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A downstream exploration of the geospatial data ecosystem

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1.Introduction

The growth of geospatial data in recent years has created a wealth of options for industries and organizations to gather actionable information and make informed decisions. But the abundance of data and the variety of sources it comes from has also made collaboration and interoperability between the public and commercial sectors difficult. With an emphasis on how interoperability can be improved and how the public and private sectors could collaborate more closely to fully exploit the promise of this data, this thesis attempts to study the downstream components of the geospatial data ecosystem. The Euroconsult report[1] estimates that the global space economy in 2021 was $370 billion, including the space market (337B) and government spending (33B) on space activities. It predicts 74% growth by 2030 to reach $642 billion (6.3% CAGR).The report notes that satellite communications in terms of revenue will gather 60% of the total in 2021, largely due to services enabled by global navigation satellite systems and their related devices. The downstream market for satellite services, i.e. the use of data and information gathered from space missions, is currently experiencing a period of growth. This growth is closely correlated with two main factors: demographic evolution and the evolution of the regional standard of living. These factors generate an increase in the need for connectivity and navigation services. Furthermore, the need for broadband connectivity has been further fueled by the ambition of various governments to reduce the digital divide through development programs, such as RDOF (Rural Digital Opportunity Fund), which funds satellite connectivity. The downstream market is dominated by satellite navigation services (SatNav), this segment is heavily influenced by "space-enabled applications" (vs. revenues from the core space industry). These activities generate revenue based on the use of GNSS (Global Navigation Satellite Systems) signals. They include various activities that are only indirectly related to the space industry. Satcom represents the second largest fraction of the downstream market, still dominated by a dwindling satellite TV business, but increasingly driven by connectivity needs for governments, businesses, and individuals. Other markets account for a more modest share of the services market, with specific dynamics: despite growth, Earth observation accounts for only a modest 2% of downstream space markets due to the absence of large B2Cs. In general, the downstream industry has a very diverse landscape, largely dominated by commercial activities. Private companies and private end users remain the main customers of satellite signals, driven by the mass market nature of the B2C SatNav and Satcom markets. Despite historical ownership of their assets, defense actors increasingly tend to contract specific tasks from the private sector, especially for satellite imagery.

1 Space Economy Report 2022 url: https://digital-platform.euroconsult-ec.com/wp-content/uploads/2023/01/Sp_Economy_2022_extract.pdf?t=63c16ea575274

Critical military systems usually remain the property of the Ministry of Defences, but outsourcing to commercial players becomes an increasingly common practice. Civilian government spending is driven by the ordering of Earth observation or security satellite systems. Earth observation systems, like navigation systems, are used to stimulate economic growth by offering a free service to the population to promote their development. In general, it can be stated that the downstream market of satellite services is characterized by a wide range of players and constantly evolving dynamics, and represents a key area for the development and use of space technology.

2. *Overview of the geospatial data ecosystem*

To begin exploring the ecosystem that hosts geospatial data, it is necessary to start with a general description of all the parts that make up this whole.

Starting from the various types of data both from a technical and legal point of view. Continuing with a description of the European legislation that has evolved over time around the different technologies that have enriched this context. Continuing towards an analysis of the economy of space reporting numerical data that highlight the strengths of this sector. Finally, a description of the technologies and standards that have brought the exploitation of this type of data to this point.

2.1. *Types of geospatial data*

Commercial and open geospatial data are the two main categories of geospatial data. Private companies create and maintain commercial geospatial data, which is then sold for use by businesses or the general public. While this data is often of a high standard and offers precise geospatial information, it is always subject to limitations in terms of accessibility to this data and price which often do not take into consideration small customers. Free and open geospatial data, on the other hand, is accessible to the general public at no cost and is open to use and sharing. While the accuracy of this data may not be as high as commercial data, it still provides useful information for many applications. The unique requirements of the project will determine which of the two forms of data to use, and accuracy and freedom of use must be taken into consideration.

From a technical point of view, however, we can group these data into three macro categories:

Vector data, this is a type of data that represent geographic features, such as points, lines, and polygons, using mathematical equations. These equations define the shape, size, and location of features in a coordinate system. Often used in GIS (Geographical Information Systems), they can be used to create maps and perform spatial analysis. In the space industry, vector data is used for various applications, such as satellite image analysis, navigation and mission planning. They can include information such as the location, shape, and ownership of objects. For example, they can be used to create detailed maps of an area where a spacecraft is planning to land or to track the movement of orbiting satellites. Space agencies, such as NASA and the European Space Agency, use vector data to analyze images from satellites and other spacecraft to understand the earth's surface, oceans and atmosphere. In addition, they are used to calculate the trajectory of a rocket or plan the movement of an orbiting spacecraft. Private space industry companies use vector data to track and predict the movement of space debris to avoid collisions with operational satellites.

Raster data, also known as grid or image data, represents geographic features as a grid of cells, each containing a value or set of values. Used to represent continuous surfaces such as elevation, temperature, and land cover, they can include information such as elevation, vegetation, and land cover. Each cell in the grid represents a specific area on the Earth, and its value represents the characteristic of that area. In the space industry, raster data is used to represent satellite imagery such as aerial photography or remote sensing data. Used to study and monitor natural resources, such as vegetation, water, and minerals, and track land use change, urban growth, and other environmental issues. Private space industry companies use raster data to create detailed maps of the Earth for purposes such as navigation, urban planning, and natural resource management. Also used to monitor and track the movement of natural and man-made features such as disasters, oil spills, and land use changes.

Alphanumeric data is a data type that contains letters and numbers, such as text, numbers, and dates. Used to store information in a structured format such as spreadsheets or databases, they can contain names, addresses, dates, and numeric values. In the space industry, they are used in various applications such as spacecraft telemetry, mission planning, and data analysis. Also used to store information about satellite launches, payloads, and orbits, and to record spacecraft status information, such as power, temperature, and vital signs. Private space industry companies use alphanumeric data to store satellite telemetry information such as signal strength and to track and analyze the performance of spacecraft and other space assets.

In general, these data are essential for the management of space programs and mission planning, as they provide valuable information for performance evaluation and the prevention of any problems.

2.2. Legislation and distribution of geospatial data in EU.

The downstream part of the space industry is governed in Europe by a variety of different rules and regulations. These regulations aim to ensure the effective and safe use of space technology while promoting the development and expansion of the sector.

A key piece of legislation with the goal of increasing accessibility and reusability of public sector information is Directive (EU) 2019/1024[2] of the European Parliament and of the Council of June 20, 2019, on open data and the re-use of public sector information (recast). All EU member states must comply with this directive, which obliges them to make their geospatial data publicly accessible for reuse in both the public and private sectors. The directive also intends to improve geospatial data interoperability inside the EU and increase access to high-quality geospatial data. The public sector generates and manages a significant amount of geospatial data. The regulation mandates that geographical data be made freely and with few usage limitations available to the public in machine-readable formats.

Numerous important clauses pertaining to geographical data are included in the regulation. In the beginning, it mandates that all public sector organizations make their geographic data available for reuse. This includes information kept by federal, state, local, and tribal governments as well as information held by public organizations and government-run businesses. The directive also mandates that public sector organizations make their geospatial data accessible in machine-readable formats, which will facilitate the use of the data and its integration into systems by both the public and private sectors. The regulation also mandates public sector organizations to make their geographic data accessible with the fewest possible usage constraints. This indicates that the data must be freely used for future uses, including commercial ones, without the requirement of any permissions or further payments. The directive intends to expand the accessibility of this data by forcing public entities to make it available for reuse and to enhance the reliability and accuracy of the data they produce. This will enable the creation of innovative geospatial data-based applications and services as well as help the EU geospatial data industry become more competitive. The order will make it easier for both the public and private sectors to access and use geospatial data, which is one of its key advantages. The EU's geospatial data will be more interoperable as a result, making it simpler for the public and private sectors to use the data and incorporate it into their own systems.

Finally, it should be noted that Directive (EU) 2019/1024 is a crucial piece of legislation that will significantly affect the accessibility and reuse of geospatial data in the EU.

The European Space Regulations EC n. 216/2008[3] and 765/2008[4] are fundamental for regulating the downstream activities of the European space industry. These regulations provide the rules and

[2] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:218:0030:0047:en:PDF

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008R0216

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019L1024

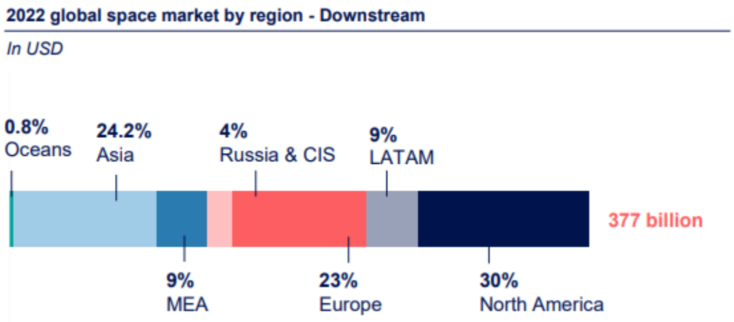
processes for placing on the market and putting into service items related to space, but especially with regards to the oversight of the space industry.
The "Regulation on the establishment of a European Defense Fund", commonly known as EC n. 216/2008: created a fund to help finance the creation and acquisition of new defense technologies and capabilities, especially those related to space systems. This legislation aims to increase the competitiveness of the EU military industry and encourage European companies to participate in the creation and purchase of defense capabilities, especially those involving outer space.
The "Regulation on Accreditation and Market Surveillance" (EC No. 765/2008) outlines the policies and phases for the commercialization and launch of space assets. It mandates that space-related products are created, manufactured and tested in line with relevant EU laws and regulations, as well as fundamental criteria for the protection of the environment, health and safety. The processes for market surveillance of space products are also established by this regulation, but there is no mention of geospatial data and the importance it can assume both from a decision-making and operational point of view and from a development point of view for nations.
Both laws aim to safeguard EU citizens from potential risks in the later stages of the space industry, while simultaneously promoting innovation and growth in the sector and ensuring the safe and effective use of space technologies, but it never stop at look at the largest chunk of the space market which is precisely the data provided for maps, GPS and other navigation systems.
The Sentinel series of satellites and other Earth observation satellites that collect geographic data are developed and operated by ESA. ESA also runs a program called 'Copernicus', which is a network of in situ sensors and Earth observation satellites that provides a wealth of geographic data about the Earth's environment and climate.
Through its Earth Observation Data Center (EODC) and the Copernicus Data and Information Access Service, it makes the visualization and exploitation of this data available for a fee.
These platforms offer tools and services to manage and analyze data, as well as access information collected by Sentinel and other satellites. ESA works with commercial partners to create new data-driven apps and services.
This is very important for what concerns the interoperability of data and provides us with proof that there is a real possibility of a complete interoperability of this type of data and the exploitation for innovation of these new technologies.
ESA also runs a program called "Enterprise Applications", through this programme, ESA works with commercial partners to create innovative data-driven services and apps, and offers funding and other support for these projects. The European Space Agency's (ESA) Business Applications program is notable for its efforts to bring public, private and commercial actors closer together. Providing cash

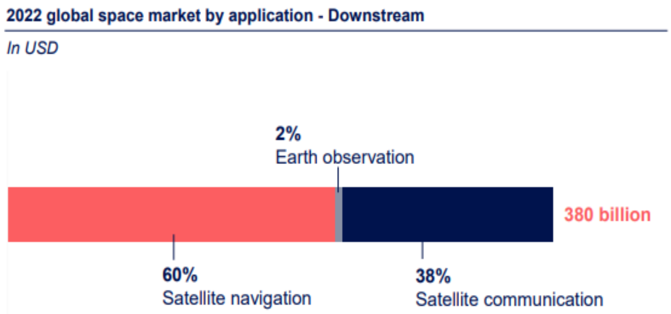
and other support for commercial enterprises using Earth observation and other space-based data is a major component of the program. This help can come in the form of money for research and development, technical support, and access to facilities and other resources. Overall, the European Space Agency (ESA) is aggressively promoting the commercialization of geospatial data by making its data and services available to commercial customers, assisting in the creation of new applications and services, and encouraging collaborations between the public sector and the private one.

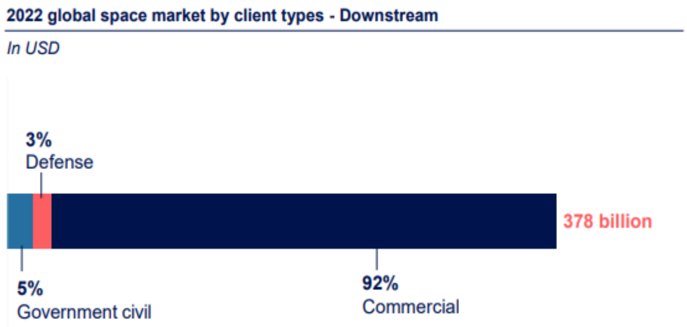
According to the World Geospatial Industry Council (WGIC) 2021 report depending on the business model of the provider, the function of a geographic information provider in relation to personal data can change. One scenario is where a third party asks the provider for geolocation data and then uses it to identify specific people. In this scenario, the third party should be considered the data controller according to GDPR. The supplier is generally considered a data processor when contracted by an organization to provide services involving the processing of personal data. In other cases, the provider may work closely with a third party to develop a product or service that handles personal data, in such circumstances, both parties can be considered joint data controllers. The source of the geospatial data may not be subject to privacy laws if it were only a provider of non-personal data, in which case it would not be subject to any legal obligation to process such data.

2.3.Global space market

The "Space Economy Report" 2021 by Euroconsult indicates that the revenues of the space market are mainly concentrated in North America, Europe, and Asia. Europe is showing slower growth than the Asian region, with a growth of 7% over the past 5 years. The other regions, which account for a smaller share of the space market at 21%, are less dynamic, driven mainly by national ambitions. The growth of the downstream market is closely linked to two main factors: the demographic evolution and the evolution of the regional standard of living, which determine the need for connectivity and navigation services. Furthermore, the ambition of various governments to reduce the digital divide through satellite connectivity development and funding programs is driving the growth in the need for broadband connectivity. The downstream space market is dominated by satellite navigation and communications (Satcom) services, which generate revenue based on the use of GPS signals and include a variety of activities indirectly related to the space industry. Satellite TV and growing connectivity needs are the main drivers of the Satcom market. Earth observation represents only a small part of the downstream market due to low demand for B2C applications. The downstream market for satellite communications is dominated by commercial activities with private companies and private end-users as the main customers. Defense actors are increasingly outsourcing specific tasks to the private sector, especially for satellite imagery. Government spending is driven by the ordering of satellite systems for Earth observation or security applications.







The expansion and potential of the world's space economy are highlighted in the McKinsey & Company essay "How Will the Space Economy Change the World." According to the publication, the global space market was estimated to be worth $383 billion in 2020 and $805 billion by 2040. Technological advancements, rising demand for goods and services related to space, and the growing involvement of the private sector in space activities are all contributing factors to this rapid expansion. Satellite communications, remote sensing, navigation, and positioning, Earth observation, and space tourism are just a few of the main elements of the space economy that are highlighted in the article. Due to the extensive use of GPS, the market for navigation services and positioning is anticipated to reach $35.1 billion globally by 2023. Through 2022, the Earth observation market is anticipated to expand at a 12.7% CAGR and generate $17.9 billion in revenue worldwide. By 2023, it is anticipated that the global space tourism sector would have a turnover of $3 billion.

The article ends by pointing out that developing the space economy will necessitate ongoing expenditures on infrastructure and technology as well as cooperation between the public and commercial sectors.

The FY 2021 National Economic Impact Study by NASA demonstrates how the entire United States gains from NASA's operations. Over $15 billion in private investments were invested in space businesses in 2021, the majority of which came from the United States. This development is largely attributable to NASA's significant backing of the country's commercial space industry through collaborations, agreements, and technology transfer initiatives. NASA's data on climate change and its numerous worldwide partnerships in space science, aeronautics, and space technology have a favorable impact on the world economy as well. For many nations, the information on climate change provided by NASA scientists and Earth observation satellites has significant strategic importance since it helps to comprehend the scope of the problem posed by climate change and offers new knowledge and instruments for mitigation and control. NASA is making a contribution to the developing space economy through the International Space Station, the Artemis and Moon to Mars programs, and international collaborations. More than $20.1 billion in total economic production is supported by NASA's M2M (Moon to Mars) expenditures, up 42.6 percent from FY 2019. Federal, state, and local tax revenue from the M2M program totals about $2.2 billion nationwide. NASA will continue to share fresh scientific findings and create the groundwork for long-term lunar exploration and development through partnerships with American and foreign businesses. NASA conducts study on a variety of topics as part of its climate research program, including greenhouse gases, temperature changes, land and sea ice changes, sea level rise, clouds and rainfall, and air pollution. The study aids NASA in determining how climate change would affect its missions and resources, assuring their resilience. More than 90 countries are actively involved in space activities, and global governments have spent more than $107 billion on these programs, according to NASA data. Worldwide, there are now 49 spaceports that are operational or under construction, with more expected in the future.

According to NASA's report[5], the number of patents awarded in the field has doubled over the previous 20 years, demonstrating the advancement of space technology. Since it has been in operation for more than 20 years, the International Space Station (ISS), which represents 15 countries and five space agencies (NASA, Roscosmos, the European Space Agency, the Japan Aerospace Exploration Agency (JAXA) , and the Canadian Space Agency), has served as a single laboratory for countless scientific experiments. In FY 2022, NASA has approximately 640 active foreign agreements for diverse scientific research and technology development initiatives in addition to the International

[5]https://www.nasa.gov/sites/default/files/atoms/files/nasa_fy21_economic_impact_report_brochure.pdf

Space Station (ISS). As the number of external partners and capabilities increases, NASA relationships continue to develop and diversify. These collaborations have significantly advanced exploration, science, and technology while supporting NASA's aims and objectives.

The development and competitiveness of the European economy also depend greatly on space operations. Programs run by the European Space Agency (ESA) have a substantial strategic influence since they foster European leadership, promote international cooperation, and develop science and technology. Minimizing the effects of space risks including asteroids, space debris, and space weather events is one of the main goals of ESA's missions. The economic feasibility of telecommunications and Earth observation activities, as well as the dependability of navigation constellations, depend on the sustainable use of orbital and other resources. In response to these issues, ESA created the Space Security Program (S2P) to take the lead in defending people and resources against the threats posed by the space environment. According to ESA data[6], the market for Active Debris Removal/In-Orbit Servicing (ADRIOS) and Space Debris Mitigation technologies is estimated to reach €2.5 billion by 2036, and S2P's advancements in these fields will help Europe take 20% of that market. The Hera mission's technologies will be crucial in a number of attractive space industries, such as the usage of resources valued at least 73 billion euros by 2045 and the market for CubeSats and small platforms, which is expected to reach $5 billion by that year. These developments will boost European industry's competitiveness in advanced nanosatellites, close-range operations, and tiny autonomous satellites.

The majority of the activities included in the Space Systems for Safety and Security (4S) program give participants the chance to expand their knowledge and technical proficiency across a variety of hardware and software areas. According to data published by ESA, the addressable market for European systems is anticipated to develop quicker, reaching €6.4 billion in 2040, while the global market for secure satellite communications is anticipated to reach €7.4 billion in 2025 and €22.2 billion in 2040. The Earth Observation (EO) market has been steadily expanding in recent years. According to ESA figures, the downstream EO sector expanded by about 6% globally and by about 12% in Europe. Big data solutions and goods related to information technology are anticipated to fuel growth in the near future. The telecommunications and embedded applications sector, which makes up a sizeable portion of the downstream industry, is carried out in partnership with industry and is typically co-funded by industry partners to the tune of 50%. Approximately 25% of the global market's worth is accounted for by the European market. Galileo's use for civil satellite navigation and positioning, as well as the use of the European Geostationary Navigation Overlay Service (EGNOS), have both had a considerable positive impact on the European Union's economy. In Europe, there has

[6] https://space-economy.esa.int/download/space-economy-brochure.pdf

been a steady increase in the use of Copernicus data and services to support national and European policy on climate change, the environment, sustainable development, and public safety. In order to incorporate European Earth observation data into official development assistance, collaboration has been developed with international financial institutions including the World Bank and the Asian Development Bank. Data from missions created by the European Space Agency is also frequently used by European meteorologists (ESA). The NAVISP initiative supports European industry and ESA Member States' public actions in the highly competitive and rapidly changing worldwide market for satellite navigation and, more broadly, positioning, navigation, and timing (PNT) technologies and services. The restoration of ESA's world-class space facilities, the adoption by many countries of the European launch vehicles Ariane 6 and Vega-C, and significant investments in technology are all contributing to the increased worldwide competitiveness of European space enterprises, both large and small. Technology investments are essential for making the ESA approach possible. Future European space missions are made possible by the technology initiatives TDE (Technology Development Element) and GSTP (General Support Technology Program), which also promote European independence. These initiatives help ESA accomplish its goals quickly and effectively while ensuring that space is utilized for societal good. Ariane 6, Europe's next-generation launch vehicle, gives the continent independent access to space and supports the autonomous global satellite navigation system, assuring secure communication for European residents. With the ability to launch payloads up to 11 tons into geostationary transfer orbit (GTO), the Ariane 6 is perfect for a variety of missions, including those involving communication satellites, earth observation satellites, and scientific missions. Vega-C, on the other hand, is a European launch vehicle intended for Low Earth Orbit (LEO) and provides a very competitive and independent solution for the expanding institutional and commercial LEO sector. The Vega-C has a redesigned fairing, a more potent second stage, and a payload capacity of over 2.5 tons, which makes it perfect for CubeSats and tiny satellites. Additionally, it will support Space Rider, a reusable European spacecraft for routine LEO arrival and return, offering a realistic solution for the institutional and commercial markets. The industrial base, knowledge, and know-how for Europe's space projects are planted by the TDE and GSTP technology programs of the European Space Agency (ESA). The Technological Development Element (TDE) initiative aids in the creation of technology projects with the goal of lowering mission risks and boosting European business competitiveness. The development of technology projects in areas that are not mission-specific but are of broad interest to the European space community are supported by the General Support Technology Program (GSTP).

2.4.Standards, technologies and tools for analyzing geospatial data

The administration and organization of geographic data is heavily dependent on geospatial standards. By ensuring data compatibility and interoperability across many systems and platforms, these standards allow for easy sharing and access to data. While there are different geographic standards, they can be divided into three groups: data, metadata, and services.

Geospatial data is stored and transferred in a standard format using data standards. Shapefile, KML, GML, OGC Simple Features, and ISO Simple Features are examples of open geospatial data standards. These standards enable Extract, Transform, and Load (ETL) processes to move data between systems. For businesses that need to share and access data across various systems and platforms, this is essential. Geospatial data metadata is stored, managed, organized, and shared through metadata standards. The Content Standard for Digital Geospatial Metadata - Federal Geographic Data Committee, ISO Metadata Specifications, OGC Catalog Service for the Web, and Z39.50 Library Catalog Services are examples of open geospatial metadata standards. These standards help companies efficiently manage and exchange metadata, enabling them to understand the context and caliber of the data.

Service standards are used to send data over the Internet or to allow remote access to data stored on a web server. Through simple web clients, these services typically allow users to interact with live, real-time data. Web Map Service, Web Feature Service, Web Coverage Service, Web Map Tile Service, and Web Processing Service (WPS) are among the OGC's open geospatial services standards.

The ArcGIS REST API (GeoServices REpresentational State Transfer) was also made available by Esri in 2010 as an open specification through the Open Web Foundation. Web clients can communicate with GIS services through the REST interface thanks to GeoServices REST services. To develop GeoServices REST as an OGC standard, Esri is collaborating with other OGC members.

We have seen how collaboration is the fulcrum of this integration we are trying to achieve, but it is evident how a high number of existing standards and the large number of platforms do not allow complete and efficient interoperability.

Going deeper into the technical analysis of the Geospatial data market we will realize that it is not just an integration problem from an operational technological point of view, but something that touches on more legal and bureaucratic aspects of the matter.

The processing and interpretation of geographic data can be done using a wide range of applications and technologies. Examples that are frequently used include ArcGIS.

It is a leading GIS software created by Esri, this program is the most popular when it comes to GIS software according to an online finance article and many others in the web (https://financesonline.com/c/gis-software/) and there is a very specific reason. It is used in producing and using maps, collecting and analyzing geographic data, sharing and discovering geographic information, using maps and geographic data in applications, and managing geographic data in databases. It includes a range of add-on products for various industries and jobs, as well as tools for data visualization, analysis and management.

But what many users find is an excessive limit to the features depending on the type of license that is purchased and obviously makes the usability of the service more difficult.

There are examples of software that bypass this obstacle.

For example, the free and open source GIS program QGIS is functionally comparable to ArcGIS, and can be used for data administration, analysis, and visualization, and supports a wide variety of data formats, researchers, students and small businesses prefer this free option.

Another part of the downstream sector of geospatial data is that which derives from all global navigation satellite systems (GNSS) navigation systems, data from GNSS receivers is processed and analyzed using GNSS software, such as Trimble Business Center or Topcon Tools. These receivers collect information about the position and movement of the receiver from signals sent by satellites orbiting the Earth, such as GPS and GLONASS (the Russian navigation system GLObal NAvigation Satellite System). Afterwards, the program is used to process the data, perform operations such as data rectification, and produce 3D maps and models.

The surveying, construction, and agricultural industries frequently use Trimble Business Center and Topcon Tools. GNSS software is used in surveying to locate and measure the elevation of locations on the earth's surface. Then, maps, land surveys are made, and construction sites are staked out using this data. GNSS software is used in construction to provide earthmoving equipment with machine guidance, ensuring they are operating in the correct area and at the correct height. GNSS software is used in agriculture to steer tractors and other machinery, enabling farmers to grow and harvest crops more effectively. The ability to perform data rectification is a major feature of GNSS software, including Trimble Business Center and Topcon Tools. By reducing inaccuracies caused by variables such as air conditions and receiver technology, this technique increases the accuracy of the data. Real-time and post-processing data rectification are the two main categories. Using a base station located in a known location, real-time correction is performed in the field. To increase the accuracy of the data, the base station transmits the correction data to the receiver. After the data has been obtained, post-processing correction is performed using software to increase the correctness of the data.

All of this real-time information and signal adjustments are only accessible to a small number of customers mainly concentrated in the military sector, but these technologies, in addition to being able to provide more informed decision-making power in many sectors, could also be a threat to how much it concerns the security of a country itself as we could see in the conflict in Ukraine that broke out in the winter of 2022 and from what Eytan Tepper reported in his article.

In the downstream sector of the geospatial data ecosystem, geospatial data visualization tools such as Google Earth and CesiumJS play an important role in helping organizations and individuals to make sense of and effectively communicate large and complex sets of geospatial data. Some examples of how these tools are used in the downstream sector include:

1. Urban Planning: City planners and architects use Google Earth and CesiumJS to create 3D visualizations of proposed development projects, allowing stakeholders to better understand the impact of the project on the surrounding area.
2. Real Estate: Real estate companies and developers use Google Earth and CesiumJS to create interactive virtual tours of properties, making it easier for potential buyers to explore properties remotely.
3. Energy: Oil and gas companies use Google Earth and CesiumJS to create visualizations of geological data, making it easier to identify potential drilling sites and plan exploration and production activities.
4. Emergency Management: Emergency management agencies use Google Earth and CesiumJS to create incident command systems, providing real-time information to first responders and decision-makers during crisis situations.
5. Environmental monitoring: Environmental organizations use Google Earth and CesiumJS to visualize and analyze environmental data, such as changes in land use, deforestation, and the effects of climate change.

3.Literature Review

In the literature review, articles between 2017 and 2023 were considered to include events and technological innovations crucial to the analysis of this topic. The geography chosen in the selection of both the documents and then the actual analysis is global, due to the extended nature of geospatial data even if the research focuses on the European environment.

3.1.Challenges and Opportunities for Downstream segment

Advances in technology and the spread of Internet-connected devices have increased the online accessibility of geospatial data, which contains details about the location of such devices and the properties of physical features on Earth.

While there are many positive uses for this data, as we've seen in the analysis done in this document, the usage of the geospatial data also poses serious security problems. These information, for example, can be used to spy on a nation or invade its privacy. In the case of the war in Ukraine, as we have seen from Tepper's article, even direct attacks on services that these data allow to provide, such as GPS for both civilian (Google Maps) and military use are a central topic as regards privacy. Organizations that manage geospatial data must put in place robust security measures to safeguard this data from misuse or illegal access.

The collection and analysis of geospatial data has the potential to compromise people's privacy, including revealing their location over time. This requires greater consideration of data privacy and transparency in the collection and use of data.

In the case of services or products that could undermine the privacy of an individual or the security of an action, it is important to adopt guidelines to make the control of the platforms that provide these services supervised and secure.

The World Geospatial Industry Council (WGIC) is an international organization that promotes the proper use and management of geospatial data.

The organization highlights how crucial it is to safeguard people's privacy when using geospatial data, explicits this concepts in its final report for 2021. As part of its standards for protecting personal information in geospatial data, the WGIC outlined guidelines for obtaining informed consent from individuals, ensuring data security and privacy, and being transparent about data collection and usage techniques. . This would offer great protection against misuse of this data. A risk-based approach to privacy, is advised by WCGI to handle geospatial data, which means they should assess the potential dangers to people's privacy and implement the necessary security measures to counter those threats.

This may involve collecting or anonymizing data, implementing security controls, and describing how that data is used. Additionally, the platform that will act as a hub for exchanging this type of data must have a robust architecture that can withstand sophisticated, state-of-the-art IT attacks to prevent misuse by anyone other than the owner.

Integrating geospatial data with other types of data, such as demographic and transactional data, can provide a more comprehensive view of trends and relationships between phenomena. This requires greater data integration capability.

After the analysis of the 38th OECD Regional Development Paper is evident how highlights the benefits and challenges of public-private partnerships in geospatial data for urban and rural governance and economic development.

The key problems facing collaboration, according to the statement, are privacy issues, the public's hesitancy to submit data, and the lack of a systematic approach to promoting responsible use. The report makes the case that governments may overcome these challenges by building public-private partnerships, developing regulatory frameworks, promoting data literacy, and enacting open data laws that encourage innovation and collaboration. The potential for combining conventional and unconventional data to inform policy and the need for granular and aggregated geospatial data to build coherent indicators. In order to facilitate data access and provide repeatable workflows for huge datasets, private enterprises are also developing open-source technologies, as confirmed by the thesis of the aforementioned document.

Geographic Information Modeling (GIM) and Building Information Modeling (BIM) systems are examples of where to operate to improve geospatial data interoperability. Although GIM and BIM were developed in different fields, it is crucial for large-scale building projects like infrastructure (roads, trains, airports...) to integrate their models and data to optimize processes. Better construction planning and execution result from the incorporation of GIM data into BIM models and updated digital representations of the actual world result from the incorporation of BIM models into GIM models. Due to the disparities in the modeling geometries and data structures, interoperability between the two models is challenging. During the course of the research, an article was identified that dealt specifically with various models for implementing this integration. Initially, interoperability between GIM and BIM has been attempted, largely through schema transformation, mapping, and conversion rules. The federated (or connected), unified, and integrated models are the three interoperability approaches that are defined in the article. The most effective method, however, is to transform models with the use of semantic web technologies like RDF and a set of mapping and conversion rules. With this method, connections between the various data models and parameters are made. However, a single model that incorporates the common elements of the two domains has not yet been developed. It is not yet obvious whether a unified or integrated model is desired in view of the difficulties presented by the conversion between BIM and GIM models. Furthermore, prior to choosing the best method to develop a domain model's interoperability, the practical experience must first define which domain model should be utilized for which purpose. The authors of the article contend that more focus should be given to advanced models connecting the two domains in actual practice. This is due to the fact that switching templates back and forth can be tedious and occasionally unworkable. In conclusion, BIM and GIM system compatibility are crucial for streamlining workflows in large-scale building projects and provides a solid foundation for advancing the interoperability of geospatial data. A single unified or integrated model has not yet been produced, despite early attempts to establish interoperability. Since changing models back and forth might be ineffective and impractical, linking the models of the two domains in a sophisticated way should be given more consideration in practice.

3.2.Research Question

In this context, it is important how to integrate geospatial data within government decisions. It was possible to outline a framework for the governance of geospatial data based on two key points, as reported by Ngereja, Zakaria & Liwa, E. & Buberwa (2018): the first was a geospatial institutional framework for governance, and the second was a way to use e-government to give government space capabilities. Work on interoperability during this digital innovation that the world is experiencing has been done and explored the topic of data integration in a general way by dividing the sectors into vertical and horizontal and proposing following an in-depth analysis of further documentation such as standard formats and compatible architectures can be a possible step towards the interoperability of this information in several sectors, as has been highlighted by the BIM and GIM analysis. While all stakeholders in a market would benefit from a single standard or platform, they are unwilling to cooperate even when trying to create one, this is known as low interoperability.

Uncoordinated changes to accepted standards, technological upheavals, and the commercial interests of stakeholders are among the causes for this. Three theoretical objectives – the network-based perspective, the perspective of a digital technology platform and the perspective of an ecosystem – as reported by Daniel Hodapp and Andre Hanelt (2022). The network-based perspective is about how a platform or standard is widely adopted and offers interoperability. The design and governance components of the platform are considered from a digital technology platform perspective to reflect poor interoperability. Furthermore, the ecosystem perspective sees poor interoperability as a bottleneck that limits communication between actors and impedes ecosystem development. All of these data efficiency issues apply to the space industry where millions of terabytes of information are collected every day in a variety of formats and platforms.

Platforms and standards are the two basic mechanisms identified in the literature. These techniques can target various architectural levels and analytical units. The IT layer, the data layer, and the software layer are layers that are often referred to. The literature also distinguishes between interoperability strategies aimed at regulators, individuals, and organizational levels. It is also important to further separate the actors using the mechanisms. Regulators and their influence on interoperability, which has received less attention in the literature than Standard-Setting Organizations (SSOs) and the consensus building they promote, platform leaders, and their architectural choices. The economics literature has studied consensus building under many parameters, and research on SSOs has focused on how to effectively organize a consensus in SSOs. Neutral third parties can expedite the process, and SSO standards and values are seen as a key factor in how the conduct of industry players engaging in SSO might affect interoperability. These considerations make us understand how a standard is what the Geospatial data ecosystem needs most at the moment as we have found following an extensive search on the sites of the companies most involved both on the B2C and on the B2B side the huge amount of formats available for the same type of data.

Interoperability has many benefits, including increasing competition by lowering barriers to entry and reducing lock-in effects, improving autonomy, facilitating access to information, and cutting transaction costs. Greater interoperability, however, comes with some dangers. According to Hodapp's research, one danger is that the widespread use of specific platforms or standards could give rise to monopolies, which would hinder competition and innovation. The possibility of security problems in networked systems is another problem. Also, increased interoperability could impact people's privacy. The complexity of highly interoperable systems could result in less accountability and reliability due to the high risk of theft and violation of privacy. If we think about this problem in the use of geospatial data, we can immediately perceive the danger that could be incurred by making too simple the usability of this information. Several concerns have been identified in the current literature on digital innovation and interoperability that need to be addressed to increase understanding of this topic. An important bellwether must be placed on the traceability of who will have effective access to this type of data.

At the World Trade Organization (WTO) and through bilateral trade agreements, policymakers have worked to establish international standards to control cross-border data flows. The Agreement on Information Technology, the Agreement on Trade-Related Aspects of Intellectual Property Rights, and the General Agreement on Trade in Services are just some of the WTO agreements dealing with data and digital trade issues (GATS). The GATS, however, is considered outdated and does not directly address cross-border data flows. Some argue that for WTO standards to be applicable to new data-driven services, they need to be changed and clarified. Despite efforts to reach an agreement on new e-commerce regulations and updated GATS, many nations have differing views on the matter. Some countries prefer to keep negotiations on the current Exploratory Work Programme, while others want to go further and form new agreements. Countries have produced recommendations and baseline studies to this end, but there is still no agreement on the best course of action. On how to distinguish between e-commerce and digital commerce, different countries disagree. Meanwhile, several nations have included the language that handles cross-border data transfers in the e-commerce chapters of their free trade agreements amid a lack of progress in WTO digital trade negotiations. With the advent of huge amounts of geospatial data, appropriate regulation also applies to the trade and transfer of the latter.

Collaboration between public and commercial actors can help increase the interoperability of geographic data in numerous ways.

To begin with, public-private collaboration enables the pooling of resources, knowledge, and information. Public institutions often have access to a plethora of geographic data, although private companies may have more sophisticated technologies and specialized data management and analytical capabilities. These parties can pool their resources and expertise by cooperating to increase the caliber, accessibility, and interoperability of geospatial data.

Collaboration can help develop common standards and protocols for data sharing, both of which are necessary for interoperability. In order to create shared standards and practices for data sharing, public-private partnerships can bring together participants from many sectors. This facilitates the simple exchange and merging of data. It promotes a more open and inclusive approach to the use and dissemination of geospatial data, collaboration can also result in a more equitable realization of value. Public-private partnerships can ensure that the requirements and concerns of various groups are taken into account and that the benefits of geospatial data are shared more widely by incorporating a number of stakeholders into the decision-making process.

Contrarily, we have shown that if not properly controlled and monitored, a high degree of interoperability can also be a source of issues. As we have seen, there is little documentation pertaining to the issue in the particular sector (geospatial data), and even the laws currently in effect never refer to this category directly but are instead defined in an alternative way by integrating it with other larger categories. As a result, the problem of privacy and data exploitation are topics that this field is very interested in. We must start seeing this data as an underlying theory that requires its own legislation with regard to commercialization as well as a standard for the architectures to ease communication and study using these instruments.

Due to the substantial use of space resources and cyber attacks from both sides, the ongoing conflict in Ukraine it is referred to as the first space-computer warfare, as Tepper (2022) suggest in his writings. In response to the Russian invasion of Ukraine in 2022, US-based satellite broadband provider Viasat experienced a service outage that cut off internet access for police, intelligence services and military forces. Ukrainian armies. In addition, Russia is alleged to have interfered with GPS signals in Ukraine, preventing Ukrainians from navigating and aiming their weapons. The conflict has also impacted commercial space companies, with Google Maps cutting off live traffic updates in Ukraine and both sides using commercial satellite imagery for military purposes. Despite the fact that the satellites were not physically destroyed in this fight, Russia, the United States, China and India are all capable of carrying out such attacks. These maneuvers that affect the functioning of services based on geospatial data make us understand the importance of this type of information also for the well-being of a country. If services that exploit these technologies are also targeted in military conflicts, we have to think of a way to protect this type of data both physically and from a legislative point of view. The aforementioned article continues by making an analysis focused on the importance of cyber-security, discovering a sore point in this picture, the fact that there is not a branch of this huge market that deals specifically with space infrastructures.

As a research problem, we can therefore say that in the downstream sector what has been most noticed is the large quantity of technologies and sources involved which creates great difficulty for anyone who wants to use this geospatial data for any private work. Now to better define the question we have to think that these data are subject to many transformations and changes over time.

This is important information for anyone who has to work on it, for this purpose following the analysis of many documents, we can say that an environment in which different types of data can be collected is the one that will be most needed in the future to be able to make the most of this new type of information.

In this research, CLEOS could be the right case study to analyze what has already been achieved and what could be improved in this sector. In this case, Ostrom's literature serves as an index of the key points on which a platform of this type should rest. There are obviously some issues in adapting the theory of the commons to this type of product, firstly the very nature of the collection of this data. Because in order to obtain this type of data, a private individual should have the economic means to build and launch into orbit a satellite equipped for this type of operation and have a reception and subsequent processing station for the distribution of the latter. Therefore an open partecipation is rather unrealizable, but as far as the whole legislative and governance part is concerned, there is a lot to work on, first of all, a regulation integrated into the GDPR could be a first step towards an aware management of this data in terms of the current state of affairs we have no record of it. A universal regulation on how to market in a controlled manner and which does not incur a violation of privacy by the providers of these services.

Having reached the end of the analysis of the literature, in order to continue with the research it is appropriate to dwell on a very specific question that can be summarized with this question: "How do the ideas of common goods, polycentric governance and the roles of public and private stakeholders in geospatial data sharing connect with the interoperability of shared data via marketplace platforms?”

3.3.Elinor Ostrom’s Framework

The theory of polycentric governance[7] argues that small groups can efficiently manage the commons without state or market assistance. This concept underlying Ostrom's theories as a result of understanding the ecosystem in which geospatial data lives was a pivotal point behind the answer to the research question.

The Bloomington School of Political Economy established the idea of polycentric governance, or PG, which deals with decision-making procedures within a group or community. It involves all the choices that influence the alternatives people, groups and organizations will have in the future. Make choices about a wide variety of closely related practical issues while taking into account the interests and goals of numerous parties. Furthermore, it involves the evaluation of the results of the collective activity, as well as the monitoring and implementation of the agreements. Choosing which forms of collective activity are legal and acceptable is the goal of polycentric government.

US political scientist John W. Meyer created the idea of "polycentric government". Meyer investigated how institutions and organizations relate to each other in various social and cultural situations and how these relationships affect governance and regulation in his research about him. Furthermore, he created the concept of "institutional polygamy" to explain how different types of government can coexist and work together in society. His research has shown that local communities and interest groups can effectively manage commons such as grasslands, fishing boats and groundwater without help from the state or the market. To explain the laws and organizations that control the use of the commons, he also invented the idea of "governance regime". Ostrom and John W. Meyer collaborated frequently, and she provided him with some of her knowledge of complex government.

The main ideas of Ostrom's theory from her "Governing the Commons: The Evolution of Institutions for Collective Action":

[7]https://ostromworkshop.indiana.edu/research/space-governance/polycentric-multilateralism.html

➔ Active involvement: the management of the commons requires the active participation of the community.

➔ Shared regulation: the community must define and supervise the rules for the management of the commons.

➔ Sanctions and Monitoring: Community members must be able to keep tabs on how the commons are being used and punish anyone who breaks the rules.

➔ Common Property: Commons should be viewed as the collective property of the community, not as the exclusive possession of any single person or entity.

➔ Cooperation: To properly administer the commons, community members must work together.

Over time, Ostrom's idea has impacted the way numerous groups, including fishing communities, community landowners, and water management organizations, manage the commons.
In addition, it has served as the foundation for other commons management policies and initiatives around the world.
This makes us think that even in an environment like that of geospatial data there is room to start a discourse of this kind.
Elinor Ostrom's theory of polycentric governance could be used to manage many types of space industry data.
Her idea could also be applied to encourage international collaboration in spatial data management between the public and private sectors. Data from an international space mission, for example, might be controlled through a polycentric governance system, with governments and the organizations involved working together to set guidelines and oversee the use of the data.
To manage data successfully, all members of the scientific community should work together and have equal access to the data, although it needs to be clear who has insight into the data and how it will be used.
A conference on spatial data as a commons, organized by the United Nations Educational, Scientific and Cultural Organization (UNESCO), was also held in 2018, discussing how spatial data can be used to benefit of humanity and how spatial data governance should be established to ensure equitable access and sustainable use.

There are numerous conversations and discussions going on around the governance of spatial and geospatial data. Elinor Ostrom's theory of polycentric governance provides a useful framework for contemplating these problems and formulating workable responses.

4.Key case studies of geospatial data in downstream segment

4.1.Case 1 'Sentinel Hub'

The Copernicus program of the European Space Agency provides users with a quick and efficient way to access and handle enormous amounts of satellite data (ESA). A platform called Sentinel Hub[8] is used to retrieve and interpret data from satellite pictures. Sentinel Hub, a cloud-based platform for managing satellite data, was created by the business Sinergise. Based on Synergise's cloud GIS platform, Geopedia, Sentinel Hub's distribution service for satellite imagery. With more than a million users annually, Geopedia is a web-based spatial management solution that is ideal for large-scale spatial deployments. Users can access and manage satellite images and other geospatial data from a single, centralized location using the platform, which also offers tools for processing, analyzing, and displaying the data. Users of Geopedia may quickly visualize, process, and analyze vast amounts of geospatial data, enabling them to draw conclusions from the data and take appropriate action. The platform is intended for a wide spectrum of users, including small and large businesses as well as government entities. Sinergise is in charge of maintaining the platform's technology and infrastructure as well as offering support and services to its users in its capacity as the creator and operator of Sentinel Hub. The system is designed to be user-friendly and accessible to a range of users, including geospatial experts, businesses, and researchers. One of Sentinel Hub's key features is its ability to analyze satellite data in real time. Using the platform's powerful algorithms and tools, you can swiftly process and analyze enormous amounts of data, allowing you to deliver real-time insights and monitor changes as they take place. In terms of data interoperability, Sentinel Hub complies fully with all global geospatial data standards, including those set forth by the Open Geospatial Consortium (OGC). Because of this, Sentinel Hub's processed data is completely compatible with other geospatial platforms and applications, which makes it simple for users to add data to already-established workflows. Customers can access and modify data using a variety of APIs and other tools that Sentinel Hub provides. Customers can thus use the platform's data and processing capabilities to build their own distinctive apps and workflows. The automated processing of satellite data made possible by these

[8] https://www.sentinel-hub.com/about/

tools enables users to finish difficult data processing jobs quickly and efficiently. Sentinel Hub strictly adheres to privacy and data security when managing data.

Only users who have been granted access to the platform can access the data, which is safeguarded from unauthorized users by stringent security measures. The platform also ensures the security and privacy of user information by completely adhering to all EU data protection rules, including the General Data Protection Regulation (GDPR).

Depending on the amount of data retrieved and how many queries are run, Sentinel Hub does have a variety of pricing options. With different monthly credit arrangements at different prices. Furthermore, Sentinel Hub offers an open and transparent data policy that allows users to access and use the data for a variety of purposes. Non-commercial users may utilize the platform data without charge, while commercial users may access the data charging a reasonable fee. This policy encourages innovation and collaboration within the geospatial community by ensuring that data is accessible to a wide range of users. The supporters of this platform are many and the main ones are ESA, the EU and AWS (Amazon Web Services). In fact users of Sentinel Hub, have access to robust computing capabilities as well as a reliable and secure platform for their data and services thanks to Sentinel Hub's hosting on Amazon Web Services (AWS). One of the most comprehensive sources of satellite images is now accessible to the general public thanks to Synergise's partnership with AWS.

The hosting of Sentinel Hub on AWS is made possible by an AWS in Education Research Grant, underscoring the platform's dedication to offering dependable and open access to satellite data services. By giving users easier access to and support for analyzing the data they require, the funding advances the use of satellite data in research and teaching.

4.2. Case 2 ‘UP 42’

On May 7, 2019, UP42[9], a division of Airbus Defence and Space, unveiled an open platform and marketplace to assist entrepreneurs and developers in building and expanding geospatial solutions. The platform combines Airbus' expertise in space technology and its expertise in artificial intelligence and machine learning. UP42's goal is to provide customers with geospatial data that is easily accessible and actionable to support their data-driven, informed business decisions. The platform develops this concept by offering solutions based on satellite, airborne and terrestrial data, making it possible to

[9] https://up42.com/company (About page)
https://inspire.ec.europa.eu/sites/default/files/3-up42_-_list_jrc_data_ecosystems_for_geospatial_data.pdf
https://www.directionsmag.com/pressrelease/8780
https://spacenews.com/airbus-subsidiary-up42-unveils-data-analytics-platform/

analyze and use this data for a wide range of applications. Three fundamental ideas served as the basis on which the platform's development team constructed the platform. First, cooperation, a priority by data owners, and awareness of the lack of expertise in geographic data marketplaces The team promoted venturing outside of comfort zones and reconsidering conventional approaches in order to engage data owners. Second, security. In order for the market to succeed, data owners needed to be given a lot of authority and seen as a safe place to conduct business. In the current environment of geographic data marketplaces, the team highlighted the difficulty of distributing data in multiple forms with a lack of search and delivery API.

The user's needs and the procedure of UP42 are its focal points. Users can quickly search and choose the data they need thanks to the simple and intuitive design of the platform. Once chosen, the data can be processed using the range of pre-defined algorithms provided by UP42 or using bespoke algorithms which can be developed using the UP42 API. Users can then immediately gain insights and make well-informed decisions by further viewing and analyzing the processed data. With its self-adapting computing infrastructure, it ensures data and algorithm compatibility. Developers can leverage the full potential of UP42 through its powerful platform APIs and open-source Python SDK that integrates with Jupyter Notebooks. The platform's simple user interface allows anyone to discover and preview data from multiple vendors, build processing workflows, and extract insights, all without writing any code. UP42's open marketplace provides easy access to data and analytics from leading geospatial companies with transparent pricing and revenue sharing for partners on every transaction. Data interoperability is a priority for UP42. This indicates that the platform is designed to readily interact with other tools and systems, enabling customers to quickly add UP42 to their current processes. The goal of UP42's data interoperability policy is to be open and transparent. Users get access to the data they need when they need it in the format that is most convenient for them thanks to the platform's open API and its standards-based approach to data integration. Users won't have to worry about the UP42 not working with current workflows thanks to this integration. UP42 is dedicated to both data security and privacy. The platform adheres to industry-standard security procedures and all information is held in secure data centers. Users can manage and restrict access to their data with the help of a variety of data management and access controls offered by UP42.

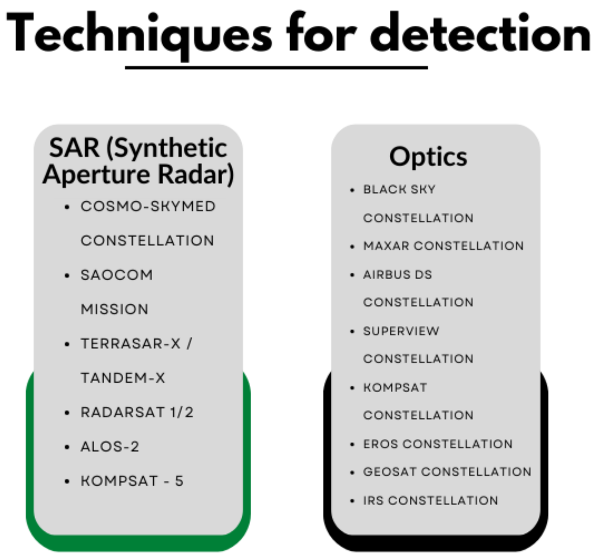
This platform, therefore, is a great option for businesses that need to manage, analyze, and visualize geographic data due to its user-centric design, dedication to interoperability, and emphasis on data protection and security. Whether you work as a developer, data analyst, or GIS expert, UP42 offers the resources you need to gain knowledge and make informed choices.

4.3. Case 3 'CLEOS'

The CLoud optimized Earth Observation Services (CLEOS[10]) platform is a cloud-based data processing platform owned by e-GEOS that allows users to access, process, and use satellite data in a simple and intuitive way. The platform supports multiple data sources, including radar and optical data, and offers a variety of data processing tools, including image analysis, classification, information mining, and mapping services. CLEOS is designed to support a broad range of applications, including environmental monitoring, natural resource management, emergency management, remote sensing, and GIS application development.

The CLEOS platform places a strong emphasis on data governance to ensure the security, integrity, and compliance of the data it processes and stores. To this end, it uses security measures such as encryption and access controls, as well as stringent data management policies to ensure data integrity such as version control, backup, and disaster recovery procedure.

Additionally, it has a robust data governance framework that allows organizations to easily comply with regulations such as GDPR (The General Data Protection Regulation is a regulation of the EU that went into effect on May 25, 2018, it replaces the 1995 EU Data Protection Directive), and FedRAMP (Federal Risk and Authorization Management Program, is a U.S. government-wide program that provides a standardized approach to security assessment, authorization, and continuous monitoring for cloud products and services). This includes features like data retention policies, data classification, and data lineage tracing, to easily trace where your data came from and how it was processed over time. In addition, it provides an audit trail functionality that allows you to track accesses, actions performed, and times, to meet compliance requirements.



[10] https://www.cleos.earth/

During the investigation, I had the opportunity to interview a CLEOS team member, the Head of e-GEOS' Big Data, Analytics, and Artificial Intelligence Competence Center. The interview starts off by describing how Telespazio won a 2009 ASI tender for the commercialization of data from the COSMO and SKYMED satellites. After that, both (Telespazio 80%, ASI 20%) contributed to the creation of the joint venture e-GEOS. While Telespazio was in charge of supplying the division of the business that deals with Earth observation, ASI contributed the exclusivity of these data. Continues by explaining how e-GEOS is involved in every step of the industry's production process, from data collection using survey equipment in Matera (where their ground section is located) through the creation of info products, analytics, the development of geoinformation platforms, and training.
E-GEOS was established as a business with the only right to commercialize the information produced by the COSMO and SKYMED satellites, as well as a broad network of partnerships with other significant industry players like AirBus, Maxar, and BlackSky. The foundation of the driving forces behind the development of CLEOS was to preserve market competitiveness and boost data interoperability. To do this, a platform with a comprehensive and well-organized catalog and the ability to conduct microtransactions was developed in order to reach a bigger audience of customers.
Contrary previous DIAS systems, this geoinformation marketplace is the first to be entirely sponsored by private investment. In order to integrate the normal "machine to machine" and "machine to human" interactions found in a marketplace through APIs, the CLEOS team set out to develop a technological product. However, it did so while maintaining total control over the platform.
The standardization of the offering, which was a vital step for the creation of the platform itself, had to be accomplished in order to develop the CLEOS product catalog.
In an increasingly platform-based digital economy, the vital function of customer service was emphasized. A staff made up of humans will be available to assist customers in exploring and selecting the best product for their needs.
The team will work to gradually increase access to value-added service options through CLEOS in the many industries they are involved in, including marine surveillance, agricultural, infrastructure, land monitoring, and disaster management.
It's significant since the CLEOS platform's goal is to make contract negotiations easier.
As a result, CLEOS wants to make it possible for customers to buy access to information updating services. This has sparked a debate over the limitations that users will have to live with.
Examples can be users with geographical limits or caps on the number of recurring logins (monthly or weekly).

It is important to note the restrictions placed on data from commercial satellites like e-GEOS, as opposed to other data like that given by Copernicus, which has an open and free data policy. In reality, as a national corporation, e-GEOS will be obligated to submit reports on a regular basis to the Italian State that list all users who have access to the platform, the platform data they use, and the purposes for which they were used.

In terms of security, it has become clear that the priority for Earth observation is data integrity, and a blockchain method could be a useful way to keep track of the history of this data.

As far as the invasion of privacy caused by satellite data is concerned, we are very far from a real threat because the image's level of detail makes it impossible to accurately depict a person's face or a license plate's characters.

In conclusion, the interview revealed some extremely intriguing details about the interoperability of geospatial data and gave us a clear understanding of what the actors in this industry are attempting to accomplish, even in the most disparate ways. Other businesses, like UP42 (AirBus), have concentrated more on implementing a wide range of services within their platform than E-GEOS, which on the one hand tries to offer a catalog consistent with what it already has available as an offering. However, the choices always depend on the investment capacity.

Similar to e-GEOS, other firms are expanding their product lines, and every year, more and more entrepreneurs attempt to enter this fiercely competitive market that is rife with entry-level restrictions.

4.4. Comparative Analysis

To answer the research question found in chapter 3 during the analysis, was adopted the Ostrom framework, reported in the third chapter, which provided the basis for comparing these three platforms.

The first point is the active participation by the community and in all platforms due to the very nature of the collection of this type of data it is not possible to have support from the community, what however we try to do through platforms of this type is to make the exploitation of this data accessible even to small businesses. For CLEOS, microtransactions are a strong point from this point of view and the free access by Sentinel Hub for non-commercial users is a great way to open up to the participation of the scientific community.

The second aspect is that of shared regulation. The three platforms provide shared access to geographic data and can be understood as user communities collaborating to manage this data effectively and sustainably. To facilitate the development of data-driven goods and solutions, the three platforms also provide various pricing options and analytics services. When user communities decide how to use and pay for access to data, it can be said that the price structure is a sort of shared regulation.

Sanctions and community oversight are crucial components in Elinor Ostrom's ideas of shared regulation of the commons for maintaining the long-term viability and effectiveness of the administration of the commons. Ostrom emphasizes the need for community oversight and sanctions to make sure that people follow the law and do not misuse public property. The three platforms may have both explicit and informal policies governing the usage of geographic data, and they may impose sanctions on violators. In order to make sure that users are not abusing geographical resources and that data is used sustainably, platforms could also feature a community monitoring system.

The fourth point perhaps the pillar of all Ostrom's literature speaks of common goods, and treating these data as common goods is certainly one of the focuses of the European directives developed over the years, however the platforms in question sin in this as they always remain data owners and do not make them accessible for free, only Sentil Hub offers the possibility to exploit the data for research and non-commercial purposes. However, it is important to underline how the catalog offered both in the CLEOS platform and in the UP42 platform often also includes data of an open and free nature, however having to face an expense in any case as commercial operators would be disadvantageous for companies such as e-GEOS or AirBus.

The last point of the analysis focuses on the pivotal cooperation both in Ostrom's discussions and in the realization of these platforms in all three case studies. CLOES which was born from the collaboration between Telespazio and ASI, the platform was only a natural evolution of a company that was born as a collaboration between public and private actors. In the case of UP42 we have a collaboration between two private actors who operate on different geographies UP42 itself a German company that is acquired and by AirBus a multinational company with operational headquarters in France. To conclude, Sentinel Hub which above all promotes collaboration with the free opening to a pool of non-commercial customers for free and cooperates with other companies to make the platform operational (Sinergise).

	CLEOS	UP42	Sentinel Hub
Active Involvment	Possibility of carrying out microtransactions for portions of satellite images, this allows both small businesses and amateur scientists to exploit this asset.	The catalog offered are aimed at an audience with large financial resources and cuts less influential realities out of its market.	Possibility to its customers to use the data that it makes available free of charge for non-commercial purposes.
Shared Regulation	In line with the european and national (Italy) Directives.	In line with the european and national (Germany) Directives.	In line with the european Directives.
Sanctions and Monitoring	Annual report of the accounts name and usage to national authorities.	Annual report of the accounts name and usage to national authorities.	Tracks users through account registration both for free and for commercial purposes.
Common Property	Data Owner: Accessible only through paid subscription or purchase.	Data Owner: Accessible only through paid subscription or purchase.	Data Owner: Possibility to its customers to use the data that it makes available free of charge .
Cooperation	ASI has delegated Telespazio to commercialize the COSMO-SKYMED data leading to the creation of e-GEOS	AirBus acquires UP42 to collaborate on their data marketplace.	ESA collaborated with Sinergise for the creation of the data exchange platform

Table 1

In Cloud-Based ecosystems such as the platforms analyzed in this chapter, three bottlenecks can be identified: legal compliance on data control, data sovereignty on access, storage and processing, finally data interoperability, as suggested by Niloofar Kazemargi, Paolo Spagnoletti, Panos Constantinidesi and Andrea Prencipei (2023). According to the first point, consumers of cloud services may find it challenging to confirm that their providers adhere to industry-specific requirements for user data control. European cloud service consumers in particular struggle to make sure that non-European cloud service providers adhere to General Data Protection Regulation (GDPR) and other EU data control laws. Connecting this point to points 2 and 3 of **Table 1** is clear by the importance of surveillance. The second bottleneck illustrates how stored and processed data lacks of visibility and authority. Users of cloud services struggle to fully control the data that is processed and stored; this concept is strongly related to Ostrom's (1990) ideas about sanctions and monitoring by the community, and about the commons. The lack of publicly available infrastructures to interchange and process data is the fundamental issue that we are attempting to address with the framework utilized in this chapter, and it is highlighted by the third point, which focuses on data interoperability. Effective governance of distributed data in a multi-stakeholder environment, such as Open Source Innovation (OSI), requires three dimensions: openness, accountability and power, as reported by Thomas Gegenhuber, Johanna Mair, Ren´e Lührsen, Laura That (2023). To remove obstacles to collaboration and innovation, openness refers to the unrestricted sharing of data and information. Accountability requires that participants are prepared to offer justifications or explanations for their behavior. Accountability in a multi-stakeholder setting enables management of actor behavior as well as the appropriateness and effects of their decisions. According to a relational viewpoint, power is the extent to which one actor can affect another actor's choices and behavior because he has access to the resources that the other actor need. Power dynamics can have an impact on the allocation of resources and the capacity of players to influence decision-making in the context of data governance in OSI. To ensure that data is controlled and used responsibly and ethically, distributed data governance must be designed to balance power relations among stakeholders; these features are consistent with the study of the three platforms, as shown in **Table 1**.

5.Conclusions

The theory of polycentric governance has influenced many people and served as the foundation for management regulations for the commons around the world. These concepts could offer a framework for managing the commons in the case of geospatial data and encourage cooperation and coordination among many stakeholders. Examples of platforms that operate within this polycentric governance architecture are CLEOS, UP42, and Sentinel Hub. These examples give users access to geospatial data and analytical tools for a variety of uses, from urban planning to agriculture. They work to democratize access to geospatial data by improving its usability for local communities, governments and commercial enterprises. By providing access to geospatial data and analytical tools to numerous stakeholders, including government agencies, commercial enterprises and communities, CLEOS, UP42 and Sentinel Hub enhance the concept of polycentric governance. This strategy helps ensure that the use of geospatial information is determined by the needs and goals of the communities and organizations that use it by encouraging collaboration, cooperation and equitable benefit sharing among all stakeholders. In summary, polycentric governance offers a sound strategy for managing geographic data, allowing different actors with different interests to work together and cooperate within a shared governance framework. Platforms such as CLEOS, UP42 and Sentinel Hub, which offer access to geographic data, tools for teamwork and an environment for the exchange of data and services, can play a significant role in facilitating the implementation of polycentric governance as the technology develops.

The commercial sector, governments and community organizations all need to be involved for the implementation of polycentric governance to be successful. Under the right circumstances, polycentric governance can offer a just and sustainable method of managing geographic data that benefits all parties.

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