the services and should be complemented by market analysis and user consultation activities, to capture also innovative and unexpected uses. Such information is often consolidated in EU and other web resources and publications, including as non-exhaustive examples:

- **EGNOS services**: information on EUSPA website as well as the EGNOS user support portal[47], including the featured success stories;
- **Galileo services**: information from EUSPA website, including the info notes[48] published for the most recent services, as well as ESA resources;
- **Copernicus services**: information from multiple sources, importantly the websites, product catalogues and use cases of the six Copernicus services[49];
- **Copernicus data**: as Copernicus data, together with other EO and non-EO data is combined to serve specific end user needs by EO and information service providers, identifying and determining which EO applications make use of Copernicus is not necessarily straightforward. While case-study resources exist, showcasing selected cases of Copernicus data use for specific purposes[50], the work of exploring the relevant applications is ongoing and it entails exploring the portfolio of service providers (along with the use of taxonomies[51]), followed by investigating the role and added value of Copernicus data in the service architecture.

A second part is developing **a well-developed understanding of user requirements**. These are typically collected and systemised in technical studies related to the various services and are also consolidated in several documents from the European Commission[52] and EUSPA[53]. More specifically, EUSPA runs a systematic consultation process (the User Consultation Platform - UCP) with the community of users of space enabled services.

[47] HOME | EGNOS User Support (essp-sas.eu)

[48] See e.g. Galileo OSNMA Info Note and Galileo HAS Info Note.

[49] See e.g. the website of Copernicus Land Monitoring Service.

[50] See e.g., the Sentinel benefits study - earsc.org/sebs

[51] See e.g., the EARSC Taxonomy eoTAXONOMY - EARSC

European Commission. (2019). 'Expression of User Needs for the Copernicus Programme – Commission staff working document'.

[53] EUSPA. (2021). 'User needs and requirements (*various*)'

The results of the UCP, including the collection and review of user requirements are public and are formalized as User requirement Documents which provide information/data essential not only for the update of the state of the art of such requirements, but also for the release of updated public Reports[54].

3.3.3 Definition of socio-economic chains of causal effects

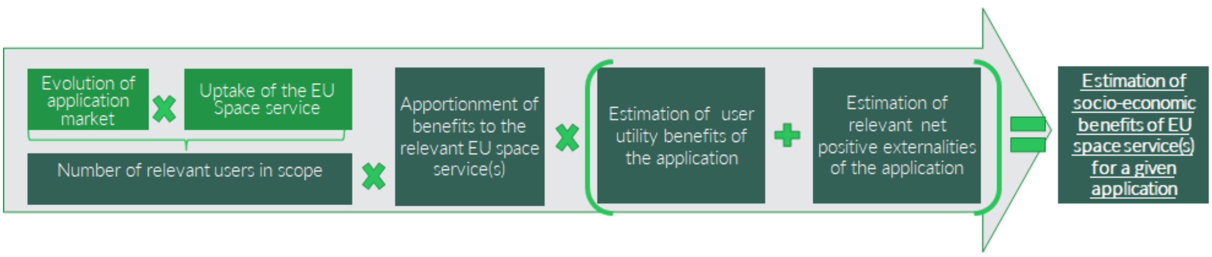
The chains of causal effects for socio-economic benefits explain how the relevant services produce benefits for the users and the society in the applications of interest. As mentioned above, it is important to specify that the services offered by the various components of the EU Space Programme differ considerably in terms of type of data and information made available, the required processing, the frequency of provision of related data, intended and possible uses as well as relevant users. Also, the utility and externalities that the users and the society can derive from the EU Space services can be realized if such services are put at use within an application.

Taking the above into account, at **application level** there are nevertheless a series of elements that represent the building blocks of the socio-economic chains of causal effects:

- The definition of the market size and the evolution of the level of adoption of the relevant application;
- More specifically, the assessment of the uptake of the EU Space service within the application itself, versus alternative services and solutions that could be used as substitutes;
- The apportionment of the benefits of the relevant EU Space service, versus other relevant solutions and components of the application. Within this step, it is of particular importance the definition and assessment of the counterfactual case, i.e., the scenario of the application operating without such service in place.
- The assessment and quantification of the relevant socio-economic benefits of the considered application. This includes:
    - The benefits connected to user utility, i.e., the savings or gains achieved by the users of the space-enabled application;
    - The benefits associated to positive externalities from the use of space-enabled applications.

The key logic interrelations for socio-economic chains of causal effects at application level are depicted in the figure below.

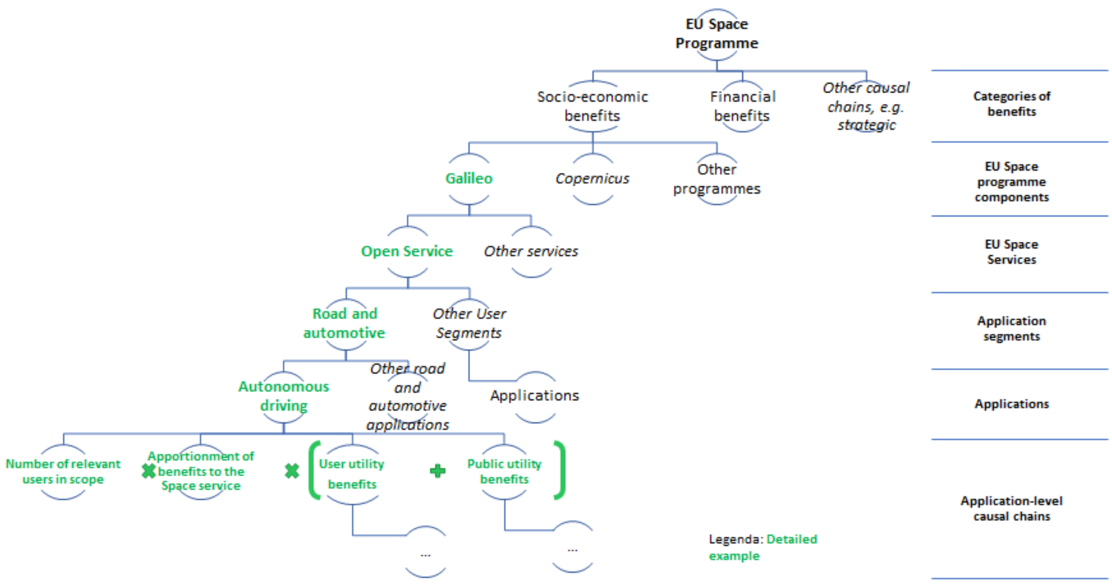
Figure 5: Building blocks of socio-economic chains of causal effects at application level



[54] https://www.gsa.europa.eu/gnss-applications/user-needs-and-requirements

Looking at the **EU Space Programme level,** the total socio-economic benefits generated correspond to the sum of the benefits produced by all the space services that are offered by the programme in the relevant applications, clustered by application segments, as illustrated in the figure below.

Figure 6: Socio-economic chains of causal effects at EU Space programme level



The conceptual framework for socio-economic benefits outlined above can also be subsumed by looking to the relevant applications as a unit of measurement, by assessing and quantifying the socio-economic benefits of the different relevant EU space services for each of the existing downstream applications.

3.4 Other chains of causal effects

Financial and socio-economic chains of causal effects aim to estimate benefits in a quantified and monetised manner, capturing the euro-value of the benefit, or failing that, at least counting the impact using a reasonable metric (CO_2 emissions avoided, lives saved, or similar depending on the type of benefit).

Beyond the quantifiable benefits that can be estimated through the financial and socio-economic chains of causal effects outlined above, there are a series of benefits which are difficult to quantify with granularity but should nevertheless be considered at least on a qualitative basis. These include:

- **Abnormal benefits:** financial and socio-economic chains of causal effects both capture the benefits of the EU Space Programme in what one might deem to be normal conditions. However, other benefits may accrue from EU Space services, including in abnormal situations, where the usual order is out of service.
- **Strategic autonomy:** benefits arising from European strategic autonomy (e.g., through independence of space assets owned by foreign actors and European control of critical infrastructure in space) are difficult to monetise because the value is only truly realised in events

where the foreign provider of infrastructure is unwilling or unable to continue service. These strategic benefits of the EU Space Programme are therefore not intended to be quantified in monetary terms; they need to be considered in a qualitative manner to allow their inclusion in any report and subsequent use of the benefits estimation.

- **Technology transfers:** technology transfers refer to the technology spillovers derived from space technology to non-space sectors (medical, manufacturing, etc.). Although space technology transfers do give stimulus to innovation in such sectors, enabled improvements are often difficult to quantify. The methodologies used to investigate and assess technology transfers include case studies, as evidenced by recent ESA activities on the subject[55].

[55] See ESA, Exploiting the remarkable potential of space technology transfer (esa.int)

4 Impact analysis

To support the definition of how the benefits from the EU Space Programme are actually measured, this section presents how to **categorise and analyse**, **value**, and **standardise** the measurement of benefits, referring to the EU Space Programme as a reference example to elaborate on each of these concepts.

4.1 Methodology

4.1.1 Categorization of benefits

A conceptual framework that aims to value benefits of the European space programmes needs to be based on the idea that these programmes can lead to identifiable economic, social, or other benefits for the population in scope (see section 2.2). Thereby, each of these benefits could be categorised as one of the following types of benefits:

- **Monetised financial benefits**: these benefits take into account the measurable financial transactions that occur in the market that pertain to the relevant space programmes. These could include direct exchanges of currency in return for space programme derived services, employment supported by the development of the programmes, and any quantifiable spillover effects of research efforts. Data sources for these can be found in various market and industry reports as well as individual company financial reports.
- **Monetised economic benefits**: these benefits refer to a given product or service where either market prices do not exist, or market distortions prevent to appropriately assess the social opportunity cost of goods and services[56]. Hence, alternative methods may be used to estimate prices. The application of the framework should include an active decision point, which allows explicit choice over whether these benefits will be monetised. If, monetisation is selected, this requires surveying of the identified potential or actual beneficiaries, exploring the use they do of a good or survey and appraising the "utility" that they can derive. These benefits could be found in the existing literature, explored as part of ongoing surveying programmes, or explored specifically for the population of the framework. There are two available alternative methods that fall into the category, 'revealed preference' and 'stated preference':
    - **Revealed preference** methods infer values from observed behaviour. The value that consumers derive from a good is estimated by observing their purchase of goods in the market that directly (or indirectly) relate to the product or service being examined. The strength of these approaches is that they are based on actual decisions made by economic agents, which should in theory mean they are based on reliable indicators of people's preferences. These include techniques such as:
        - **Hedonic pricing**: estimates the value of non-market goods by observing prices for a market good via which the non-market good is implicitly traded[57].

[56] See European Commission, Guide to Cost-Benefit Analysis of Investment Projects, 2014.

[57] For example, while there is no directly observable market price for "quiet residential environments" it is possible to measure the premium that is paid for a quieter versus a noisier but otherwise identical house.

Hedonic studies have been used to identify the value of non-market goods (or bads) such as road traffic, aircraft noise, air pollution, water quality, and risk of death or injury[58].

- **Travel Cost** (i.e., '**opportunity cost'**): even when a product or service does not have a market price, it may be the case that other resources are expended in order to make use of it. In the case of free-to-use recreational areas, for example, there are the monetary costs of travelling (transport costs, wear and tear and depreciation of the vehicle) and cost of time spent travelling. Values for time are often obtained from wage rates, with empirical work suggesting that time spent travelling is valued at somewhere between one third and one half of the wage rate[59].
- **Averting behaviour** or **defensive expenditure**: costs incurred to avoid or minimise exposure to non-market bads through expenditure on market goods[60].
- **Lost output**: similar to defensive expenditures, we can estimate the loss of output at prevailing market prices – often wage rates for changes in labour supply.

o **Stated preference** methods involve direct valuation, which are undertaken by asking potential or actual users hypothetical questions in carefully designed surveys so that individuals explicitly assign value to services. Where these benefits are identified, the appropriate survey population should also be identified. Relevant techniques include:

  - **Willingness to pay (WTP)** methods, estimating, via a range of techniques (conjoin analysis, etc.) how much a given customer would be willing to pay for a particular product or service;
  - **Willingness to accept (WTA)** methods, estimating the minimum monetary amount that a user/consumer is willing to accept to sell a good or service.

▪ **Non-monetizable benefits**: these benefits include strategic benefits that are generated by European space programmes' contributions to wider EC strategic objectives as well as economic benefits that cannot yet be directly attributed to programmes because it is not yet clear which share of the overall economic benefits in these segments can be attributed. These are to be addressed qualitatively, e.g., via a discussion of the progress towards stated goals of relevant stakeholders. For example, the European Commission's six strategic priorities[61] provide goals against which non-monetised benefits can be assessed.

[58] Possible issues include: imperfect information of consumers (so choices do not accurately reflect true value, and hence estimates of value obtained from choices do not either); multicollinearity (non-market characteristics tend to move in same direction – e.g. more noise and air pollution, making it difficult to separate out values); careful (and accurate) specification of the universe of options considered by agents is crucial to understand what decision is actually being made.

[59] Englin, J. & Shonkwiler, J.S. (1995). 'Modeling Recreation Demand in the Presence of Unobservable Travel Costs: Toward a Travel Price Model'

[60] Examples include double-glazed windows to decrease exposure to road traffic noise, and direct insurance products. Note that these are generally considered a lower bound estimate of the value of the impact of the non-market item on wellbeing.

[61] Strategic priorities and description: European Commission, 6 Commission priorities for 2019-24, available at: https://ec.europa.eu/info/strategy/priorities-2019-2024_en.

4.1.2 Valuing benefits according to categorisation

The categorisation of benefits according to the benefit types within the chains of causal effects is outlined in the table below.

Table 3: Categorisation of benefits according to benefit types

	Benefit type	Benefit category
Financial chains of causal effects	Procurement upstream - direct	Monetised financial benefits
	Procurement upstream - spillover	
	R&D upstream – direct	
	R&D downstream - spillover	
	Procurement downstream – direct	
	Procurement downstream – spillover	
	R&D upstream – direct	
	R&D downstream - spillover	
	Market creation	
	Public sector	
Socio-economic chains of causal effects	User utility	Monetised economic benefits
	Net positive externalities	
Other chains of causal effects	Abnormal benefits	Non monetizable benefits
	Strategic benefits	
	Technology transfers	

Following the categorisation of benefits, these need to be valued according to the most appropriate method. For this process, a greater understanding on how benefits are generated should be developed, allowing specific allocation of the benefit value generated by a space programme. The next section covers more into details the analysis methodology.

4.1.3 Analysis methodology

This section outlines the methodological approach for the three categories of benefits (financial, socio-economic, other) defined in the conceptual framework, further developing the concepts outlined in Section 3. By providing higher details on the conceptual elements underlying the different benefits and possible approaches, the following paragraphs are also intended as guidelines for practitioners willing to use the framework to appropriately estimate the benefits of space services in general.

Financial benefits

It worth considering the estimation of financial benefits as an exercise in 'following the money'. It is useful to follow the categorisation outlined in the causal chain description in Section 3.1, namely split between direct and spillover.

Direct benefits

The most intuitive financial benefit could well be that which arises **directly** from the **procurement** of the system(s). Understanding the full extent of expenditure and contractual information on the beneficiary organisations allows the analyst to apportion the expenditure into specific companies in direct terms.

Armed with this information, it is merely a case of analysing the company's financial accounts to understand the number of jobs supported in each of the categories of expenditure for each of the companies. This will allow aggregation of these company-level data to extract the total number of jobs supported by the procurement. Similarly, it is possible to determine the company's average ratio of GVA to turnover, to determine what proportion of the procurement value translates into direct GVA.

To capture the full procurement effect, specifically the **indirect and induced effects**, supply-and-use tables supplied by national statistics agencies or for Europe, the FIGARO inter-country input-output tables should be analysed using input-output analysis.

Input-output or supply-and-use tables show how outputs are generation in each statistical sector based on inputs from domestic and import sources at the sector level. Correspondingly, outputs from each sector can be traced into the sector where they are demanded, including for export and final consumption.

Input-output analysis is a well-established discipline of economics, and the methodology is described in detail in multiple textbooks. However, two important caveats should be noted in regard to input-output analysis for the space economy.

Firstly, the underlying data from statistics agencies rarely offer the granularity required to isolate space-related activity from the rest of the sector (for example in NACE code 2611: Manufacture of electronic components will include components that are space-qualified as well as electronic components for household appliances). ESA, JRC, and Eurostat's ongoing activity to create a space economy thematic account for Europe is expected to mitigate against this current weakness. The thematic account aims to capture the space economy upstream and downstream activities as defined within the OECD value chain framework. Nevertheless, space derived applications fall outside the scope of the ESA, JRC, and Eurostat project. Hence, the thematic account cannot fully mirror all space-related activities as defined under this conceptual framework for measuring space economy benefits.

Secondly, input-output analysis typically serves the purpose of assessing short-term impacts arising from a marginal change in final demand, where prices do not react to changes in demand and supply. Besides, it serves to describe the way economic sectors interact among each other and among other economic agents such as households, government and external trade. Therefore, the evaluation of medium and long-term impacts of the EU Space Programme would require the introduction of dynamics in the input-output system and/or other type of input-output related general equilibrium models. This second caveat is particularly important when analysing the EU Space Programme as its share of European government space budgets amounts to approximately 20%.[62] As such, the existence of the EU Space Programme will have moved the economy to a new equilibrium, and input-output analysis for the EU Space Programme in aggregate should therefore be interpreted with caution.

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[62] Approx. €10bn in total budgets, Euroconsult. (2022). 'Space economy report 2022'

Additionality needs to be assessed at all stages of the assessment of financial benefits, with particular emphasis placed on **deadweight**, **displacement**, and **leakage**.

The impact of the EU Space Programme through public sector activities is limited to the employment supported by the European Commission, its Agencies, and in Member States with direct reference to the EU Space Programme. The methodology to estimate the impact is simply to identify all relevant units and agencies and consult annual reports or other sources to count the number of jobs. This activity would benefit from validation by representatives from the European Commission to ensure no activity is missed.

Further information is included in the annexes.

Spillover benefits

Spillover impacts from **procurement** need to be considered on a firm-by-firm basis and should be based on a survey-based approach. Organisations that have supplied the EU Space Programme in the past ought to have a good understanding of the degree to which they have been able to leverage the knowledge, capacity, and flight heritage gained from the programme into other contracts. High-quality survey inputs (or potentially inputs sourced through stakeholder consultation) are required to produce a credible estimate of the additional sales generated by suppliers to the EU Space Programme. A lack of such inputs would necessitate the use of generalised ratios from the literature (which is extended regularly).

To estimate the impact of **R&D funding,** the analyst needs to source estimates on the amount of R&D funding dispersed to the space industry through the EU Space Programme. In **direct** terms, this funding supports jobs in the space industry with the purpose of generating skills and capabilities to supply the EU Space Programme. These jobs can be estimated based on generalised ratios of jobs to turnover in the organisations that receive the funding. National statistics and the Community Innovation Survey can be used to source this information at the industry level, while company-specific data exists in annual reports (for companies that are at least *medium-sized*).

Impact of **R&D funding** in the **space applications sector** follows a different path as companies that receive funding through Horizon and its predecessors use the skills, knowledge, IP, and capabilities generated via the grant to improve competitiveness in the market. Data on revenues and market share of European companies (for GNSS and Earth Observation (EO) can potentially be used to determine the current state of play in terms of European competitiveness. Matching market share, revenues and grant funding in companies could support the analyst to gain an understanding of the reach of the EU grant funding mechanisms[63].

Spillover benefits accrue to these organisations as improved skills and capabilities enable them to secure contracts from the EU Space Programme. However, even organisations that do not secure contracts from the EU Space Programme could benefit from the R&D funding as the upskilling might be in demand from other parts of the space industry (EU or international). To understand the spillover impact of funding would require a stakeholder engagement-based approach or, alternatively, the use of generalised ratios widely available in the literature.

The challenge is to determine the degree to which grant funding induces impact in the form of jobs and GVA. Impact assessments undertaken specifically for Horizon and other programmes would be

[63] The explanatory power of such analysis should be put into context, as there are also other factors that influence revenues and market share, and changes may not be due to R&D funding alone

a starting point for determining this information, but supplementary surveys of grant recipients would help assess the marginal impact on the market share.

Using the forecasts from a range of sources and reports would allow the analyst to assess the total size of the pie held by European companies, and the slither that is attributable to grant funding. The table below shows an example of funding options for GNSS companies in Europe, capturing different sources and indicating ticket sizes. Note that not all these sources are directly related to the EU Space Programme.

Table 4: Examples of funding options, for GNSS companies in EU

Example

Source	EUSPA	ESA	Horizon Europe, EIC Accelerator, CASSINI	InnovFin Space Equity Pilot, InvestEU	InvestEU
Type	Zero equity finance, grants, procurement	Zero equity finance, procurement	Grants, seed capital, blended finance	Equity co-investment via Venture Capital funds	Loan guarantees
Ticket Size	€10k-5m	€50k-3m	€10k-15m	€7.5m-75m	€7.5m-75m
Target companies	Start-ups onwards	Start-ups onwards	Start-ups onwards	Early-stage onwards	Growth and mature

Source: EUSPA and EIB (2021). European GNSS Investment Report 2021

The estimation of the impact of R&D funding needs very careful consideration of additionality, with particular emphasis placed on **deadweight**, **displacement**, and **leakage**.

Another way in which the EU Space Programme impacts the space applications sector is through its overall **market creation** activities for downstream space-enabled applications. Two channels of impact need to be considered.

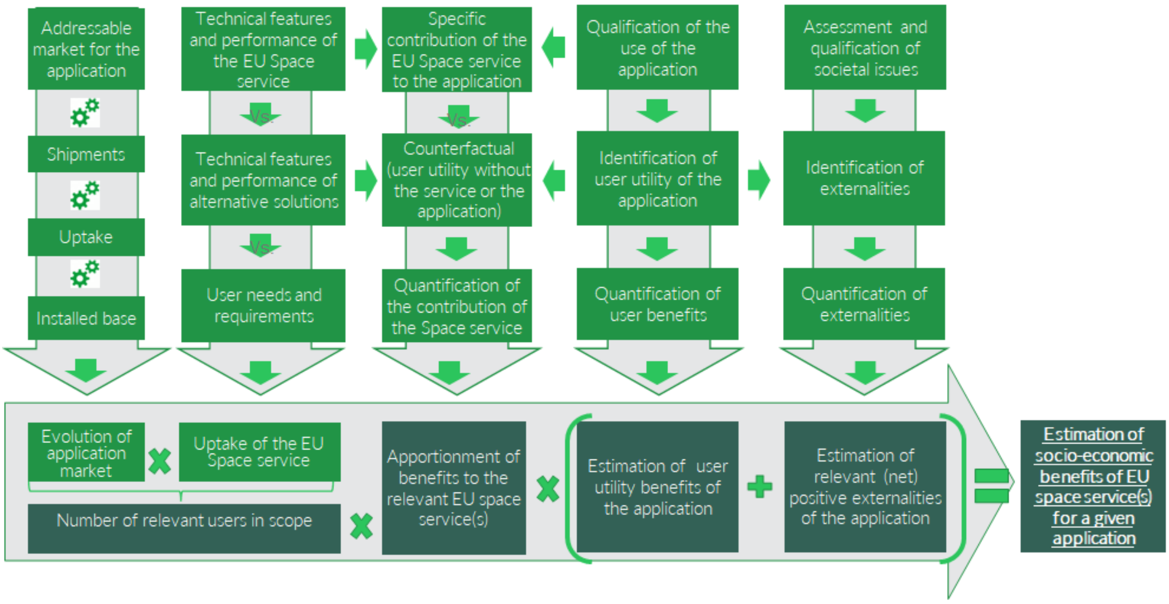
Firstly, the market development activities undertaken by the European Commission and its agencies (notably EUSPA and Entrusted Entities) result in an **increase** in the overall market for space applications and therefore a larger pie from which European companies can hold a slice. This impact is inherently difficult to measure as the counterfactual market size is extremely difficult to ascertain. The increased market is the result of two groups of actions, namely regulatory and voluntary. Regulatory actions are where the EU Space Programme induces regulation to push adoption (e.g., the eCall mandate), while voluntary actions are the result of market development and information campaigns to make stakeholders consider space as an option. The size of the impact cannot be assessed based on secondary research, and an approach based on the *Delphi method* involving a set of market experts is deemed the most appropriate option.

Secondly, the existence of the EU Space Programme and its assets contributes to the availability of signals and services and therefore could be argued to support the very **existence** of the market. In the case of unique services offered by the EU Space Programme, such markets can reasonably be argued to be enabled by the Programme, but there are many caveats in the analysis and to genuinely make the argument that the existence of EU Space Programme has created a market requires a very detailed and transparent analysis of additionality over and above the systems available from other states or private companies.

Socio-economic benefits

The estimation of socio-economic benefits should be considered as an exercise connecting the building blocks of the application-level chains of causal effects, outlined in Section 3.3. In turn, each of the building blocks is made of specific chains of causal effects, which are summarised in the figure below and explained in the next sections.

Figure 7: Analysis methodology for socio-economic benefits



Number of relevant users in scope

The first and second building blocks (evolution of the application market and uptake of the EU Space service) are ancillary to defining the relevant **user base** that drives the generation of benefits.

The first building block (*evolution of the application market*) consists in the determination of the size of the market for the relevant application and the related evolution. Ultimately, the most important information when it comes to the assessment of socio-economic benefits are the *installed base*, of either devices and services (for instance of GNSS-enabled devices for vehicle navigation, EO-derived risk management tools for insurance and finance, etc.), and/or the *number of users* (for example of the Copernicus Emergency Management Service – Rapid Mapping). While the installed base and the number of users might not necessarily be directly available, they can be derived leveraging the connections between market driver (the platform supporting GNSS or Satcom receivers or, if relevant, hosting the user-side client of EO-enabled services), shipments, market penetration and device/service lifetime.

The second building block (*uptake of the EU Space Service*) consists in determining the uptake of the relevant EU space service within the application. Both in the case of GNSS and Earth Observation applications, it cannot be taken for granted that Galileo/EGNOS services and Copernicus services and data respectively are being adopted. While in the short term a possible low uptake for EU solutions might depend on legacy aspects, such as old GNSS receiver technology on the side of the users, in the long run the diffusion of EU space services *depends on the extent to which these services,* *once embedded in applications, manage to fulfil user needs and to satisfy user requirements, ideally outperforming alternative solutions* in terms of performance, cost, or both.

The uptake of space services is typically quantified as a *market penetration* over the installed base of the application, reflecting the share of users, devices or services that adopt the given European space service in their application. Such market share can be derived from surveys and literature in ex-post assessments, and a variety of techniques for forward-looking assessments (conjoint analysis, forecasting techniques based on historical series, etc.).

Apportionment of benefits to the relevant EU space service(s)

In downstream space applications, space data is typically used in combination with other information, to feed the systems or software solutions adopted by users. The apportionment of benefits is a necessary step to appropriately reflect the actual contribution of the specific EU space service to the benefits generated by the application, since it avoids overestimation of such benefits.

The apportionment therefore consists in the determination of the *share of benefits* that can be attributed to the considered EU space service, taking into account its technical features and performance within the context of the alternatives at application and user level.

To estimate the relevant share of benefits, a *counterfactual assessment* is typically performed to appraise the role of the considered EU space service in the mix of solutions adopted.

Estimation of user utility benefits of the application

The *user* utility benefits are associated with the benefits and advantages that users derive from adopting space-enabled products, data, or services. These benefits are relevant for both consumers, business, and institutions, depending on the end user of the application. The range of potential user utility benefits is very wide and can include reduction of operating costs, other types of savings, enhanced productivity, as well as non-quantifiable impacts such as improved well-being. While several techniques (see also Section 4.1) can be used for the valuation of such benefits, a solid logic theory needs to be developed around the use of the application to correctly define and qualify those benefits, including:

- The qualification of the use of the application, in terms of purpose of the application and modality of use;
- The identification of the relevant user benefits deriving from the use of the application;
- The quantification of user benefits. The approach can be based on different techniques and data inputs, depending on the user scenarios and type of benefits.

Estimation of positive externalities of the application

The *positive externalities* benefits comprise spill-over effects (or externalities) from the use of space, which produce a (net) positive impact on the society but for which no monetary compensation is provided. Positive externalities include, as examples, environmental, economic, health and safety benefits[64].

[64] See Better Regulation Toolbox, e.g., Tool #24

A range of different techniques exist for the assessment and valuation of externalities, including dedicated methodologies for the various categories. In line with the logic proposed for user utility benefits, independently from the valuation methodologies adopted, a framework is required to understand, describe, quantify, and ultimately monetise[65] the positive externalities. Such framework comprises the following elements:

- Assessment and qualification of societal issues and their costs: the identification and definition of the relevant public bads (road traffic, aircraft noise, air pollution, water quality degradation, climate change, risk of death or injury, ...) that can be addressed by the application being used;
- Identification of positive externalities associated with the use cases of the application. This step stems from the identification of the benefits of the use cases of the application (often also generating user utility) and investigates for each of the benefits, the relevant externalities.
- Quantification (and monetisation) of the externalities: the last step consists in the quantification of the externalities. Similar to the quantification of user utility benefits, the approach can be based on different techniques and data inputs, depending on the user scenarios and type of benefits. Relevant literature and dedicated studies are typically used to determine the quantification. Where literature on the quantification of impacts is not existing, demonstrations and case studies, as well as ad-hoc modelling are typically developed. Following quantification of impacts, the last activity consists in the monetisation of positive externalities. There are diverging views on whether, for societal impacts, monetisation should be performed, versus the option of developing meaningful indicators for relevant impacts (e.g., number of lives saved, etc.) without monetising them. In the EU impact assessment practice, these impacts are typically monetised, with dedicated guidelines developed to this end[66].

Estimation of the socio-economic benefits for a given application

After the steps above, socio-economic benefits for a given application and services can be quantified as an algebraic sum of all the identified and estimated user utility benefits, as well as the positive externalities. Upon quantification, results should be validated, in particular considering the elements outlined in Section 2.3 (theory of change, the detailed causal chain, adopted data inputs and assumptions, and the quantifications of outputs).

Other benefits

Other benefits related to EU strategic autonomy and independence need to be assessed qualitatively based on secondary literature and potentially consultation with European Commission and Member States representatives to understand the relevant arguments to be made.

[65] According to, among others, EU impact assessment guidelines and the Handbook on the External Costs of Transport

[66] See, European Commission, EU impact assessment guidelines (2009) and the Handbook on the External Costs of Transport (2020)

4.2 Data collection: categories of data inputs

This section outlines the main categories of data inputs that are necessary to estimate the different categories of benefits. As mentioned in the OECD Handbook on Measuring the Space Economy, due to several factors, most space economy impact assessments rely on hybrid approaches, with the estimated effects based on a combination of **official statistics, academic and grey literature, survey data, ad hoc data collection, interviews and expert opinions**. This is due to a lack of easily accessible and distinct economic statistics on the space economy, as well as to the nature and complexity of the effects and dynamics of the space economy.

In the section below, the suggested data sources to cover the different steps of the analysis are presented. The suggested data sources take into account the level of priority to be attributed to data based on the expected quality (with the sources above to be used in descending order of priority), but also the availability of different data sources for each of the elements to be estimated.

4.2.1 Financial benefits

Data inputs required to estimate the financial benefits are (note: more detail is provided in a step-by-step guide in Annex 2, which also presents a worked example):

1. **Total programme expenditure** (official statistics from Multiannual Financial Framework and delegated sources), including any Member State-level expenditure that can be irrefutably linked to the EU Space Programme and would not exist without it;
2. **Total space-related R&D expenditure** (e.g., relevant projects from Horizon and other dedicated funds related to the Programme);
3. Identity of **contractors and grant recipients**;
4. **Key financials** for contractors and grant recipients (at the micro level) through annual reports or key financial ratios for the relevant part of the space economy sourced from national statistics and provided by Eurostat;
5. **Supply-and-use tables** and associated multipliers from Eurostat (direct communication with Eurostat recommended for maximum granularity). At the time of writing, ESA, JRC, and Eurostat are creating a thematic account for space comprising national space economy Supply and Use Tables (SUTs) and inter-country SUTS, both aligned with Eurostat's FIGARO tables. This will offer greater granularity and more space-specific outputs that are more directly suitable for the analysis;
6. **Spillover ratios** and induced sales figures from stakeholder consultation;
7. **Impact factors** from R&D expenditure from dedicated impact assessments or stakeholder consultations;
8. Total **downstream market size** and European market share from authoritative sources, including e.g., European Association of Remote Sensing Companies (EARSC) survey of European EO companies;
9. Output from **Delphi method consultations** with space market experts on EU Space Programme impact on the market size;
10. Number of **employees related to the EU Space Programme in the public sector** from annual reports and consultations with European Commission and Member State representatives.

4.2.2 Socio-economic benefits

Data inputs required to estimate the socio-economic benefits include (note: the numbering is used in the guide in the Annexes (note: assumptions might need to be developed in case data are missing):

1. **Data** from technical documentation on the **features and performance of EU Space programme components and services** (e.g., European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document, Info Notes on the performance and feature of EGNSS services, Copernicus services catalogues, Copernicus user and technical guides, etc.);
2. **Data** and information **to identify the relevant space-enabled applications** making use of the space services mentioned above. Desk sources, in particular on available taxonomies of applications (see Annex 6), represent a starting point, to be complemented by primary research inputs from market experts.
3. **User needs and user requirement data** from space services for the applications, included for example in studies on space services, the Reports on User Needs and Requirements by EUSPA, and/or similar sources;
4. **Total and application specific downstream market size** (including the demand from public players), evolution, and installed base from, e.g. EUSPA Market Report (for GNSS and EO) and/or similar publications or activities, including free and commercial sources;
5. **Data** and statistics **to quantify relevant user-related dimensions**, e.g., from Eurostat as well as other statistical databases, including United Nations, World Bank, FAOSTAT, CIA, etc.;
6. **Data** from Delphi method consultations with users and space market experts **on the perceived added value of EU space services** for the considered space-enabled applications;
7. **Data on** relevant **application benefits for users,** from EU-space-service level analyses, including but not limited to cost-benefit analyses developed to evaluate ex-ante or ex-post the feasibility of space services, as well as from experts in the field;
8. Technical **documentation** and expert views **on the apportionment of use of space services**;
9. **Literature** and data **on public bads and societal impacts**;
10. **Literature on the monetisation of both user utility benefits** (e.g., business case documentation) **and externalities** (e.g., documentation on external costs of human activity).
11. **Further primary data collection** activities **to cover gaps** in existing literature and data.

4.2.3 Other benefits

The data required to analyse other benefits are in qualitative form and include policy documents pertaining to the strategic objectives of the European Commission and the Member States. As public documents may differ from the private objectives, the secondary analysis needs to be supplemented by stakeholder consultation.

4.3 Estimation of benefits

Following the definition of the logic frameworks of the chains of causal effects, the quantification of the benefits can be achieved by calculating the benefits from each of the specific chains of causal effects that belong to the main categories. Reminding that "other" chains of causal effects (e.g., strategic impacts) should be assessed qualitatively, the overall results of the benefits calculated in the conceptual framework can be subsumed in the equation:

Total benefits = Σ Benefits from financial chains of causal effects + Σ Benefits from socio-economic chains of causal effects – Σ double counting

When it comes to double counting, two main categories of double counting should be addressed:

- Double counting *within the calculation of benefits from socio-economic chains of causal effects*: This double counting should be checked for when multiple EU space services are relevant for the functioning of a specific application – to avoid double counting, a consistency check needs to be run to determine the total apportionment of benefits to EU space solutions, as a sum of the individual apportionment of benefits for each service;
- Double counting between benefits from financial chains of causal effects and socio-economic chains of causal effects: When estimating total benefits, it should be taken into account that the market creation benefits (revenues) generated for businesses active in the space industry, represent costs for the end users. As an example, following the theory developed at EU level[67], to avoid double counting economic benefits should be calculated net of the price paid by end users.

4.3.1 Comparison against costs

Even though the comparison against costs is not strictly part of a conceptual framework to estimate benefits, in reality the estimation of benefits alone is of limited use to evaluate the effectiveness of interventions, policy and programmes – such assessments normally require the estimation of *net* benefits, taking therefore into account the cost incurred to enable estimated benefits to be realized.

Space makes no exception – In the specific example of the EU, the investment in space has been growing over time. Between 2007 and 2013, 6 billion EUR were invested in Galileo, EGNOS and Copernicus, whilst from 2014 until 2020 the investment has soared to 12.3 billion EUR as the space infrastructure for Galileo and Copernicus was deployed and entered exploitation. Further to that, for the 2021-2027 MFF period, a budget of 14.4 EUR billion in current prices was assigned to the three programme components in Regulation (EU) 2021/696, to further enhance Europe's leadership in space, to reinforce the EU as a world space player and to successfully compete with both other state and private-sector space actors[68] .

[67] European Commission, Guide to Cost-Benefit Analysis of Investment Projects - Economic appraisal tool for Cohesion Policy 2014-2020, 2014

[68] Beyond the investment in Space Programme, additional resources are dedicated to space, e.g., as part of the MFF budget for Horizon Europe. Moreover, further investments are being injected into the space sector. As a selected example, the European Investment Fund (EIF), announced that it is partnering with the Commission to invest €300 million into the EU space sector, supporting ground-breaking innovation in the industry and growth of European smaller and medium-sized space technology companies. See Space Sector: European Investment Fund announces €300m (europa.eu)

The table below provides an overview of the budget that has been allocated for the Galileo, EGNOS & Copernicus Programme throughout the years.

Table 5: Budget for the Galileo, EGNOS and Copernicus programme components

Galileo & EGNOS				
(In million EUR)	Before 2014	2014-2020	2021-2027	Total until 2027
Budget	**4693**	**7990**	**9018**	**21701**
Copernicus				
(In million EUR)	Before 2014	2014-2020	2021-2027	Total until 2027
Budget	**1290**	**4363**	**5421**	**11074**
Total for the three space programme components	**5983**	**12353**	**14439**	**32775**

Sources: European Court of Auditors for the periods before 2014 and 2014-2020; Regulation (EU) 2021/696 (Article 11) for the 2021-2027 period.

To enable evaluating the socio-economic return on the investment, relevant costs should be considered. For the EU, such costs include:

- **For the entire EU Space Programme**: all costs incurred after the go/no go decision, including R&D, system development, operation, user service and helpdesk, awareness and promotion, etc. Like with benefits, it could be equally important to identify and consider the direct, indirect and induced costs[69] related to the programme implementation and not only the direct costs related to the Programme.
- **For a single component of the Programme**: as above, but limited to a specific Programme component (e.g., Galileo);
- **For a specific service within a Programme component**: an appropriate share of the costs of the programme component, plus the specific R&D, system development and operation costs that are unique to the service.

4.4 Standardisation of benefits

The standardisation of the benefits enables all evaluations needing to be valued in common terms, so to allow their comparison and aggregation. Therefore, the standardisation should consider the following elements:

- **Currency** – which should be in Euros, to eliminate the effects of exchange rates. For countries that do not use the Euro, the ECB's average annual exchange rate should be used for the conversion.
- **Present Valuation** – the present discounted value is the value of a future amount or stream of benefits from the viewpoint of a defined point in time, to eliminate the time-distorting

[69] E.g., the negative externalities, such as CO2 emissions, employment loss, opportunity costs, transaction costs, etc.

effects of considering differently-timed investments and benefits. The Better Regulation Toolbox can be referred to in order to determine the appropriate discount factors[70].

- **Time period of analysis** – while the time period of the analysis and the relevant baseline should be set in the beginning of any application process of the framework, as described in Section 2.2, during the estimation phase it should be ensured that values that accrue over many decades are not directly compared to early-stage and hence short-lived sources of value.
- **Geography** – based on the geographical scope defined for the application of the framework (See Section 2.2), the coverage area actually considered when calculating values, including how well the available data approximates and can be corrected for the theoretical ideal geographical scope. This step of standardisation is important when existing data sources do not cover exactly the intended geographical coverage.

[70] https://commission.europa.eu/law/law-making-process/planning-and-proposing-law/better-regulation/better-regulation-guidelines-and-toolbox_en

5 Results

Any activity employing this Conceptual Framework to estimate benefits of the EU Space Programme should result in a report providing a narrative on the benefits causally produced by the EU Space Programme. The report should present benefits as well the mechanisms through which these benefits are generated. A **methodology** presenting the considered programme components and services, the relevant applications, and the chains of causal effects as employed in the estimation should be provided alongside the final economic model and a final presentation.

The benefits of the EU Space Programme using the present Conceptual Framework should produce two categories of narrative outputs: Firstly, a set of standard outputs that is consistent across all the implementations of the conceptual framework, to enable easy and consistent comparison of reports. Secondly, a set of bespoke outputs that meet specific requirements of the particular implementation of the conceptual framework. The second set of outputs is expected to vary over time and to depend on political priorities, e.g., those set annually in the European Commission's work programme.

All Euro-values presented should be appropriately standardised following the guidance in the Annexes.

5.1.1 Standard results and validation

All implementations of this Conceptual Framework must produce standardised outputs in the following dimensions:

a) **Financial** benefits;

b) **Economic** benefits;

c) **Other** benefits (qualitative);

d) **Total** benefits, representing the sum of quantitative benefits minus the removal of double counting. Quantitative total benefits should be complemented by the description of qualitative benefits.

Based on available resources, each dimension may be subdivided to improve the granularity of the assessment as required to improve comprehensiveness of the resulting report, along the following dimensions:

- **Time**, with annual benefits concurring to determine total benefits for the selected time period;
- **Geography**, with financial end economic benefit split by region and/or country;
- **Application,** with attribution of the specific financial and economic benefit to the relevant space-enabled application.

It is recommended that **financial benefits** be divided into upstream and downstream benefits or into direct and spillover benefits.

Economic benefits may be divided between user benefits and benefits for society, with further subdivision along the axes of:

- **User utility benefits**: the main categories identified in the OECD Handbook and the better regulation toolbox include cost avoidance, productivity improvements and additional revenues.
- **Positive externalities**: e.g., **health-related benefits** (lives saved, lives improved, reduced injuries or their consequences, …) and **environmental externalities** (e.g., reduction of air, water or soil pollution, reduction of CO_2 emissions).

All quantifiable **economic** benefits should ideally be presented before and after valuation. In concrete terms, the amount of fuel saved (in litres) is an interesting output in its own right and should be presented alongside the Euro-value of the same saving.

Strategic benefits may be presented following a breakdown similar to the objectives set at the commencement of the programme.

As mentioned in Section 2.3, in particular quantifiable outputs should be validated, in particular with regards to the underlying theory of change, the chains of causal effects, key data inputs and assumptions, and ultimately the actual quantifications.

5.1.2 Bespoke outputs and comparability with relevant costs

Bespoke outputs vary depending on the work programme of the European Commission to allow the report resulting from the application of the Conceptual Framework to align with the political current. Other drivers of bespoke outputs include the specific objectives at the core of the evaluation activity. For example, if the Conceptual Framework is used for an evaluation of a proposed set of new services from one of the components of the EU Space Programme, then the report must present a breakdown of socio-economic and financial benefits that captures all the different new services in isolation and at a suitable level of aggregation, to allow comparability with incurred costs as explained in Section 4.3.1.

Annex 1 Definitions

The following definitions are adopted in this report:

- **Space economy**: the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space. Hence, it includes all public and private actors involved in developing, providing and using space-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the space economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society (source: OECD)
- **Space Upstream**: the scientific and technological foundations of space programmes (including science, R&D, manufacturing, and launch) (Source: OECD – Note: for the identification of economic activities, please refer to the list of NACE codes listed in Annex 7)
- **Space Downstream**: from the space infrastructure operations to "down-to-earth" products and services that directly rely on space data and signals to operate and function (Source: OECD - Note: for the identification of economic activities as upstream vs. downstream, please refer to the list of NACE codes listed in Annex 7)
- **Space-derived activities:** these are derived or induced from space activities but are not dependent on it to function. Such activities include, but are not limited to, technology transfers to various sectors, including automotive, medical, etc. sectors.
- **Space-enabled applications:** applications that use data and information from space-based systems for their functionality to serve a specific purpose, directly or in combination with other data, software or hardware (Source: authors based on various sources);
- **Conceptual framework for measuring the benefits of a space programme**: a structure of ideas or principles to appraise the benefits of space programmes not only across the whole spectrum of the space economy, but also considering the socioeconomic impact that space-enabled applications produce on the users and on the society as a whole (Source: authors based on various sources);
- **EU Space Programme:** the EU Space Programme, established by EU Regulation (EU) 2021/696;
- **EU Space Programme components:** the components of the EU Space Programme, i.e., Galileo, EGNOS, Copernicus, SSA and GOVSATCOM, as defined in Article 3 of EU Regulation (EU) 2021/696, complemented by IRIS[2].
- **EU Space services:** the services delivered by one of the Programme components, e.g., the six services of Copernicus or the Open Service, the High Accuracy Service, etc. of Galileo.
- **Causal effects:** The causal effect of an intervention is the consequence (i.e., the effect) attributable to it. Causal analysis aims to identify the effect of the intervention, such as the EU Space Programme, on the outcomes of interest, considering (or controlling for) other causes of the phenomenon generating the outcomes, including other interventions[71].

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[71] See

- **Chains of causal effects:** the specific pathways leading from the changes produced by the space programme (and/or relevant subsets) lead to the generation of benefits. Relevant stakeholders for validation include socio-economic assessment experts, the upstream and downstream industry, and users and authorities.
- **Utility** is a term used to determine the worth or value of a good or service. More specifically, utility is the total satisfaction or benefit derived from consuming a good or service.
- **User utility benefits:** the benefits associated with total satisfaction or benefit derived from consuming a space good or service[72].
- **Externalities:** Externalities include environmental, economic, health, safety or other costs and benefits generated by a product or service and not reflected in its price or cost.
- **Strategic benefits:** benefits related, e.g., to the enhancement of the safety and security of the Union and its Member States and the reinforcement of the autonomy of the Union, in particular in terms of technology[73].

[72] The definition and concept of utility matches the one referred to in the Better Regulation Toolbox, see Tool #57.

[73] See Regulation (EU) 2021/696.

Annex 2 Steps to be adopted for financial benefit estimation

This Annex presents the steps that are needed to estimate the financial benefits of the EU Space Programme. The Annex covers steps and data sources and presents the approach in a bespoke example considering Galileo. The Annex's structure mirrors that in section 3.2. However, to comprehensively estimate the impact of the European Space Programme, this guidance will need to be replicated many times over for completeness.

A2.1 Direct benefits

Direct benefits primarily accrue to Europe's space manufacturing industry, but there are examples of activities further downstream being procured by the EU Space Programme. Benefits result directly from the spending of EU funds. In case non-European benefits are in scope, then inter-country analysis is required. In that case the inter-country FIGARO tables can be used to inform the non-European impact. For **direct** benefits, the following steps are required for the monetisation of benefits, noting the data sources required (in reference to the items listed in the data shopping list in section 4.2.1 and summarised here).

1. Total programme expenditure
2. Total space-related R&D expenditure
3. Identity of contractors and grant recipients
4. Key financials
5. Supply-and-use tables
6. Spillover ratios
7. Impact factors
8. Total downstream market size
9. Delphi method consultations
10. Number of employees related to the EU Space Programme in the public sector

- **Step 1:** source total programme expenditure on the EU Space Programme, including both expenditure on procurement and on space-programme related R&D. [1., 2.];
- **Step 2:** review contracts for the space programme to compile expenditure by contractor and by grant recipient for each year [3.];
- **Step 3:** validate contracting information with procurement agents, if possible;
- **Step 4:** classify contractors and grant recipients according to NACE codes;
- **Step 5:** source ratios for contractors (e.g., GVA/turnover, employees/turnover), either based on company-level information from annual reports, based on standardised NACE codes from Eurostat[74] or space-specific information derived from the thematic account for the space economy in Europe developed by ESA, JRC, and Eurostat, with support from OECD and US Bureau of Economic Analysis (BEA) [4., 5.];

[74] E.g. Enterprise statistics by size class and NACE rev. 2 activity, [sbs_sc_ovw]

- **Step 6:** estimate direct GVA and employment in contracting organisations based on contract revenue and (standardised) ratios;
- **Step 7:** assess additionality of the procurement through deadweight, displacement, transfers, substitution, and leakage [use the framework outlined in Section 4.1.3];
- **Step 8:** Compute direct benefits net of additionality;
- **Step 9:** Source indirect and induced effects multipliers either from Eurostat's standard provision of input-output tables, bespoke extract from Eurostat if feasible, or from the thematic account for the space economy in Europe [5.], estimated through input-output analysis;
- **Step 10:** Estimate indirect and induced effects.

The example below focuses on the direct benefits of one project undertaken by the EU space programme.

Step (above)	Example	Commentary
2/3	In early **2010**, the **European Commission** awarded three contracts to procure Galileo's initial operational capabilities. One of these, signed with **OHB System AG**, specified an order value of **€566 million** for an initial procurement of 14 satellites, delivered every 1.5 months over 19 months. This contract is the subject of this example.	Source: (1)
4	OHB System is classed as a **manufacturer of air and spacecraft** (NACE code: 30.3). This is a subcategory of CPA_C30: **Manufacture of Other Transport Equipment**	
5	The FIGARO supply and use tables provide standardised multipliers by industry. Other Transport Equipment is recorded as providing: **GVA/turnover - 0.244** **Employee compensation/turnover – 0.19** (additional data on average salary in the sector required to estimate number of employees.)	Source: EU27 I/O tables, 2011. The most granular data available provides these at the level of CPA_C30. More granular data expected from the thematic account for the space economy, or to be accessible through engagement with Eurostat.
6	**Direct economic benefits** can therefore be calculated as **0.244 x €566 million** = **€138 million**. Employment impact requires information on average salary by multiplying **employment/turnover ratio** by €566 million.	This assumes the figures identified in (5) are representative for the Galileo programme. More accurate data expected from the space economy thematic account from Europe.
7/8	Understanding additionality requires a clear statement of the counterfactual, assessed through stakeholder consultations.	This is firm dependent and not covered in this example
9	The latest FIGARO tables give a total **output multiplier** of **1.35** for Other Transport Equipment.	Source: (2). Ideally, data on indirect and induced multipliers could be obtained, but these are not currently publicly available on the Eurostat platform. Consultation with Eurostat required.
10	Therefore, once indirect and induced benefits are accounted for, the total economic benefit from this contract amounts to **1.35 x the additionality-adjusted direct impact**.	

(1) ec.europa.eu/commission/presscorner/detail/en/IP_10_7

(2) https://ec.europa.eu/eurostat/databrowser/view/NAIO_10_COOUT__custom_7314129/default/table?lang=en

This approach generalises to capture all contracts, including grants from Horizon or similar sources. If individual contract information is not available for all contracts, a generalised ratio based on observable data can be used for unobserved expenditure.

Public sector impact follows the same logic, replacing "contracts" for expenditure in the European Commission, its Agencies, and any other relevant organisation. These data are generally easier to validate as the information should be readily available, so the challenge here is to find the correct person to validate with [10.]. Public sector GVA is not in scope, only employment impact is.

A2.2 Spillover benefits

Spillover benefits arise through two main channels, namely a) when the activities of the EU Space Programme allow its participants to leverage skills, capacity, or experience for activities outside the direct channels and b), when the existence of the EU Space Programme creates a market that allows further economic agents to trade.

Regarding **funding spillovers** from contracts and R&D funding, the following steps are recommended:

1. Source company-level information on spillovers, ensuring representative sample
2. Compute ratio of spillovers to direct funding [6.]
3. Apply ratio to full population of funded companies
4. Ascertain and correct for additionality

Regarding the first channel, spillovers can exist for multiple reasons, but are mostly firm-specific. One firm might have secured a large contract which has enabled the construction or acquisition of further manufacturing capacity, which can be used for unrelated activities once the contract is delivered, other firms may have proven specific components that can be sold to non-EU Space Programme-related customers (perhaps outside the space economy altogether), while others still have successfully developed the intellectual property, they set out to capture through a Horizon project. Given the disparate nature of impacts, consultation with stakeholders, or as part of specific impact assessments for component parts will be required [6., 7.]. The response rate for such engagements is generally not high, so it is imperative that enough effort is expended to achieve a representative sample. Selection bias is a real risk that must be overcome (i.e., companies that succeed through the engagement are more likely to respond than those that do not – or cease trading entirely). It is not possible to obtain quality data on all companies and generalisation is therefore necessary – hence why the representativeness must be maximised.

The example below presents a brief case study of the spillover impact on a contractor for the Galileo programme.

CASE STUDY – SPILLOVER BENEFITS[75]

[75] This case study was first reported in London Economics (2017). *The economic impact on the UK of a disruption to GNSS. Available at:* https://londoneconomics.co.uk/blog/publication/economic-impact-uk-disruption-gnss/

Surrey Satellite Technology Limited (SSTL) – jointly awarded a contract in **2010** (with OHB Systems) for construction of **22 payloads for Galileo**. The contract was worth **€236m** to SSTL directly.[76]
Firm-specific spillovers identified in consultation with stakeholders: **Growth**: Award of the €236m contract allowed SSTL's **turnover to more than double**. This facilitated SSTL attaining 40% market share (self-reported) by 2015. **Capabilities**: The Galileo payload contracts enabled SSTL to build an **advanced 3700 sqm facility in 2012**, in turn allowing SSTL to deliver more advanced satellites aside from the Galileo projects (e.g., the Eutelsat Quantum platform). **Reputational Spillovers**: SSTL became increasingly known for the construction of small satellites, culminating in an **"outstanding contribution"** award from the ESA for delivering the GIOVE A satellite. **Business Knowledge**: several stakeholders (not just SSTL, mitigating concerns about sample composition) reported gaining knowledge of GNSS as a result of their involvement with Galileo which proved subsequently useful for downstream-focused business.
Quantification of these benefits and establishing a counterfactual are, by their nature, very challenging, and do not generalise easily from firm to firm. Nevertheless, once a value for firm-level spillovers has been identified, and adjusted to capture **additionality**, this can be **scaled** to estimate the spillovers at the population level, on the assumption that the sample is representative.

Regarding market creation benefits, the following steps are needed:

1. Overall downstream market size
2. Attribution to EU market development activities
3. Assessment of EU market share

A key component of the EU Space Programme is the market development activity undertaken by EUSPA and other organisations. Successful market development ensures that more economic agents start using space-based products and services than would have otherwise been the case. This has a positive impact on the EU space industry, predominantly in the downstream, and in turn supports employment and value-added. However, the EU Space Programme does not operate in a vacuum, and across its components, other solutions are available. It is therefore necessary to determine the share of the global downstream market [8.] that is attributable to EU market development activities [9.]. Econometric analysis is not a viable option, so a Delphi process with experts is proposed. Knowing total market size, and share that is attributable to EU market development, in consort with recurring activities to estimate the European share of the market yields European revenue supported. Using the same NACE code-based approach as above for the identified population of the downstream space industry yields sufficient information to estimate employment and GVA supported, with FIGARO tables used to derive indirect and induced effects.

[76] Note the impact on SSTL is captured through the multiplier analysis in the direct benefits section.

Annex 3 Steps to be adopted for socio-economic benefits estimation

The steps required to estimate the socio-economic benefits of the EU Space Programme follow the logic depicted in Figure 7. They are described below, referring to the shopping list outlined in Section 4.2.2:

1. Data on the features and performance of EU Space programme components and services
2. Data to identify the relevant space-enabled applications
3. User needs and user requirement data
4. Total and application specific downstream market size
5. Data to quantify relevant user-related dimensions
6. Data on the perceived added value of EU space services for the considered space-enabled applications
7. Data on application benefits for users
8. Documentation on the apportionment of use of space services
9. Literature on public bads and societal impacts
10. Literature on the monetisation of both user utility benefits and externalities
11. Further primary data collection to cover gaps

A3.1 Understand the number of relevant users in scope

The first step consists in determining how many users are in scope, as a combined effect of the assessment of a) the evolution of the application market and b) the uptake of the relevant Space Service – *note: to assess the full range of socio-economic benefits of a specific Space service, all relevant applications need to be identified, and the relevant user base assessed.*

The estimation of the user base leverages data from Points 1, 2, 3, 4, 5, 6 and 10 as mentioned above

These sub-steps are described more into details below.

Evolution of the application market

As mentioned in Section 4.1.3, ultimately, the most important information when it comes to the assessment of socio-economic benefits is the *installed base*, of either devices and services, and/or the *number of users*. While these might not necessarily be directly available, they can be derived leveraging the connections between market driver (the platform supporting the relevant receivers or services for the application), shipments, market penetration and device/service lifetime.

The approach to the quantifications will depend on the available data. Two main scenarios could occur: either it is possible to find directly comprehensive datasets, or related but partial data (e.g., on yearly sales) can only be retrieved. When partial data is only available, again the modelling approach can be different depending on the application and the underlying data.

CASE STUDY – EVOLUTION OF THE APPLICATION MARKET FOR GNSS-ENABLED RECREATIONAL NAVIGATION
The potential market for GNSS devices in *Recreational navigation* is the number of recreational vessels multiplied by the average number of GNSS devices per vessels; in recreational navigation, it is assumed that each vessel will carry an average of **one** device. The second step on the way is to assess what proportion of the potential market is *addressable* by GNSS, i.e., is there a reason to believe that some potential users are not able to use GNSS due to some technological limitations (e.g., in the absence of regulatory requirements, GNSS equipment is typically only used on vessels beyond a certain size/autonomy). The third step is to find a starting point for modelling. In the case of recreational navigation, the starting point is the *current* share of vessels that are GNSS enabled; the so-called *GNSS penetration*. The necessary data might be available through desk sources, or it might be necessary to collect it via industry and/or user surveys. By multiplying the *addressable market* with the *GNSS penetration* for the defined base year, the initial *installed base* of GNSS devices is obtained. To address the evolution of installed base over time, the next step is to model *shipments* of GNSS devices and populate the *installed base* and *GNSS penetration* for the remaining years, taking also into account the *GNSS device lifetime*. These statistics are heavily interlinked. *Shipments* are modelled based on three assumptions, the *addressable* market, the *device lifetime* and the *installed base*. *Installed base* of GNSS receivers over the years is calculated as the sum of *installed base* the previous year and *shipments* in the current year less retired devices. In the years following the base year, GNSS penetration is calculated as *installed base* divided by *addressable market*.

Uptake of the EU space service

The *uptake of the EU Space Service* consists in determining the level of adoption of the relevant EU space service within the application, as both in the case of GNSS and Earth Observation applications, it cannot be taken for granted that Galileo/EGNOS services and Copernicus services and data respectively are being adopted. The diffusion of EU space services *depends on the extent to which these services, once embedded in applications, manage to fulfil user needs and to satisfy user requirements, ideally outperforming alternative solutions* in terms of performance, cost, or both.

The uptake of space services is typically quantified as a *market penetration for the EU service* over the space-enabled installed base of the application, finally enabling to estimate the share of users, devices or services that adopt the given European space service in their application.

The approaches to determining the uptake of the EU space service depend on a case-by-case basis, in light of available data. Industry surveys and literature typically support historical estimates, while a variety of techniques is available forward-looking assessments (conjoint analysis, forecasting techniques based on historical series, etc.). Most of the forward-looking methodologies triangulate the following elements:

- The technical performance of the services that are part of the EU Space Programme; vis a vis:
- The identification of relevant user needs and requirements in the relevant applications that can make use of such services.

A3.2 Apportionment of the benefits to the relevant EU space service(s)

The apportionment of benefits is a necessary step to appropriately reflect the actual contribution of the specific EU space service to the benefits generated by the application, since it avoids overestimation of such benefits. The apportionment to the relevant space service is then typically modelled as a percentage to be applied over the total benefits produced by the space-enabled application (see next step).

To estimate the relevant share of benefits, a *counterfactual assessment* is typically performed to appraise the role of the considered EU space service in the mix of solutions adopted, based on technical documentation (Point 7 of section 4.2.2) and integrated as needed with primary data (Point 10).

CASE STUDY – APPORTIONMENT OF EGNOS OS BENEFITS IN AGRICULTURE FOR THE MACHINE GUIDANCE APPLICATION
In the case of the "machine guidance" application in agriculture and focusing on the apportionment of the benefits of EGNOS Open Service (OS), this relates to the incremental performance of within the mix of satellite navigation services adopted, for the relevant user requirements of the application – e.g., in terms of positioning accuracy and the assessment of the counterfactual of the application being used without EGNOS OS. If the EU space service is an essential enabler of the application, counterfactual for applications of interest should also be assessed (e.g., in absence of EU space programme, what the next best alternative that would be available with the same development time would be).

A3.3 Estimation of user utility benefits at application level

The *user* utility benefits are associated with the benefits and advantages that users derive from adopting space-enabled products, data, or services. These benefits are relevant for both consumers, business, and institutions, depending on the end user of the application. The range of potential user utility benefits is very wide and can include reduction of operating costs, other types of savings, enhanced productivity, as well as non-quantifiable impacts such as improved well-being. While several techniques (see also Section 4.1) can be used for the valuation of such benefits, a solid logic theory needs to be developed around the use of the application to correctly define and qualify those benefits, including:

- The qualification of the use of the application, in terms of purpose of the application and modality of use (points 6, and 10 of Section 4.2.2).
- The identification of the relevant user benefits deriving from the use of the application (points 6, 9 and 10 of Section 4.2.2).
- The quantification of user benefits. The approach can be based on different techniques and data inputs, depending on the user scenarios and type of benefits (points 6, 9 and 10 of Section 4.2.2).

CASE STUDY – USER UTILITY BENEFITS IN AGRICULTURE FOR THE MACHINE GUIDANCE APPLICATION
The steps summarised for the assessment of user utility benefits can be exemplified for the machine guidance application: ▪ **Qualification of the use of the application:** In agriculture GNSS- and EGNOS Open Service enabled machine guidance solutions are adopted by farmers to automate – to different extents – the steering of tractors and implements and improve the precision of manoeuvring, reducing overlaps of operations by improving the so-called pass-to-pass accuracy[77]; ▪ **Identification of the relevant user benefits deriving from the use of the application.** Farmers and their contractors, thanks to the use of machine guidance solutions achieve different types of benefits, including: o Savings on agricultural inputs: more precise placement also means optimization of the application of inputs such as seeds and nutrients; o Time savings: the reduction of overlaps between rows means that less time is required to perform operations on the field; o Fuel savings: likewise, less overlaps mean lower distance to be covered by the tractor. ▪ **Quantification of user benefits:** Focusing on fuel savings, these can be calculated by determining average figures of tractor fuel consumption, the estimation of the total area to be covered, the counterfactual scenario without space-enabled solutions (level of overlaps between rows) and the estimation of the efficiency gains in terms of reduced overlaps. Benefits can then be monetised by estimating fuel costs.

A3.4 Estimation of positive externalities from application use at application level

As mentioned in Section 4.1.3, the benefits from positive externalities comprise net positive spill-over effects from the use of space, which produce a positive impact on the society but for which no monetary compensation is provided.

Externalities include several types of environmental benefits (such as reduction of air and noise pollution), safety-related benefits (prevention of accidents and related fatalities and injuries), reduction of damage to public and private property, etc. It should be noted that positive externalities should ideally be calculated as net, i.e., subtracting the value of any negative externalities due to use of the applications from the value of the positive ones.

While different techniques exist for the assessment and valuation of externalities, independently from the valuation methodologies adopted, a logic framework is required to understand, describe, quantify, and ultimately monetise[78] the impacts. Such framework comprises the following elements:

- Assessment and qualification of societal issues and their costs: The identification and definition of the relevant public bads (road traffic, aircraft noise, air pollution, water quality

[77] The accuracy which can be achieved between tractor passes in a typical field.

[78] According to, among others, EU impact assessment guidelines and the Handbook on the External Costs of Transport

degradation, climate change, risk of death or injury, …) that can be addressed by the application being used (see point 6, 8 and 10 of Section 4.2.2);

- Identification of positive (and negative) externalities associated with the use cases of the application. This step stems from the identification of the impacts of the use cases of the application (often also generating user utility) and investigates for each of the benefits, the relevant externalities (see point 6, 9 and 10 of Section 4.2.2).
- Quantification (and monetisation) of the net benefits. The last step consists in the quantification of the externalities. Similar to the quantification of user utility benefits, the approach can be based on different techniques and data inputs, depending on the user scenarios and type of benefits. Relevant literature and dedicated studies are typically used to determine the quantification. Where literature on the quantification of impacts is not existing, demonstrations and case studies, as well as ad-hoc modelling are typically developed. Following quantification of impacts, the last activity consists in the monetisation of the externalities. There are diverging views on whether, for societal impacts, monetisation should be performed, versus the option of developing meaningful indicators for relevant impacts (e.g., number of lives saved, etc.) without monetising them (see point 6, 9 and 10 of Section 4.2.2). In the EU impact assessment practice, these impacts are typically monetised, with dedicated guidelines developed to this end[79]. An illustrative list of externalities[80] include the following categories and sample indicators:
    - **Health and safety**: saved lives, improved lifespan, avoided injuries, reduced consequences of injuries, …;
    - **Economic:** for example, avoided damage to public and private property, …;
    - **Environmental:** reduced emissions of carbon dioxide, and reduced pollution, in the form of reduced air, noise, soil, sea pollution, ….

CASE STUDY – POSITIVE EXTERNALITIES FROM IMPROVED FLOOD PREPARENESS IN EMERGENCY MANAGEMENT AND HUMANITARIAN AID THANKS TO EARTH OBSERVATION
The steps summarised for the assessment of positive externalities can be exemplified for the preparedness application focusing on floods: ▪ **Assessment and qualification of societal issues and their costs:** The occurrence and magnitude of natural disasters have been both increasing in recent years. In the EU, the average economic loss is projected at € 12 billion per year. To address this, nations across the world have sought to strengthen their disaster risk management activities. In this framework, it is imperative that stakeholders involved in disaster risk management work seamlessly together and that all available sources of information are effectively used. Thus, having the best possible situational awareness – i.e., what is happening, where and when, is of key importance; ▪ **Identification of the relevant user benefits deriving from the use of the application.** Satellite-based Earth Observations support the full cycle of disaster risk management. The Copernicus Emergency Management Service provides a wide range of information products, generated using satellite based EO data (obtained by Copernicus Sentinels and commercial providers through the Contributing Missions mechanism). Focusing on

[79] See, European Commission, EU impact assessment guidelines (2009) and the Handbook on the External Costs of Transport (2020)

[80] See, e.g., the Better Regulation Toolbox, Tool #24.

CASE STUDY – POSITIVE EXTERNALITIES FROM IMPROVED FLOOD PREPARENESS IN EMERGENCY MANAGEMENT AND HUMANITARIAN AID THANKS TO EARTH OBSERVATION
Flood Management and early warning tools as an example, *the incorporation of information derived from satellite data is contributing to avoided damages thanks to better investment in defences and flood relief schemes*. ▪ **Quantification of positive externalities:** In this case, EU benefits, focusing on preparedness for flood management, can be quantified by (a) looking at the part of investments which is sensitive to information derived from satellite data, (b) applying a well-justified return on investment on this part, (c) making assumptions on the improvement in decision making thanks to Satellite data (using e.g. the findings for Ireland from studies such as the ones produced by EARSC and ESA[81]), (d) extrapolating benefits identified from available local sources taking into account the annual public budget expenditure in the EU for disaster prevention (3Bn€).

[81] See https://earsc.org/sebs/flood-management-in-ireland/

Annex 4 Approach to estimate other benefits

Other benefits need to be assessed qualitatively as quantification is either not meaningful or not possible with a sufficient level of comprehensiveness. Qualitative analyses start from the strategic objectives of the programmes (were they met?) and the political level (does space help address macro developments).

Desk-based research is needed to establish these objectives and analysis of the EU Space Programme and its outcomes is needed to determine whether the objectives are met. Stakeholders from the European Commission, in particular, need to be engaged early and consistently, and KPIs reported on mandate from relevant regulation should be used extensively to answer the questions.

Annex 5 Literature, references and insights on conceptual frameworks

As widely recognised and mentioned in the body of the report, there is a lack of an internationally recognized and widely adopted conceptual framework definition for the benefits of space programmes. Moreover, the necessary data to populate such framework are typically not readily available and often gathered on a case-by-case basis. Information on non-market effects (captured by our conceptual framework through the socio-economic chains of causal effects) is particularly scarce.

To address the issue of lack of harmonisation, this conceptual framework was developed taking into account, as far as feasible, previous work on the topic by following a structured approach: each study or report tracking the growth of the space sector usually creates its own implicit or explicit framework. Despite the variety in these different frameworks, as long as they are explicitly defined it is possible to outline the major components of each framework, which were taken into account for the development of our conceptual framework.

One of the key aspects that appears in all literature is the discussion of **stakeholders**. It is present in reports for national (such as Australian Space Agency[82] and UK Space Agency[83]) and international (such as the EU[84]) organisations or agencies. This is often established as part of the statement of the purpose of the report by identifying for whom it is important, who sets the objectives of the report, and other related issues. Consulting shareholders is one of the instruments discussed in the Better Regulation toolbox[85]. This consultation process supports the 'participative approach' and 'transparency' principles and is documented both in the Better Regulation guidelines[86] and in the toolbox: an explicit definition of the stakeholders is a necessary part of any conceptual framework which allows for these guidelines and tools to be applied.

The second key concept that features near-universally in conceptual frameworks is a precise definition of the **objectives** of the framework. Without this definition the frameworks produced do not sufficiently inform users what it is the framework is designed to measure. Examples across the literature state in unequivocal terms what the goal of their framework is, with objectives including 'consistent and comprehensive economic data about the U.S. space economy'[87], 'To provide more targeted estimates of the size of the space economy than are currently employed'[88], and 'establish[ing] a… starting point of the sector's size and characteristics, and track[ing] its growth…'[89].

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82 Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

83 London Economics. (2018). 'Spillovers in the space sector'

84 Regulation (EU) No 549/2013 of the European Parliament and of the Council of 21 May 2013 on the European system of national and regional accounts in the European Union, OJ L 174, 26.6.2013

85 European Commission. (2021). ''Better regulation' toolbox 2021'

86 European Commission. (2017). 'Commission Staff Working Document: Better Regulation Guidelines'

87 Highfill, T., A. Jouard and C. Franks. (2020). 'Preliminary estimates of the US space economy, 2012–2018'. Available at: https://apps.bea.gov/scb/2020/12-december/1220-space-economy.htm

88 Crane, K. et al. (2020). 'Measuring the space economy: Estimating the value of economic activities in and for space'. Available at: https://www.ida.org/-/media/feature/publications/m/me/measuring-the-space-economy-estimating-the-value-of-economic-activities-in-and-for-space/d-10814.ashx

89 Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

Another important part of any framework is the definition of its **scope**. This is usually determined by stakeholders and in the context of the space economy these stakeholders commonly define what is and what is not to be included. By creating an explicit definition of what is being measured, reports provide crucial information for the impact measurement, evaluation instruments, and core principals such as 'coherent approach' as mandated by the Better Regulation guidelines. The space economy definition provided in the OECD handbook[90] is widespread and used quite often[91] but other definitions (especially for US space economy[92,93]) are used as well. The difference in definitions makes it more difficult to compare numerical estimates from the resulting frameworks across different studies and reports, it is still possible to account for those differences as long as the definitions are explicit, and insights in the actual products, services or applications to be considered are provided. For reports where that is not the case, it severely impedes the wider use of their work and limits the impact such work can have on policymaking.

Depending on the purpose of the report and the stakeholders, it can be useful to identify the opportunities for the organisation to enact change and how that change would manifest. For example, if the framework's objective is to measure the impact of a policy or programme then identifying how the impact is expected to propagate is an important concept before attempts to measure said impacts are made. This identification process is often done either by incorporating the causal links of the organisation[94] or by providing policy suggestions in the report itself[95]. This is consistent with the 'Better Regulation' principles of 'comprehensive approach' that mandates that 'considerations should cover all relevant economic, social and environmental impacts, all interested parties and every phase in the policy cycle'. In order to properly assess the impact (and benefits) of a policy or an intervention, their **causal effects** must be examined[96]. One clear example of this is the framework used by the Australian Space Agency[97] which categorises all space economy activities into 'three main value chain segments: *manufacturing and core inputs*, *space operations*, and *space applications*; all supported by a fourth *enablers* value chain segment'.

The methodology of impact assessments is thoroughly described in the EU 'Better Regulation' Guidelines and Toolbox and are widely used across a range of different studies and reports. A key part of this methodology is the approach taken to **measuring the impact** identified by the framework's earlier stages. This often includes categorisation of benefits, identifying indicators or relevant proxies of the things being measured, and standardisation of parameters such as time period units, currency, and geography. Given the abundance of guidance on instruments like impact assessment, this is often the part of the literature that displays the most similarity across frameworks.

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[90] OECD. (2022). 'OECD Handbook on Measuring the Space Economy, 2nd edition'

[91] See: Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

[92] Crane, K. et al. (2020). 'Measuring the space economy: Estimating the value of economic activities in and for space'. Available at: https://www.ida.org/-/media/feature/publications/m/me/measuring-the-space-economy-estimating-the-value-of-economic-activities-in-and-for-space/d-10814.ashx

[93] Highfill, T., A. Jouard and C. Franks. (2020). 'Preliminary estimates of the US space economy, 2012–2018'. Available at: https://apps.bea.gov/scb/2020/12-december/1220-space-economy.htm

[94] London Economics. (2018). 'Spillovers in the space sector'

[95] ESPI. (2020). 'Towards a European approach to space traffic management' https://www.espi.or.at/reports/towards-a-european-approach-to-space-traffic-management/

[96] See TOOL #68. METHODS FOR EVALUATING CAUSAL EFFECTS in the EU Better Regulation Toolbox.

[97] Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

Some form of impact assessment is available in reports for national (such as Australian Space Agency[98] and UK Space Agency[99]) and international (such as the EU[100]) organisations and agencies.

The reports whose previous parts were well-defined, were also able to include the 'Better Regulation' principle of 'learning from experience' by **validating** their results against other similar reports and studies[101,102]. Furthermore, including an ongoing internal review process that engages relevant stakeholders and experts throughout the use of a given framework is a crucial part of a successful framework. As noted by the OECD handbook[103], there is a 'great discrepancy in estimates' of the space economy and only when the conceptual frameworks include provisions to ensure that users do not go too far astray can those estimates be meaningfully compared.

A selection of relevant references and frameworks is provided below.

A5.1 OECD Handbook on measuring the Space Economy

In 2012, the OECD published its first Handbook on Measuring the Space Economy, deriving from the work of the OECD Space Forum as well as extensive consultation of space and non-space stakeholders.

The objective of the Handbook, which now features a second edition published in 2022, is to "*systematically define and measure the "space economy" and its constituent economic activities* (OECD, 2012). The second edition of the Handbook takes into account the changing landscape of space activities, technologies and subsequent evolving user needs, as well as going into further details on how data collection can be facilitated.

While the Handbook focuses essentially on a different objective vis-à-vis the conceptual framework (i.e., measuring the space economy, as opposed to measuring the benefits produced by EU or other space programmes, within and beyond the scope of the space economy), the conceptualization of the space economy and the methodological considerations included in the Handbook represent relevant inputs and baselines for the assessment of the benefits considered in our conceptual framework.

A5.2 The Better Regulation Toolbox

The better regulation guidelines[104] from the European Commission set out the principles that the European Commission follows when preparing new initiatives and proposals and when managing

[98] Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

[99] London Economics. (2018). 'Spillovers in the space sector'

[100] Regulation (EU) No 549/2013 of the European Parliament and of the Council of 21 May 2013 on the European system of national and regional accounts in the European Union, OJ L 174, 26.6.2013

[101] Crane, K. et al. (2020). 'Measuring the space economy: Estimating the value of economic activities in and for space'. Available at: https://www.ida.org/-/media/feature/publications/m/me/measuring-the-space-economy-estimating-the-value-of-economic-activities-in-and-for-space/d-10814.ashx

[102] Highfill, T., A. Jouard and C. Franks. (2020). 'Preliminary estimates of the US space economy, 2012–2018'. Available at: https://apps.bea.gov/scb/2020/12-december/1220-space-economy.htm

[103] OECD. (2022). 'OECD Handbook on Measuring the Space Economy, 2nd edition'

[104] Presented in the EC Staff Working Document SWD (2021) 305 final.

and evaluating existing legislation[105]. The better regulation toolbox[106] complements the better regulation guidelines, presenting guidance, tips and best practice for the implementation of the guidelines. Several tools in the toolbox address benefit estimation and represent references for this framework, including:

- Tool #56. Typology of costs and benefits
- Tool #57. Methods to assess costs and benefits
- Tool #61. Simulation models
- Tool #62. Multi-criteria decision analysis
- Tool #63. Cost-benefit analysis
- Tool #64. Discount factors
- Tool #65. Uncertainty and sensitivity analysis
- Tool #67. Data identification for evaluation and impact assessment
- Tool #68. Methods for evaluating causal effects

A5.3 The UK Green Book

The UK Treasury Green Book is a guidance document for the appraisal of policies, programmes and projects and can be supplemented by the Aqua Book, setting out standards for the assurance of analytical modelling and the Magenta Book, which provides guidance for evaluation methods.

Careful selection of guidance from these three guidance sources can be tailored to the needs of the EU Space Programme and the OECD Handbook "Measuring the Space Economy" to answer the European Court of Auditors recommendation that there should be a "conceptual framework for estimating benefits in the domain of space infrastructure [and] …. a structured system for compiling statistical data on the benefits of space services".

The Green Book of the UK Government is a set of guidelines for assessing policies, programmes and projects and is introduced as follows:

> "The Green Book is guidance issued by UK HM Treasury on how to appraise policies, programmes and projects. It also provides guidance on the design and use of monitoring and evaluation before, during and after implementation. Appraisal of alternative policy options is an inseparable part of detailed policy development and design. This guidance concerns the provision of objective advice by public servants to decision makers, which in central government means advice to ministers…… The guidance is for all public servants concerned with proposals for the use of public resources, not just for analysts. The key specialisms involved in public policy creation and delivery, from policy at a strategic level to analysis, commercial strategy, procurement, finance, and implementation must work together from the outset to deliver best public value."

The Green Book methodology provides insightful guidance for the Conceptual Framework. The recent addition of Appendix A7 is particularly relevant to address claims that the space industry offers notable economic productivity gains by systemically based positive returns or feedback

[105] Better regulation: guidelines and toolbox (europa.eu)

[106] BR toolbox - Jul 2023 - FINAL.pdf (europa.eu)

effects, for example through suggestions that space-based navigation (Galileo, GPS and other programmes) constitute a General-Purpose Technology[107], offering a facilitating sub-structure to widely diffused, related innovations. (However, note a counterargument that **no** examples of such a transformative technology exist.[108])

A5.4 EUSPA market analysis and user requirement studies

The European Union Space Programme Agency (EUSPA) is entrusted to accomplish specific tasks related to the European Union Space Programme as indicated in the EU Regulation (EU) 2021/696, including market (and technology) monitoring activities, as well as user relationship management including monitoring of user needs and requirements.

When it comes to market monitoring activities, EUSPA runs a continuous activity of monitoring the development of the growing market for space downstream applications, based on a selection of best practice economic modelling methodologies, as well as analyses of drivers and market trends and on the available market data. The market modelling run by EUSPA represents the market intelligence behind the market data published in the GNSS and EO Market Report.

Considering user needs and requirements, the interaction with user communities is essential to implement an impactful market adoption, which in turn will bring socio-economic benefits. Moreover, the user needs represent a driver for the design, implementation, and evolution of the EU Space Programmes. Considering these needs, EUSPA is leading the User Consultation Platform (UCP), a systematic consultation process with the community of space application users to know their needs so that they can be taken into account by the European Space Programme. The results of the UCP are used to compile and update a series of Reports on User Needs and Requirements per market segment, which represents useful information for the applications that are covered to date.

The market and user requirements related intelligence produced by EUSPA represents therefore an example of key source of information to feed the corresponding elements of the chains of causal effects defined in the conceptual framework.

A5.5 ESA/JRC/Eurostat project on the European Thematic Account

The European Space Agency's current project, in conjunction with the Joint Research Centre and Eurostat (statistical office of the European Union) concentrates on a European version of a thematic account. A thematic account enables the visualisation of the role of a sector in the economy, in terms of what it needs (the 'supplying' industries) and what uses it (the 'using' industries)[109].

The dedicated European Space Economy thematic account will be based on FIGARO inter-country input-output tables and will capture output, Gross Value-Added (GVA) and employment of the space sector, unravelling the role of the space sector in the economy in terms of supply (producers) and demand (consumers) in an extended input-output framework. This framework would capture the

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[107] Arthur DJW, Jenkins B, von Tunzelmann GN, Styles J (2005). The macroeconomic impacts of Galileo. Proceedings of the 18th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 2005). Sept 13-16, 2005, Long Beach Convention Center, Long Beach CA. **The Macroeconomic Impacts of Galileo (ion.org)**

[108] Ristuccia CA, Solomou S (2014). Can general purpose technology theory explain economic growth? Electrical power as a case study, *European Review of Economic History*, 18(3), August 2014, 227–247, https://doi.org/10.1093/ereh/heu008

[109] The methodology report for the thematic account was published on December 15th.

direct, indirect and induced contribution of the space sector to Gross Domestic Product (GDP) and employment, using official statistics. The methodology of the thematic account for the European Space Economy will follow the approach of the US BEA (Highfill & MacDonald, 2022) and take into account the lessons learned from the establishment of other thematic accounts within the EU and the guidelines provided by the OECD handbook of measuring the Space Economy (OECD, 2012 & 2022). Furthermore, it will rely on the 2008 SNA concepts and the UN Guidelines on GVC Satellite Accounts and Integrated Business Statistics (United Nations, 2021[110]). The thematic account for the European Space Economy aims to cover the 27 EU Member States, including 19 ESA Member States, four ESA associate states and five ESA cooperating states, except Canada) as well as the three associated members of the European Space Agency that are not members of the EU.

The work on the European space economy thematic account, once finalised, will support the assessment of the financial impact of the European Space Programme on the space industry. As an example, knowing the detailed official statistics data on the suppliers to the development and manufacture of the hardware (and other inputs) will help determine how much GVA and how many jobs are created by the investment.

Moreover, it will support the assessment of the direct impact of support to the downstream space industry, e.g., through R&D support schemes such as the Horizon programme, thanks to the knowledge of the actual ratios of GVA and jobs to turnover.

A5.6 European Space Agency studies

The European Space Agency has been studying the socio-economic impact of its programmes since the mid-1990s. The main aim of such studies is to measure the transformative impact of space activities on the economies and industries of ESA member states from an ex-post or ex-ante perspective[111].

The studies performed or sponsored by ESA represent useful resources, both from standpoint of the methodological aspects and the results on benefits. Selected studies include:

- Ex-ante socio-economic impact assessments are conducted in the frame of the Agency's Discovery and Preparation element;
- A series of case studies from Technology Transfers in preparation of the 2022 ESA Council at Ministerial level (CM22), with the objective to provide strong examples of the use of space outside of the space industry itself, demonstrating benefits in terms of technological innovation, commercialisation, economic growth, and for the European society overall;
- The Sentinel Benefits Studies conducted by the European Association of Remote Sensing Satellites, analysing and assessing the economic benefits generated along the value chain of selected examples of usage of Sentinel data.

[110] United Nations, 2021. Accounting for Global Value Chains: GVC Satellite Accounts and Integrated Business Statistics. Department of Economic and Social Affairs. United Nations Statistics Division. Studies in Methods. Series F No. 120. New York https://unstats.un.org/unsd/businessstat/GVC/Accounting_for_GVC_web.pdf

[111] Further information available at ESA - Socio-economic impact of space activities

A5.7 US Bureau for Economic Analysis

Related to the ESA/JRC/Eurostat work, the US Bureau for Economic Analysis has undertaken recent work on measuring the space economy[112,113]. The BEA is assisting in defining the scope for the ESA/JRC/Eurostat space economy thematic account for Europe.

The paper "Estimating the United States Space Economy Using Input-Output Frameworks" examines two first-of-their-kind economic datasets about the United States (US) space sector that use input-output (I-O) frameworks at their foundation. It explains what these data tell about the impact on the US economy stemming from National Aeronautics and Space Administration (NASA) spending and the production of space-related goods and services. Overall, the data show NASA's total economic output in 2019 was $64.3 billion and supported over 312,000 jobs. Additionally, space-related production was found to represent 0.5 percent of US gross domestic product in 2018. We describe the advantages of using I-O-based data like these over revenue-based economic reports that are commonly used in the space policy arena and that suffer from important measurement issues.

A5.8 NASA studies

The North American Space Agency has employed a team at the University of Illinois at Chicago to carry out an economic impact study[114].

This study is an assessment of the economic impacts of the National Aeronautics and Space Administration (NASA) and the Moon to Mars Program (M2M) for the Fiscal Year 2019. The assessment consists of two parts. The first part presents the estimation of NASA impacts on the U.S. as a whole, fifty (50) states, and the District of Columbia (DC). The second part analyses economic impacts attributable to the M2M program on the same set of regions. The purpose of the economic impact assessment is to quantify the changes in employment, income, levels of business activity, and government revenue throughout the entire economy that result from NASA's activities and that of the M2M programme.

A5.9 Studies from the US Institute for Defense Analysis

The US Institute for Defense Analysis[115] has published a report on Measuring the Space Economy: Estimating the Value of Economic Activities in and for Space. Its purpose is summarised thus:

"To provide more targeted estimates of the size of the space economy than are currently employed. It does so by adopting a more restrictive definition of the space economy that only includes the value of goods and services provided to governments, households, and businesses from space or used to support

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[112] Estimating the United States Space Economy Using Input-Output Frameworks - ScienceDirect Highfill TC, MacDonald AC (2022). Estimating the United States Space Economy Using Input-Output Frameworks, Space Policy, Volume 60, https://doi.org/10.1016/j.spacepol.2021.101474.

[113] SCB, Preliminary Estimates of the U.S. Space Economy, December 2020 (bea.gov)

[114] NASA economic impact study National Aeronautics and Space Administration & Moon to Mars Program. Economic Impact Study (2020). The Nathalie P. Voorhees Center for Neighbourhood and Community Improvement, University of Illinois at Chicago

[115] Measuring the Space Economy: Estimating the Value of Economic Activities in and for Space (ida.org) March 2020.

activities in space; it excludes activities that are enabled by space but are primarily generated terrestrially.

Although the scoping of this report takes a narrower definition of than the ones adopted for example by the OECD, it includes relevant methodological reflections for the conceptual framework.

A5.10 Publications from the Canadian Space Agency

The Canadian Space Agency regularly publishes the State of the Canadian Space Sector Report[116], providing information about the Canadian space sector. The report covers the economic impact analysis, the assessment of the overall results, the revenues by market and customers and innovation, featuring Business Expenditures on R&D (BERD) and R&D intensity data.

A5.11 Studies from the Australian Space Agency

International organisations such as the Australian Space Agency[117] track the growth of their national space sector with the explicit definition and use of a framework. This framework defines the sector and value chain before using these definitions to define the overall space economy, key indicators, and measurement methodology.

[116] 2020 State of the Canadian Space Sector Report - Facts and Figures 2019 | Canadian Space Agency (asc-csa.gc.ca)

[117] Australian Space Agency. (2021). 'Economic snapshot of the Australian space sector: 2016-17 to 2018-19'. Available at: http://www.industry.gov.au/sites/default/files/2021-02/snapshot-report-australian-civil-space-sector-2016-17-to-2018-19.pdf

Annex 6 Taxonomies of space-enabled applications of interest for satellite navigation and Earth Observation

As mentioned in the report, since the benefits for users and the society are produced through space-enabled applications, developing an understanding of these applications is fundamental. In this sense, taxonomies represent useful tools as they can be used to populate, organize and index the necessary knowledge. Focusing on space-enabled applications, effective taxonomies meet two requirements; a) they are exhaustive in their coverage of applications and b) are mutually exclusive. In other words, the categorisation should ensure that no overlap ideally exists among the applications that are part of the taxonomy.

In the frame of the application of the conceptual framework to appraise the benefits of a given space service, taxonomies provide an operational support as they enable to identify and choose the relevant applications that are expected to use the said service and, consequently, are relevant for the calculation of socio-economic benefits.

The table below shows an exemplification of taxonomy of applications and their relevance for GNSS and Earth Observation from EUSPA's GNSS and EO Market Report, issue 2. The description of the applications is featured in Annex 3[118].

Table 6: Taxonomy of space-enabled applications in the GNSS and EO Market Report – issue 2

Segments	Subsegments	Applications	GNSS	EO	Synergy
Agriculture	Environmental monitoring	Carbon capture & content assessment		x	
		Environmental impact monitoring		x	
	Natural resources monitoring	Biomass monitoring			x
		Crop yield forecasting			x
		Soil condition monitoring			x
		Vegetation monitoring		x	
	Operations management	Asset monitoring	x		
		Automatic steering	x		
		CAP monitoring			x
		Farm machinery guidance	x		
		Farm management systems			x
		Field definition			x
		Livestock wearables	x		
		Pastureland management		x	
		Precision irrigation			x
		Variable rate application			x
	Weather services for agriculture	Climate services for agriculture		x	
		Weather forecasting for agriculture		x	
Aviation and drones	Communication	ATM System Timing	x		
	Environmental Monitoring	Aircraft Emission Measurement and Monitoring			x
		Particulate Matter Monitoring		x	
	Navigation	Drone navigation	x		
		Performance Based Navigation (PBN)	x		
		Performance Based Navigation (PBN) for drones	x		
		VFR complement	x		

[118] By covering only GNSS and EO, the conceptualisation is not exhaustive for all the components of the EU space programme. Moreover, it is not exhaustive in terms of application domains, since technical and market innovation continuously leads to new ways of embedding and use space data and services. Moreover, only applications where the use of solutions involves financial transactions are covered by the taxonomy, which excludes some of the applications used by governmental organisations.

Segments	Subsegments	Applications	GNSS	EO	Synergy
	Operations Management	Aircraft Maintenance and Operation Optimisation		x	
		Airport Capacity and Safety		x	
		Drone Operations Planning	x		
		Monitoring Terrains Obstacles		x	
		U-space services	x		
	Surveillance	Electronic Conspicuity (uncertified)	x		
		Electronic Conspicuity (certified)			
		GADSS	x		
		Infrastructure Timing	x		
	Weather Services	Hazardous Weather Identification		x	
Climate, Ecosystems and Biodiversity	Biodiversity, Ecosystems and Natural Capital	Animal tracking for biodiversity purposes	x		
		Ecosystems monitoring		x	
	Climate services	Climate change mitigation and adaptation		x	
		Climate monitoring and forecasting		x	
		EO-based climate modelling		x	
		GNSS-based climate modelling	x		
	Environmental monitoring	Environmental auditing		x	
		Environmental impact assessment and ESG		x	
		Environmental resources management		x	
Consumer solutions, tourism and health	Corporate	Location-based billing	x		
		Geo-advertising			x
		Mapping & GIS			x
		Workforce management	x		
	Health & Lifestyle	Air quality monitoring		x	
		Games			x
		Geo-tagging			x
		mHealth	x		
		Safety and emergency	x		
		Social networks	x		
		Sport, fitness and wellness incl. specialist support tracking			x
		UV monitoring		x	
		Tourism Fruition	x		
	Navigation & Tracking	Navigation	x		
		Personal & asset tracking	x		
		Visually impaired support	x		
	Robotics	Consumer robotic	x		
		Enhanced human	x		
Emergency management and humanitarian aid	Prevention & Mitigation	Impact exposure analysis and proactive mitigation measures		x	
	Preparedness	Early warning emergency applications			x
		Hazards monitoring			x
	Response	Crisis area assessment			x
		Operational wildfires modelling		x	
	Post-event recovery	Post-crisis damage assessment and building inspection			x
		Restoration of supply chain and infrastructure services			x
	Humanitarian aid	Health and medicine response and coordination (incl. anticipatory humanitarian action)			x
		Management of refugee camps		x	
		Population displacement monitoring		x	
		NGO's asset management	x		
		Welcome applications to people in need of humanitarian aid	x		
	Search and Rescue	SAR operations: at sea	x		
		SAR operations: aviation	x		
		SAR operations: land	x		
		Situational awareness supporting SAR		x	

Segments	Subsegments	Applications	GNSS	EO	Synergy
Energy and raw materials	Energy Network Fidelity	Energy Network conditions monitoring		x	
		Phasor Measurement Units (PMU)	x		
	Environmental Impact Monitoring	Environmental impact assessment for energy and raw materials		x	
	Market Intelligence	Supply chain insights		x	
	Raw Materials	Illegal mining monitoring		x	
		Mining vehicle management and control	x		
		Mineral exploration, site selection planning/monitoring			x
	Renewable Energy	Renewable energy assessment potential and forecast		x	
		Renewable energy plant design optimisation		x	
		Risk assessment for renewable energy assets		x	
		Renewable energy site selection, planning and monitoring			x
Fisheries and aquaculture	Aquaculture	Aquaculture operations optimisation			x
		Aquaculture site selection		x	
	Fisheries	Illegal, unreported and unregulated fishing (IUU) control			x
		Catch optimisation		x	
		Fish stock detection and modelling		x	
		Fishing aggregating devices	x		
		Fishing vessels navigation	x		
Forestry	Environmental monitoring	Biomass monitoring			x
		Deforestation/degradation monitoring		x	
	Natural resources monitoring	Forest Inventory monitoring			x
		Forest vegetation health monitoring		x	
		Illegal logging monitoring		x	
	Operations management	Automatic steering	x		
		Forest asset management	x		
		Forest certification		x	
		Forest machinery guidance	x		
Infrastructure	Environmental Impact Monitoring	Environmental impact assessment of infrastructure		x	
	Infrastructure Construction and Monitoring	Construction Monitoring			x
		Monitoring of impact of human activities on infrastructure		x	
		Oracle Database Appliance (ODA) Support Monitoring		x	
		Pipeline Monitoring			x
		Post-Construction Monitoring			x
	Infrastructure Planning	Infrastructure Site Selection and Planning			x
		Permitting		x	
		Vulnerability Analysis		x	
	Timing & Synchronisation of Telecommunication Networks	Data Centre	x		
		Digital Cellular Network (DCN)	x		
		Professional Mobile Radio (PMR)	x		
		Public Switched Telephone Network (PSTN)	x		
		Satellite Communication (SATCOM)	x		
		Small Cells	x		
Insurance and finance	Finance	Commodities trading		x	
		ESG Reporting		x	
		Risk assessment		x	
		Timing and synchronisation for finance	x		
	Insurance for natural disasters	Event footprint		x	
		Index production		x	
		Risk modelling		x	
Maritime and inland waterways	Inland waterways	Autonomous Surface Vessels			x
		Collision Avoidance (AIS, VDES)	x		
		GNSS vessel engine management system	x		
		Inland waterways navigation			x
	Maritime engineering	Marine surveying and mapping			x

Segments	Subsegments	Applications	GNSS	EO	Synergy
		Dredging			x
	Merchant vessels	Collision avoidance (AIS, VDES)	x		
		GNSS vessel engine management systems	x		
		Maritime Autonomous Surface Ships			x
		Merchant navigation	x		
		Navigation through sea ice			x
		Ship route navigation			x
	Ocean and Environmental monitoring	Maritime pollution monitoring		x	
	Port	Automated port operations	x		
		Piloting assist at ports			x
		Port safety			x
		Port security		x	
		Port Operations	x		
	Recreational craft	Recreational navigation	x		
	Vessel tracking	Dark vessel monitoring			x
Rail	Attractiveness enhancement	Passenger information systems	x		
		Public Transport – Tram and Light Rail	x		
	Maintenance improvement	Condition-based maintenance	x		
		Infrastructure monitoring		x	
		Predictive maintenance	x		
	Safety related	Enhanced Command & Control Systems	x		
		Trackside personnel protection systems	x		
	Train driving optimisation	Driver Advisory Systems (DAS)	x		
		Fleet management	x		
Road and automotive	Asset management	Bike sharing	x		
		Public transport - buses	x		
		Road fleet management	x		
	Liability and enforcement	Insurance telematics	x		
		Road User Charging (RUC)	x		
		Smart tachographs	x		
	Safety related	Connected and Automated Driving (CAD)	x		
		Emergency assistance	x		
	Smart mobility	Congestion control			x
		Infotainment services			x
		Navigation – In-Vehicle Systems (IVS) & Personal Navigation Devices (PND)	x		
Urban development and cultural heritage	Environmental Monitoring	Air quality monitoring in urban environments		x	
		Light pollution		x	
		Thermal auditing		x	
		Urban greening			x
		Urban heat islands		x	
	Smart Cities Operations	Smart streetlights	x		
		Smart waste management	x		
	Urban planning and monitoring	Informal dwellings		x	
		Real estate		x	
		Surveying and mapping of urban areas			x
		Urban modelling, 3D modelling, Digital Twins			x
		Urban planning		x	
Space	Supporting or Acting as Mission Payloads	Technology Demonstration (TechD)	x		
		Scientific & Operational Missions (SOM)	x		
	Lunar Applications	Lunar Orbit (LO)	x		
		Moon Surface Positioning (MS)	x		
		Translunar Orbit (TLO)	x		
	Guidance, Navigation and Control (GNC) Subsystem	Attitude Determination (AD)	x		
		Precise Orbit Determination (POD)	x		
		Real Time Navigation (RTN)	x		
		Space Timing and Synchronisation (S-T&S)	x		

It is important to highlight that, beyond EUSPA's taxonomy, other taxonomies do exist and are equally suitable to support the assessment of benefits from space programme, as long as they are comprehensive and mutually exclusive from the standpoint of covering the application. Selected examples of other taxonomies include:

- For GNSS, the taxonomies developed within studies on benefit estimations, including as selected examples, the list of application sectors published on GPS.gov[119]; the study on Economic Benefits of the Global Positioning System (GPS), sponsored by the National Institute of Standards and Technology;
- for Earth Observation, the EO EARSC EO taxonomy[120], the taxonomy produced in 2019 for the UK Space Agency[121], etc.

[119] GPS.gov: Applications

[120] https://earsc-portal.eu/display/EOwiki/EO+Taxonomy

[121] The-many-uses-of-Earth-Observation-data.pdf (ukspace.org)

Annex 7 List of relevant NACE codes for the space economy[122]

As presented in the table below, a total of 51 NACE codes and 221 CPA codes have been identified as relevant for the European space economy. Most of the CPA codes fall under the section C – Manufactured products (83), section J – Information and communication services (57), and section M – Professional, scientific and technical services (34). Moreover, CPA codes were identified within the sections F – Construction and construction works (16), O – Public administrative and defence services; compulsory social security services (12), P – Educational services (12), H – Transportation and storage services (3), K – Financial and insurance services (2), and R – Arts, entertainment and recreational services (2).

Table: NACE and CPA codes for space activities

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		C - MANUFACTURED PRODUCTS	
20.11	Manufacture of industrial gases	20.11.11	Hydrogen, argon, rare gases, nitrogen and oxygen
		20.11.13	Liquid air and compressed air
		20.11.99	Sub-contracted operations as part of manufacturing of industrial gases
25.11	Manufacture of metal structures and parts of structures	25.11.23	Other structures and parts of structures, plates, rods, angles, shapes and the like, of iron, steel or aluminium
		25.11.99	Sub-contracted operations as part of manufacturing of metal structures and parts of structures
25.29	Manufacture of other tanks, reservoirs and containers of metal	25.29.11	Reservoirs, tanks, vats and similar containers (other than for compressed or liquefied gas), of iron, steel or aluminium, of a capacity > 300 litres, not fitted with mechanical or thermal equipment)
		25.29.12	Containers for compressed or liquefied gas, of metal
		25.29.99	Sub-contracted operations as part of manufacturing of tanks, reservoirs and containers of metal
25.61	Treatment and coating of metals	25.61.11	Metallic coating services of metal
		25.61.12	Non-metallic coating services of metal
		25.61.21	Heat treatment services of metal, other than metallic coating
		25.61.22	Other surface treatment services of metal
25.62	Machining	25.62.10	Turning services of metal parts

[122] European space economy thematic account

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		25.62.20	Other machining services
26.11	Manufacture of electronic components	26.11.12	Magnetrons, klystrons, microwave tubes and other valve tubes
		26.11.21	Diodes; transistors; thyristors, diacs and triacs
		26.11.22	Semiconductor devices; light-emitting diodes; mounted piezo-electric crystals; parts thereof
		26.11.30	Electronic integrated circuits
		26.11.40	Parts of electronic valves and tubes and of other electronic components n.e.c.
		26.11.91	Services connected with manufacturing of electronic integrated circuits
		26.11.99	Sub-contracted operations as part of manufacturing of electronic components
26.20	Manufacture of computers and peripheral equipment	26.20.17	Monitors and projectors, principally used in an automatic data processing system
		26.20.22	Solid-state non-volatile storage devices
26.30	Manufacture of communication equipment	26.30.11	Transmission apparatus incorporating reception apparatus
		26.30.12	Transmission apparatus not incorporating reception apparatus
		26.30.22	Telephones for cellular networks or for other wireless networks
		26.30.23	Other telephone sets and apparatus for transmission or reception of voice, images or other data, including apparatus for communication in a wired or wireless network (such as a local or wide area network)
		26.30.40	Aerials and aerial reflectors of all kind and parts thereof; parts of radio and television transmission apparatus and television cameras
		26.30.50	Burglar or fire alarms and similar apparatus
		26.30.60	Parts of burglar or fire alarms and similar apparatus
		26.30.99	Sub-contracted operations as part of manufacturing of communication equipment
26.51	Manufacture of instruments and appliances for measuring, testing and navigation	26.51.11	Direction-finding compasses; other navigational instruments and appliances
		26.51.12	Rangefinders, theodolites and tachymetres (tachometers); other surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		26.51.20	Radar apparatus and radio navigational aid apparatus
		26.51.41	Instruments and apparatus for measuring or detecting ionising radiations
		26.51.43	Instruments for measuring electrical quantities without a recording device
		26.51.44	Instruments and apparatus for telecommunications
		26.51.45	Instruments and apparatus for measuring or checking electrical quantities n.e.c.
		26.51.51	Hydrometers, thermometers, pyrometers, barometers, hygrometers and psychrometers
		26.51.52	Instruments for measuring or checking the flow, level, pressure or other variables of liquids and gases
		26.51.53	Instruments and apparatus for physical or chemical analysis n.e.c.
		26.51.66	Measuring or checking instruments, appliances and machines n.e.c.
		26.51.81	Parts of radar apparatus and radio navigational aid apparatus
		26.51.85	Parts and accessories of instruments and apparatus of 26.51.65, 26.51.66 and 26.51.70
		26.51.99	Sub-contracted operations as part of manufacturing of measuring, testing and navigating equipment
26.52	Manufacture of watches and clocks	26.52.13	Instrument panel clocks and clocks of a similar type for vehicles
26.70	Manufacture of optical instruments and photographic equipment	26.70.11	Objective lenses for cameras, projectors or photographic enlargers or reducers
		26.70.21	Sheets and plates of polarising material; lenses, prisms, mirrors and other optical elements (except of glass not optically worked), whether or not mounted, other than for cameras, projectors or photographic enlargers or reducers
		26.70.22	Binoculars, monoculars and other optical telescopes; other astronomical instruments; optical microscopes
		26.70.23	Liquid crystal devices; lasers, except laser diodes; other optical appliances and instruments n.e.c.
		26.70.24	Parts and accessories of binoculars, monoculars and other optical telescopes, of other astronomical instruments, and of optical microscopes

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		26.70.25	Parts and accessories of liquid crystal devices, lasers (except laser diodes), other optical appliances and instruments n.e.c.
		26.70.99	Sub-contracted operations as part of manufacturing of optical instruments and photographic equipment
27.90	Manufacture of other electrical equipment	27.90.13	Carbon electrodes and other articles of graphite or other carbon for electrical purposes
		27.90.20	Indicator panels with liquid crystal devices or light emitting diodes; electric sound or visual signalling apparatus
		27.90.40	Other electrical equipment n.e.c. (including electro-magnets; electro-magnetic couplings and brakes; electro-magnetic lifting heads; electrical particle accelerators; electrical signal generators)
		27.90.51	Fixed capacitors for 50/60 Hz circuits having a reactive power handling capacity â‰¥ 0,5 kvar
		27.90.52	Other fixed capacitors
		27.90.53	Variable or adjustable (pre-set) capacitors
		27.90.60	Electrical resistors, except heating resistors
		27.90.81	Parts of electrical capacitors
		27.90.82	Parts of electrical resistors, rheostats and potentiometers
		27.90.99	Sub-contracted operations as part of manufacturing of other electrical equipment
28.12	Manufacture of fluid power equipment	28.12.11	Linear acting hydraulic and pneumatic motors (cylinders)
		28.12.12	Rotating hydraulic and pneumatic motors
		28.12.13	Hydraulic pumps
		28.12.14	Hydraulic and pneumatic valves
		28.12.15	Hydraulic assemblies
		28.12.16	Hydraulic systems
		28.12.20	Parts of fluid power equipment
		28.12.99	Sub-contracted operations as part of manufacturing of fluid power equipment
30.30	Manufacture of air and spacecraft and related machinery	30.30.11	Aircraft spark-ignition engines
		30.30.12	Turbo-jets and turbo-propellers
		30.30.13	Reaction engines, excluding turbo-jets
		30.30.15	Parts for aircraft spark-ignition engines
		30.30.16	Parts of turbo-jets or turbo-propellers
		30.30.20	Balloons and dirigibles; gliders, hang gliders and other non-powered aircraft

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		30.30.40	**Spacecraft (including satellites) and spacecraft launch vehicles**
		30.30.50	Other parts of aircraft and spacecraft
		30.30.60	Overhaul and conversion services of aircraft and aircraft engines
		30.30.99	Sub-contracted operations as part of manufacturing of air and spacecraft and related machinery
32.99	Other manufacturing n.e.c.	32.99.11	Safety headgear and other safety products
33.16	**Repair and maintenance of aircraft and spacecraft**	33.16.10	Repair and maintenance services of aircraft and spacecraft
	F - CONSTRUCTION AND CONSTRUCTION WORKS		
41.00	Buildings and building construction works	41.00.25	Traffic and communication buildings
		41.00.45	Construction works in traffic and communication buildings
42.11	Roads and motorways; construction works for roads and motorways	42.11.10	Motorways, roads, streets and other vehicular or pedestrian ways and airfield runways
		42.11.20	Construction works for motorways, roads, streets and other vehicular or pedestrian ways and airfield runways
42.22	Construction of utility projects for electricity and telecommunications	42.22.11	Long-distance electricity power lines and communication lines
		42.22.12	Local electricity power lines and communication lines
		42.22.21	Construction works for long-distance electricity power lines and communication lines
		42.22.22	Construction works for local electricity power lines and communication lines
42.99	Constructions and construction works for other civil engineering projects n.e.c.	42.99.11	Mining and manufacturing constructions
		42.99.19	Other civil engineering constructions n.e.c.
		42.99.21	Construction works for mining and manufacturing
		42.99.29	Construction works for civil engineering constructions n.e.c.
43.12	Site preparation	43.12.11	Soil and land preparation works; clearance works

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		43.12.12	Excavating and earthmoving works
43.13	Test drilling and boring works	43.13.10	Test drilling and boring works
43.21	Electrical installation	43.21.10	Electrical installation works

H - TRANSPORTATION AND STORAGE SERVICES

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
51.22	Space transport	51.22.11	Space transport services of passengers
		51.22.12	Space transport services of freight
52.23	Service activities incidental to air transportation	52.23.20	Services incidental to space transportation

J - INFORMATION AND COMMUNICATION SERVICES

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
58.11	Book publishing	58.11.11	Printed educational textbooks
		58.11.12	Printed professional, technical and scholarly books
		58.11.13	Printed children books
		58.11.14	Printed dictionaries and encyclopaedias
		58.11.15	Printed atlases and other books with maps
		58.11.19	Other printed books, brochures, leaflets and the like
		58.11.20	Books on disk, tape or other physical media
		58.11.30	On-line books
		58.11.50	Publishing of books on a fee or contract basis
58.29	Other software publishing	58.29.11	Operating systems, packaged
		58.29.12	Network software, packaged
		58.29.13	Database management software, packaged
		58.29.14	Development tools and programming languages software, packaged
		58.29.31	System software downloads
		58.29.32	Application software downloads
		58.29.40	On-line software
		58.29.50	Licensing services for the right to use computer software
60.10	Radio broadcasting	60.10.11	Radio programming and broadcasting services
		60.10.12	Radio broadcasting originals
		60.10.20	Radio channel programmes
		60.10.30	Radio advertising time
60.20	Television programming and broadcasting activities	60.20.11	On-line television programming and broadcasting services, except by subscription
		60.20.12	Other television programming and broadcasting services, except by subscription
		60.20.13	On-line television subscription programming and broadcasting services

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		60.20.14	Other television subscription programming and broadcasting services
		60.20.20	Television broadcasting originals
		60.20.31	Television channel programmes, except for subscription television
		60.20.32	Subscription television channel programmes
		60.20.40	Television advertising time
61.10	Wired telecommunications activities	61.10.11	Fixed telephony services - access and use
		61.10.12	Fixed telephony services - calling features
		61.10.13	Private network services for wired telecommunications systems
		61.10.30	Data transmission services over wired telecommunications networks
		61.10.41	Internet backbone services
		61.10.42	Narrow-band Internet access services over wired networks
		61.10.43	Broad-band Internet access services over wired networks
		61.10.49	Other wired Internet telecommunications services
61.20	Wireless telecommunications activities	61.20.11	Mobile telecommunications services - access and use
		61.20.12	Mobile telecommunications services - calling features
		61.20.13	Private network services for wireless telecommunications systems
		61.20.20	Carrier services for wireless telecommunications
		61.20.30	Data transmission services over wireless telecommunications networks
		61.20.41	Narrow-band Internet access services over wireless networks
		61.20.42	Broad-band Internet access services over wireless networks
		61.20.49	Other wireless Internet telecommunications services
		61.20.50	Home programme distribution services over wireless networks
61.30	Satellite telecommunications activities	61.30.10	Satellite telecommunications services, except home programme distribution services via satellite
		61.30.20	Home programme distribution services via satellite

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
61.90	Other telecommunications activities	61.90.10	Other telecommunications services
62.01	Computer programming activities	62.01.11	IT design and development services for applications
		62.01.12	IT design and development services for networks and systems
		62.01.21	Computer games software originals
		62.01.29	Other software originals
62.02	Computer consultancy activities	62.02.10	Hardware consultancy services
		62.02.20	Systems and software consultancy services
		62.02.30	IT technical support services
62.09	Other information technology and computer service activities	62.09.20	Other information technology and computer services n.e.c.

K - FINANCIAL AND INSURANCE SERVICES

65.12	Non-life insurance	65.12.33	Other aircraft insurance services
		65.12.36	Freight insurance services

M - PROFESSIONAL, SCIENTIC AND TECHNICAL SERVICES

70.22	Business and other management consultancy activities	70.22.11	Strategic management consulting services
		70.22.12	Financial management consulting services (except corporate tax)
		70.22.13	Marketing management consulting services
		70.22.14	Human resources management consulting services
		70.22.15	Production management consulting services
		70.22.16	Supply chain and other management consulting services
		70.22.17	Business process management services
		70.22.20	Other project management services, except construction project management services
		70.22.30	Other business consulting services
		70.22.40	Trademarks and franchises
71.12	Engineering activities and related technical consultancy	71.12.11	Engineering advisory services
		71.12.17	Engineering services for industrial and manufacturing projects
		71.12.18	Engineering services for telecommunications and broadcasting projects

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
		71.12.19	Engineering services for other projects
		71.12.34	Surface surveying services
		71.12.35	Map-making services
72.19	Other research and experimental development on natural sciences and engineering	72.19.11	Research and experimental development services in mathematics
		72.19.12	Research and experimental development services in computer and information sciences
		72.19.13	Research and experimental development services in physical sciences
		72.19.14	Research and experimental development services in chemistry
		72.19.29	Other research and experimental development services in engineering and technology, except biotechnology
72.20	Research and experimental development on social sciences and humanities	72.20.11	Research and experimental development services in economics and business
		72.20.12	Research and experimental development services in psychology
		72.20.13	Research and experimental development services in law
		72.20.19	Research and experimental development services in other social sciences
		72.20.29	Other research and experimental development services in humanities
		72.20.30	Research and development originals in social sciences and humanities
73.11	Advertising agencies	73.11.11	Full service advertising services
74.90	Other professional, scientific and technical activities n.e.c.	74.90.11	Bill auditing and freight rate information services
		74.90.13	Environmental consulting services
		74.90.14	Weather forecasting and meteorological services
		74.90.15	Security consulting services
		74.90.19	Other scientific and technical consulting services n.e.c.
		74.90.20	Other professional, technical and business services n.e.c.

O - PUBLIC ADMINISTRATIVE AND DEFENCE SERVICES; COMPULSORY SOCIAL SECURITY SERVICES

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
84.11	General public administration activities	84.11.13	Overall economic and social planning and statistical services
		84.11.14	Government services to fundamental research
		84.11.19	Other general (overall) public services
		84.11.21	General personnel services for the government
84.13	Regulation of and contribution to more efficient operation of businesses	84.13.12	Administrative fuel- and energy-related services
		84.13.14	Administrative transport- and communications-related services
		84.13.16	Administrative services related to tourism affairs
		84.13.17	Administrative multipurpose development project services
84.21	Foreign affairs	84.21.13	Foreign military aid-related services
84.22	Defense Services	84.22.11	Military defence services
		84.22.12	Civil defence services
84.24	Public order and safety services	84.24.19	Other public order and safety affairs-related services
		P - EDUCATIONAL SERVICES	
85.41	Post-secondary non-tertiary education	85.41.11	On-line post-secondary non-tertiary general education services
		85.41.12	Other post-secondary non-tertiary general education services
		85.41.13	On-line post-secondary non-tertiary technical and vocational education services
		85.41.14	Other post-secondary non-tertiary technical and vocational education services
85.42	Tertiary education	85.42.11	On-line short-cycle tertiary education services
		85.42.12	Other short-cycle tertiary education services
		85.42.21	On-line Bachelor's or equivalent level tertiary education services
		85.42.22	Other Bachelor's or equivalent level tertiary education services
		85.42.31	On-line Master's or equivalent level tertiary education services
		85.42.32	Other Master's or equivalent level tertiary education services
		85.42.41	On-line Doctoral or equivalent level tertiary education services
		85.42.42	Other Doctoral or equivalent level tertiary education services

NACE CODE	NACE CODE DESCRIPTION	CPA CODE	CPA CODE DESCRIPTION
	R - ARTS, ENTERTAINMENT AND RECREATION SERVICES		
91.02	Museums activities	91.02.10	Museum operation services
		91.02.20	Museum collections

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