D2.2 *Applications, Services and Supporting Technologies*

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Abstract

Under the framework of the T2200: Applications, Services, and Supporting Technologies (M6-M24), a comprehensive **survey** (Activity 1) was conducted to gain insights into the **European space ecosystem**, with a particular focus on **current ongoing programmes, applications, services, and supporting technologies**. This endeavour involved engaging with various stakeholders in the industry, including also academia and research centres. The goal was to evaluate the current offerings in the space sector, assess ongoing European Union-facilitated programs, and identify future opportunities. The survey, which successfully gathered 22 responses, played a crucial role in supplementing the created desktop research, .

Furthermore, the second activity was an in-depth **market analysis**, thereby enriching the understanding of market dynamics and business trends in critical areas such as Earth Observation, Satellite Communication, Navigation, Access to Space and Launch Systems, and Space Safety. Part of the market analysis included creating **a catalogue of space Applications, Services, and Supporting Technologies** accompanied by **the related needed skills**, providing a high level overview of the sector's landscape.

Keywords

Space Applications, Space programmes, Space Services, Space Supporting Technologies, European space ecosystem, Space skills, Space Market dynamics, Space Business trends, Space Industry.

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1.0	20/12/2023	Draft	Danai Bournou	Final draft
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1. INTRODUCTION - EXECUTIVE SUMMARY

1.1 Overview of the T2200 Project

The T2200 project represents a comprehensive initiative to explore and analyse the European space sector, encompassing both **a stakeholder survey** and an **in-depth desktop research** report. This project aims to synergise the insights from these two components to provide a holistic view of the sector, focusing on the alignment of skills and activities in various domains.

Stakeholder Survey

The survey component of the T2200 project plays an important role in gathering perspectives from **diverse stakeholders** within the space sector, including industry professionals, academia, and research institutions. The primary objectives of the survey are:

- **Evaluating Current Applications, Services, and Technologies**: It assesses the existing landscape of applications, services, products, and supporting technologies in the space sector. This includes understanding specialized uses of space-derived data and technologies.

- **Assessing Ongoing EU Programs**: The survey explores the impact and reach of European Union programs within the space sector.

- **Identifying Future Opportunities and Skills Alignment**: A key focus is on identifying emerging opportunities and verifying if the current activities, particularly in terms of skills and capabilities, align with the findings from the desktop research.

Desktop Research Report

The desktop research report offers an analytical perspective on the space services and business sectors, with a specific focus on:

- **Extraction of Skills in Key Domains**: The report provides a detailed examination of skills required in various domains of the space sector, such as Earth Observation, Satellite Communication, Satellite Navigation, Access to Space and Launch Systems, and Space Safety.

Integration and Correlation

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The integration of the survey and the desktop research report is a crucial aspect of the T2200 project. This process involves:

Cross-referencing Needs and Activities: Comparing the **needs of the sector** outlined in the desktop research with the activities and capabilities identified in the survey. This comparison aims to ensure that the sector's workforce is equipped with the necessary skills to meet current and future demands.

Identifying Gaps and Opportunities: The project seeks to **identify any gaps** between the required needs, skills and the existing capabilities within the industry, as well as potential opportunities for growth and development.

1.2 Conclusion and Key findings

The T2200 task, through its dual approach of **survey and desktop research**, endeavours to provide a comprehensive assessment of the European space sector. By focusing on the alignment of skills with industry activities and future needs, the project aims to offer valuable insights that can inform policy decisions, guide strategic planning, and contribute to the sector's sustained growth and innovation.

Important Note: The final results and comprehensive analysis of the T2200 project will be meticulously compiled and presented in the last and final version of the deliverable.

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2. ACTIVITY 1: SURVEY METHODOLOGY

2.1 Activity 1: Survey Design and Execution

The **"European Space Ecosystem Overview" survey** was held online over a period of six weeks. It was strategically designed to inquire various domains of the space sector, mirroring the comprehensive analysis carried out in the project's desktop research (Activity 2). The survey targeted a wide range of stakeholders, from industry professionals to researchers, to gather insights into their current involvements and future aspirations in the space sector.

Key areas of focus in the survey included domains such as **Earth Observation, Satellite Communication, Satellite Navigation, Access to Space and Launch Systems (including In-Orbit Servicing), Space Safety, Space Manufacturing, Space Exploration, Ground Segment, Space Science, Space Research & Technology, and Satellite Operations**.

This approach allowed for a detailed understanding of active and emerging areas within the space sector, aligning closely with the domains explored in the desktop research component of the ASTRAIOS project.

The chosen tool was the EU Survey, not aided in **the easy integration of our findings** with other EU tools and products across the project's various components but also aimed in supporting European-made products where the data are collected within Europe.

Link to the survey: https://ec.europa.eu/eusurvey/runner/astraios-sme4space-eu-space-ecosystem-survey

Figure 1: Figure 1: Tool of ASTRAIOS "European Space Ecosystem Overview" survey

2.2 In-Depth Analysis of Survey Design

The survey was specifically designed to **capture the perspectives of diverse stakeholders** within the space sector, including SMEs, start-ups, Research centres, Academia, and other relevant entities. This approach ensures a wide range of views and experiences are considered.

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Comprehensive Scope:

It covered a broad spectrum of the space sector, from applications and services to supporting technologies, ongoing programmes and market dynamics. This comprehensive scope enables a **holistic understanding** of the industry.

Structured Format:

The survey was divided into **five (5) distinct sections**, each focusing on different aspects such as stakeholder information, specific space domains, market dynamics, future prospects and open text discussion. This structure aids in the systematic collection and analysis of data.

Clear Definitions and Guidance:

Providing clear definitions for key terms ensures that respondents have a consistent understanding of the survey questions. This **clarity** is crucial for the accuracy and relevance of the responses.

Alignment with Project Objectives:

The survey is aligned with the ASTRAIOS project's overarching goals - to evaluate current sector offerings, assess EU programs, and identify future opportunities. This alignment ensures that the survey results directly contribute to the project's aims.

Key Elements of the Survey Design

The survey design for the "European Space Ecosystem Overview" within the ASTRAIOS project was crafted with several key elements to ensure its effectiveness and comprehensiveness:

Targeted Stakeholder Engagement/ Broad Participant Base: The survey aimed to capture a wide array of perspectives by addressing stakeholders from various sectors of the space industry. This approach was critical to gather a diverse range of insights, encompassing **views from SMEs, start-ups, Large companies, Research centres, and Academic institutions**. By engaging with such a varied participant base, the survey could effectively map the entire landscape of the European space sector.

Segmented Questions: The survey was thoughtfully organised into five (5) distinct sections, each focusing on different aspects.

- **Section 1: Stakeholder Information** to gather information on demographics, entity's size and respondents' role.
- **Section 2: Applications, Services & Market Dynamics** part focused on specific domains like Earth Observation, Satellite Communication, and Space Safety. This segmentation allowed for more focused and detailed responses, enabling participants to provide insights specific to their areas of expertise and operation.

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- **Section 3: Supporting Technologies & Value Chain** part evaluated how supporting technologies integrated with an organisation's value chain, identified any gaps or challenges due to the absence of certain technologies or collaborations, and explored potential new technologies or partnerships to enhance the value chain.
- **Section 4: Involvement in Ongoing Programmes and Future Prospects** reviewed an entity's participation in ongoing space programmes, its perceived role in these initiatives, challenges and opportunities encountered, and the skills or expertise it aims to develop for future needs.
- **Section 5: Open Discussion**. Finally, this part gave the opportunity to the respondents to share any additional thoughts or comments related to the survey's topic.

Clarity in Terms: To ensure consistency and understanding across a diverse group of respondents, clear definitions were provided for the key terms of 'Applications', 'Services/Products', 'Space related activities', and 'Supporting Technologies'. This clarity was essential for standardising responses and avoiding ambiguity, thus enhancing the quality and reliability of the data collected.

The given four (4) definitions were:

1. **Applications**: Specific uses of space-derived data, technologies, or capabilities that serve a particular function or solve a particular problem. Earth Observation Applications Example: Using satellite imagery to monitor environmental changes, urban planning, disaster response, etc.

2. **Services/Products:** Solutions provided by space entities, leveraging space assets or technologies, to fulfil particular needs of end-users or other stakeholders. Location-Based Services Example: Providing real-time navigation, tracking, and timing services using GNSS data.

3. **Space related activities**: Space related activities refer to the use of space technology in other industries and include all productive, administrative, or general operations relative to the production of goods and services having a substantial/important space component. Example: Products/services utilising space technology may include spin-offs or technology transfers from the space sector, which use space technology but do not depend on it (low incorporated quantities of "space" components (e.g., foam developed in space programme transferred to the automotive industry.

4. **Supporting Technologies**: Technologies that enable or enhance the operation, accessibility, or utility of space-based assets and services. Launch Technologies Example: Technologies like reusable rockets or advanced propulsion systems that facilitate the launching of satellites and other payloads into space.

GDPR Compliance Feature: Ensured ethical data handling and privacy protection, critical for sensitive space industry information.

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Deadline Specification: Initially set for four weeks, extended by two weeks for a total of six weeks, allowing flexibility and maximizing participation.

2.3 High-Level survey structure as published online

Survey Banner:

Figure 2: ASTRAIOS "European Space Ecosystem Overview" Survey banner

Background information

ASTRAIOS (https://www.astraios.eu/) is a EU-funded project, aiming at analysing the EU-27's Space education, forecasting the European Space industry's upcoming trends and needs, and strategies to bridge the gap between education and industry demands.

Survey Objectives

A core part of the ASTRAIOS project is investigating the views of stakeholders within the space sector, regarding current activities, ongoing programmes involvement, as well as the range of available applications, services, products and supporting technologies.

By complementing ASTRAIOS desktop research, the survey aims at:

- Evaluating the current Applications, Services, and supporting technologies within the space sector.
- Assessing the ongoing programmes facilitated by the EU.
- Identifying future opportunities in the space sector.

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Definitions

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Supporting Technologies: Technologies that enable or enhance the operation, accessibility, or utility of space-based assets and services. Launch Technologies Example: Technologies like reusable rockets or advanced propulsion systems that facilitate the launching of satellites and other payloads into space.

Deadline for participation: 30 November 2023 (final one)

GDPR Compliance: I hereby grant consent to the parties involved in the ASTRAIOS project to process and utilise data exclusively for the purposes of the ASTRAIOS survey for the European Space Ecosystem Overview.

Main Survey

2.3.1 Section 1: Stakeholder Information

Question 1.1: What is your organisation's name?

Question 1.2: What is your role within the organisation? - This field is required.

Question 1.3: In which part of the Space value chain is your company operating? Please select all the options that apply.

- Upstream
- Midstream

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- Downstream

Question 1.4: What is your organisation's primary focus area?

- Space Applications
- Space Services/Products
- Space related activities
- Supporting Technologies
- Other

Question 1.5: What type of entity is your organisation?

- Start-up
- SME
- Large Company
- Research Centre
- University
- Other

Question 1.6: What is the size of your organization in terms of employees in Annual Work Units? Please indicate your Annual Work Units (meaning your full-time equivalent employees) in units without any text, comma, or dot.

Question 1.7: What is your organisation's primary Country of operation?

- Austria
- Belgium
- Bulgaria
- Canada
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary

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- Iceland
- Ireland
- Italy
- Latvia
- Lithuania
- Luxembourg
- Malta
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- United Kingdom

2.3.2 Section 2: Applications, Services & Market Dynamics

Question 2.1: Below is a list of various space domains. For each domain that your organisation is involved in, please identify, and briefly describe any Applications, Services, or Products that you are currently developing.

- Earth Observation
- Satellite Communication
- Satellite Navigation
- Access to space and Launch Systems (including In-Orbit Servicing)
- Space Safety
- Space Manufacturing
- Space Exploration
- Ground Segment

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- Space Science
- Space Research & Technology
- Satellite Operations
- Space-related activities
- Question 2.2: How would you describe the market dynamics for your Applications?
- Increasing
- Stable
- Decreasing
- Demand trends
- Supply trends
- Competitive landscape

For each domain an additional required question was: If Yes, please describe the Applications/Services/Products being developed in the X domain.

Question 2.2: How would you describe the market dynamics for your Applications?

	Increasing	Stable	Decreasing
Demand trends	☐	☐	☐
Supply trends	☐	☐	☐
Competitive landscape	☐	☐	☐

Question 2.3: How would you describe the market dynamics for your Services/Products?

	Increasing	Stable	Decreasing
Demand trends	☐	☐	☐
Supply trends	☐	☐	☐
Competitive landscape			

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Question 2.4: In your opinion, what are the potential future advancements in:

	Please elaborate below
Space Applications:	
Space services/products:	

2.3.3 Section 3: Supporting Technologies & Value Chain

Question 3.1: How do supporting technologies integrate with your organisation's value chain in the domains listed in Section 2?

Question 3.2: Are there any gaps or challenges in your value chain due to lack of certain technologies or collaborations?

Question 3.3: Are there any technologies or partnerships you're exploring to improve your value chain?

2.3.4 Section 4: Involvement in Ongoing Programmes and Future Prospects

Question 4.1: What ongoing space programmes (under the domains in Section 2) is your organisation involved in? This can include involvement in specific space programmes, commercial ventures, partnerships, or other initiatives.

Question 4.2: Does your organisation perceive its contribution to these programmes as vital?

- Yes
- No
- Other

Question 4.3: What opportunities or challenges have arisen from your engagements, be it from programmes, commercial activities, or collaborations, and what do you see as the main barriers to growth?

Question 4.4: To prepare for these changes and challenges, what specific skills, needs, or areas of expertise is your organisation investing in or hoping to gain in the future?

2.3.5 Section 5: Open Discussion

Open Text Format: Please share any additional thoughts or comments related to the survey's topic.

2.4 Survey Preliminary Results

2.4.1 Section 1: Stakeholder Information

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Questions of this section:

1.1: What is your organisation's name?
1.2: What is your role within the organisation? - This field is required.
1.3: In which part of the Space value chain is your company operating? Please select all the options that apply.
1.4: What is your organisation's primary focus area?
1.5: What type of entity is your organisation?
1.6: What is the size of your organization in terms of employees in Annual Work Units?
1.7: What is your organisation's primary Country of operation?

Distribution of roles

1. **CEO**: 3 entries
2. **Director**: 3 entries
3. **Mechanical Engineer**: 1 entry
4. **Vice President**: 1 entry
5. **Technical Director**: 1 entry
6. **R&D Manager**: 1 entry
7. **General Management**: 1 entry
8. **Space Systems Engineer**: 1 entry
9. **Senior Project Manager**: 1 entry
10. **Project Manager**: 1 entry
11. **Business Development Engineer**: 1 entry
12. **Sales & Marketing**: 1 entry
13. **Research Associate, Data Analyst**: 1 entry
14. **Researcher**: 1 entry
15. **Administrator**: 1 entry
16. **CCO (Chief Commercial Officer)**: 1 entry
17. **Owner**: 1 entry
18. **Managing Director**: 1 entry

Value Chain Distribution

1. **Upstream**: 16 entries
2. **Midstream**: 6 entries

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3. **Downstream**: 7 entries

Entity Size and Employee Count

Type of Entities:

1. **Large Company**: 4 entries
2. **SME (Small and Medium-sized Enterprises)**: 12 entries
3. **Start-up**: 7 entries

Employees range

1. **1-10 Employees: 8 entries**
2. **11-50 Employees**: 5 entries
3. **51-100 Employees:** 3 entries
4. **101-250 Employees:** 2 entries
5. **251-500 Employees:** 4 entries
6. **501+ Employees:** 0 entries

Geographic Distribution

1. **Germany:** 4 entries
2. **Greece:** 4 entries
3. **Italy:** 2 entries
4. **Spain:** 2 entries
5. **Belgium:** 2 entries
6. **Romania:** 2 entries
7. **United Kingdom:** 1 entry
8. **Norway:** 1 entry
9. **Cyprus:** 1 entry
10. **Ireland:** 1 entry
11. **Denmark:** 1 entry
12. **Netherlands:** 1 entry
13. **Bulgaria:** 1 entry
14. **France:** 1 entry

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2.4.2 Section 2: Applications, Services & Market Dynamics

Questions of this section:

2.1 Below is a list of various space domains. For each domain that your organisation is involved in, please identify, and briefly describe any Applications, Services, or Products that you are currently developing. Are you developing any Applications/Services/Products in the one of the following domains? If Yes, please describe the Applications/Services/Products being developed in the selected domains.

[Domains: Earth Observation, Satellite Communication, Satellite Navigation, Access to space and Launch Systems (including In-Orbit Servicing), Space Safety, Space Manufacturing, Space Exploration, Ground Segment, Space Science, Space Research & Technology, Satellite Operations, Space-related activities]

2.2 How would you describe the market dynamics for your Applications? [Column: Demand trends, Supply trends, Competitive landscape / Row: Increasing, Stable, Decreasing]

2.3 How would you describe the market dynamics for your Services/ Products? [Column: Demand trends, Supply trends, Competitive landscape / Row: Increasing, Stable, Decreasing]

2.4 In your opinion, what are the potential future advancements in: [Column: Space Applications, Space services/products]

Key Areas of Focus

1. **Satellite Communication**: 3 entries
2. **Satellite Navigation**: 3 entries
3. **Access to Space and Launch Systems**: 3 entries
4. **Space Safety**: 1 entry
5. **Space Manufacturing**: 1 entry
6. **Space Exploration**: 1 entry
7. **Ground Segment**: 3 entries
8. **Space Science**: 1 entry
9. **Space Research & Technology**: 3 entries
10. **Satellite Operations**: 3 entries
11. **Space-related activities**: 4 entries

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This summary shows the distribution of the surveyed entities across various key areas of focus in the space industry. The most commonly mentioned areas are “Space-related activities”, followed by “Satellite Communication”, “Satellite Navigation”, and “Access to Space and Launch Systems”, each mentioned by three entities.

Applications

- **Demand Trends**
  - Increasing: 18
  - Stable: 4
  - Decreasing: 0
- **Supply Trends**
  - Increasing: 10
  - Stable: 9
  - Decreasing: 3
- **Competitive Landscape**
  - Increasing: 16
  - Stable: 5
  - Decreasing: 1

Services/Products

- **Demand Trends**
  - Increasing: 17
  - Stable: 5
  - Decreasing: 0
- **Supply Trends**
  - Increasing: 10
  - Stable: 11
  - Decreasing: 1
- **Competitive Landscape**
  - Increasing: 16
  - Stable: 5
  - Decreasing: 1

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Future Advancements in Applications

- **Integration with Terrestrial Networks**
- **Development of Smarter, Integrated Smaller Space Systems**
- **Multipurpose Satellites**
- **Supporting a Lunar Economy**
- **Enhanced Global Broadband Connectivity**
- **Advanced Satellite Technology for Direct-to-Mobile Communications**
- **Increased Data Rates Through Mega Constellation Developments**
- **Smarter and More Autonomous Satellite Systems**
- **Sustainability in Space Operations**
- **Exploration and Utilization of Deep Space**

Future Advancements in Space services/products:

- **Global Broadband Connectivity:** Focus on achieving universal internet access through advanced space services.
- **Advanced Satellite Technology for Direct-to-Mobile Communications:** Development of technologies enabling direct satellite communication with mobile devices.
- **More Integrated Solutions:** Trend towards system interoperability and seamless service integration in space services/products.
- **Alignment with Major Space Agendas and Accords:** Services/products aligning with international space agendas like ESA Agenda 2025 and Artemis accords.
- **Products Supporting a Lunar Economy:** Development of services/products to facilitate or benefit from lunar economic activities.
- **Shared Satellite Services:** Growing interest in collaborative and cost-effective shared satellite services.
- **Increased Data Rates through Mega Constellation Developments:** Expansion of mega constellations enhancing data transmission capabilities.
- **Versatility in Satellite Services:** Focus on developing versatile and multifunctional satellite services to cater to diverse needs.

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2.4.3 Section 3: Supporting Technologies & Value Chain

Questions:

3.1: How do supporting technologies integrate with your organisation's value chain in the domains listed in Section 2?
3.2: Are there any gaps or challenges in your value chain due to lack of certain technologies or collaborations?
3.3: Are there any technologies or partnerships you're exploring to improve your value chain?

Integration of Supporting Technologies
Based on the summary of responses:

1. **Continuous Technological Innovation and Regulatory Approvals**: Many entities emphasize the need for ongoing technological advancement and navigating regulatory frameworks, especially in the context of integrating new technologies with existing systems.
2. **Deployment of Open Standards and Data Exchange**: Several entities are working on deploying open standards for data exchange and sharing, indicating a trend towards more interoperable and standardized systems.
3. **Cybersecurity Integration**: There is a significant focus on integrating cybersecurity into development workflows, reflecting the growing concern over digital security in space technologies.
4. **Technology Supporting Data Transmission**: Some entities are developing technologies that support high-volume data transmission between satellites and Earth, showcasing the need for robust data handling capabilities.
5. **Manufacturing and Design Outsourcing**: A few entities mention outsourcing aspects of design and manufacturing, indicating a reliance on external expertise for certain technological integrations.
6. **Plug-and-Play Satellite Solutions**: Innovations in creating more user-friendly satellite solutions, like plug-and-play systems, are noted, simplifying the satellite development process for customers.
7. **Integration of Advanced Data Analytics and Machine Learning**: Integration of cutting-edge technologies like data analytics and machine learning is a focus area, especially for applications in sectors like agriculture.
8. **Environmental Monitoring and ICT Solutions**: Some entities are engaged in developing sophisticated environmental monitoring solutions using satellite data, reflecting a focus on climate change and environmental sustainability.
9. **Sustainable Technologies and Advanced Materials**: There is an emphasis on integrating sustainable technologies and advanced materials to ensure product quality and innovation.
10. **Focus on Space Electric Thrusters and In-Situ Resource Utilization**: Specific technological focus areas like space electric thrusters and ISRU technology are being explored for their potential applications in space missions.

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11. **Advancements in Satellite Communication Electronics**: Entities are working on advancements in satellite communication electronics, focusing on improvements in size, power, and data rate.
12. **Environmental Monitoring Using Lidar Technology**: Specialization in environmental monitoring and pollution detection using advanced technologies like Lidar is noted.
13. **Disruptive Technologies Integration**: Integration of disruptive technologies such as AI and blockchain is being explored to enhance monitoring and forecasting services.
14. **Focus on Resource Utilization and On-Orbit Manufacturing**: Some entities are concentrating on space resource utilization and on-orbit manufacturing, integrating disruptive technologies like quantum gravimetry and edge computing.
15. **Development of New-Space Activities and Innovative Materials**: Focus on new-space activities and the development of innovative materials, such as Shape Memory Alloys for complex systems, is evident.
16. **Ultralightweight Materials and Innovative Manufacturing Methods**: Emphasis on ultralightweight materials and innovative manufacturing methods, reflecting a trend towards efficiency and advanced material usage.

Gaps or Challenges

1. **Need for Continuous Technological Innovation and Regulatory Approvals**: Challenges include keeping up with technological advancements and navigating complex regulatory environments.
2. **Partnerships with Global Mobile Network Operators**: Some entities face challenges in forming and maintaining key partnerships, particularly with global mobile network operators.
3. **Requirement for Use of Data Standards by ESA, EU, and Governments**: Adhering to data standards set by major organizations and governments presents a challenge for some entities.
4. **Lack of Cybersecurity Know-How in the Space Sector**: A significant gap in cybersecurity expertise within the space sector impacts stakeholders and decision-makers.
5. **Funding for Technology Readiness Level Achievement**: Several entities report challenges in securing sufficient funding to support technology development and scale-up manufacturing activities.
6. **Outsourcing Design and Manufacturing**: Reliance on external parties for design and manufacturing can be a challenge, particularly in maintaining control over the production process.
7. **'Build vs. Buy' Dilemma in Satellite and Spacecraft Development**: Entities face dilemmas in deciding whether to build their solutions in-house or purchase existing technologies.
8. **Rapid Pace of Technological Development**: Keeping up with the fast pace of technological advancements and integrating state-of-the-art technology is a challenge for some entities.
9. **Integration of New Datasets into Existing Systems**: Rapid technological changes and integrating new datasets into existing systems pose a challenge, especially in environmental monitoring.
10. **Temporary Gaps in Integration Capabilities**: Rapid technological advancements sometimes create temporary gaps in integration capabilities.

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11. **Challenges in Obtaining Financing for SMEs**: Small and medium-sized enterprises in the space industry face difficulties in securing financing.
12. **Collaboration Challenges with European Enterprises**: Some entities face difficulties in establishing collaborations with European enterprises, indicating challenges in partnership or collaboration.
13. **Specialized Raw Materials Sourcing**: The expense and difficulty in sourcing specialized raw materials pose significant challenges.
14. **Component/Material Provider Limitations within the EU**: Limited options for component and material providers within the EU, coupled with import/export restrictions and bureaucracy, present challenges.
15. **Complexity of Engagement Programs and Competing Priorities**: Navigating complex engagement programs and balancing competing priorities are challenges faced by some entities.
16. **Data Access, Sharing, and Interoperability**: Challenges include accessing and sharing data, computational resources, and ensuring data interoperability.
17. **Need for High-Performance Computing Systems and AI Expertise**: The requirement for GPUs, HPCs, and collaborations with partners having strong AI backgrounds presents a challenge.
18. **Obtaining High Temporal/Spatial Resolution Earth Observation Data**: Acquiring high-resolution EO data for research purposes is a challenge for some entities.
19. **Financing for Low TRL Industrial R&D and Cash Flow Issues**: Financing difficulties for low TRL industrial R&D, cash flow issues, and lack of government support are notable challenges.
20. **Difficulty in Joining Large Institutional Space Projects**: Some entities face challenges in participating in large institutional space projects and conducting validations at higher TRLs.
21. **Real-World Use Cases and Experimentation Willingness**: Challenges include finding real-world use cases and large companies willing to experiment with new technologies.

Entities' exploration in technologies and partnerships

1. **Partnerships with Universities and Research Initiatives**: Some entities are collaborating with academic institutions and research initiatives to support the small and medium enterprise (SME) supply chain and leverage new technologies.
2. **Collaborations with European Materials Suppliers**: There's a focus on forming partnerships with suppliers in Europe, particularly for materials, indicating an emphasis on regional collaboration and resource sourcing.
3. **Exploring General Partnerships and Technologies**: Several entities are actively exploring new partnerships and technologies to enhance their capabilities, although specific details are often not provided.
4. **No Current Explorations Mentioned**: A few entities have not specified any current explorations in technologies or partnerships, indicating either a focus on existing projects or undisclosed future plans.

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5. **Vertical Integration Using Commercial Off-The-Shelf Components**: Some are focusing on the vertical integration of products using off-the-shelf components, aiming to optimize size, weight, power, and cost.
6. **Expansion into New Markets through Partnerships**: Entities are seeking expansion into new markets, evidenced by recent partnerships, especially in regions like the Americas.
7. **Engagement in EU Projects and Local Collaborations**: Participation in EU projects and local partnerships is a key focus, involving collaborations that enhance agricultural monitoring systems and integrate advanced technologies.
8. **Focus on Sustainable and Innovative Technologies**: A trend towards sustainable technologies, advanced materials, and product innovation is evident, with some entities incorporating advanced robotics and AI into their processes.
9. **Partnerships for Volume Production and Specialized Applications**: Collaborations are being formed for volume production and to meet specific application needs, though details on these technological explorations are sometimes limited.
10. **Collaborations for Space Security and Earth Observation Programs**: Involvement in space security programs and collaborations aiming to improve services in areas like Earth observation and natural hazard monitoring is noted.
11. **Engagement in Space Resource Utilization and Manufacturing Initiatives**: Entities are focusing on space resource utilization, on-orbit manufacturing, and engaging in collaborations that support innovative technologies.
12. **Challenges in Joining Large Projects and Conducting High-Level Validations**: Some entities are seeking collaborations to overcome difficulties in participating in large institutional space projects and achieving higher Technology Readiness Levels (TRLs).
13. **Exploration of New Manufacturing Technologies and Market Opportunities**: Entities are exploring innovative manufacturing methods and seeking opportunities to apply their technologies in real-world use cases.

2.4.4 Section 4: Involvement in Ongoing Programmes and Future Prospects

Questions:

4.1: What ongoing space programmes (under the domains in Section 2) is your organisation involved in? This can include involvement in specific space programmes, commercial ventures, partnerships, or other initiatives.

4.2: Does your organisation perceive its contribution to these programmes as vital?

- Yes
- No
- Other

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4.3: What opportunities or challenges have arisen from your engagements, be it from programmes, commercial activities, or collaborations, and what do you see as the main barriers to growth?
Question 4.4: To prepare for these changes and challenges, what specific skills, needs, or areas of expertise is your organisation investing in or hoping to gain in the future?

4.4 To prepare for these changes and challenges, what specific skills, needs, or areas of expertise is your organisation investing in or hoping to gain in the future?

Based on the provided data from the entities:

Summary of Perceived Contribution to Space Programs

- **Yes**: 17 entities indicated that they perceive their contribution to the programs as vital.
- **Other**: 4 responses indicated "Other".

Ongoing space programmes

1. **BlueWalker 3:** A large commercial communications array in low Earth orbit, noted for its potential impact on global connectivity.
2. **European Space Agency (ESA):** Participation in various ESA projects and collaborations with OEMs for strategic research and development.
3. **No Specific Programmes Mentioned:** Some entities have not specified their involvement in particular space programmes but are recognized in the European space market for their products.
4. **ESA Programmes:** Involvement in various programmes under the European Space Agency, focusing on security and communications.
5. **ESA Business Incubation Centres (BIC) and Accelerator Programs:** Engagement with companies within these programmes to understand new space businesses.
6. **ESA's InCubed, ARTES, Enterprise Ireland with DTIF Funding:** Support from these programmes for research and development activities.
7. **Not Currently Involved in Any Programmes:** Some entities are currently not engaged in specific space programmes.
8. **ESA's Hera Mission and Projects with Orbital Micro Systems:** Participation in these missions as a leading manufacturer in the small satellite market.
9. **EU Projects for Agricultural Monitoring Systems:** Involvement in networks and obtaining funding from EU projects for agricultural technologies.
10. **European and National Research Projects:** Participation in various research projects in Europe.
11. **EU Projects for Advanced Manufacturing and Engineering Research:** Engaging in projects under the European Union for development and innovation in these fields.

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12. **Artes AT, Lunar Pathfinder, PROBA-3 MMX Rover, and Others Under NDA:** Involvement in a range of projects, with sunsensors playing a vital role in various missions.
13. **ISRU Technology Development:** Focusing on In-Situ Resource Utilization technology for space exploration.
14. **Supplying Main Contractors to the European Space Agency:** Providing key components to major contractors like Thales, Astrium, etc.
15. **Projects like GRACE-C, Clearspace, AWS, NAOS, etc.:** Engaging in various projects that emphasize the company's role in satellite communication.
16. **ESA Projects for Environmental Monitoring and Pollution Detection:** Participation in projects that enhance the company's capabilities in environmental sectors.
17. **Various Funding Programs Like ESA, Horizon Europe:** Engaging in multiple funding programmes to support research activities.
18. **MedEWSa, Firelogue, EUSST, EMS Copernicus, and Other Projects:** Involvement as work package leaders, coordinators, and contractors.
19. **ESA and EU Horizon Tenders:** Engagement in tenders for funding and research.
20. **EU Space Program and ESA ITTs:** Involvement in programs and tenders under the European Union and European Space Agency.
21. **ESA-GSTP (General Support Technology Programme):** Participation in this programme focusing on small serial production for space.

Opportunities in the space sector

1. **Technological Advancement and Global Connectivity:** Emphasis on leveraging cutting-edge technology for large-scale communication arrays and enhancing global connectivity.
2. **Strategic Research and Development:** Utilising space programs for strategic R&D, leading to the development of new products, networks, and technologies.
3. **Cost Efficiency and Performance Enhancement:** Focus on producing products that lower mission costs without compromising performance, particularly in RF and communications.
4. **Market Expansion through Collaborations:** Opportunities arising from engaging in prime contracts and collaborations with major space agencies and other entities.
5. **New Space Business Understanding:** Gaining insights into new space businesses through engagement with accelerator programs and business incubation centers.
6. **Funding for Advanced Technologies:** Utilising funding sources for R&D in advanced technologies, including Earth Observation, AI, and secure space communications.
7. **Innovation in Small Satellite Technologies:** Expanding capabilities in areas like CubeSats and Nanosatellites to adapt to growing market needs.

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Challenges in the space sector

1. **Regulatory Approval and Strategic Partnerships:** The need for regulatory approval and forming strategic partnerships with key industry players.
2. **Industrial Take-Up and Conservative Thinking**: Overcoming conservative thinking in the industry to enhance industrial take-up of new technologies.
3. **Workforce and Skill Development:** Challenges in hiring specialized personnel such as RF Engineers, cybersecurity experts, and material scientists.
4. **Financial Constraints:** Financial challenges, including reluctance from banks to lend and difficulties in securing investment, particularly for SMEs**.**
5. **Defence Procurement and Collaboration:** Difficulties faced by small companies in defence procurement and the need for collaboration with larger entities for higher-level engagement.
6. **Bureaucratic and Sourcing Issues:** Navigating bureaucratic hurdles and sourcing challenges while maintaining operational flexibility and responsiveness.
7. **Adapting to Technological and Market Trends**: The need to keep up with technological trends and market demands through focused R&D efforts.
8. **Complex Project Engagement and Resource Management:** Managing complex engagements and addressing challenges related to data quality, computational resources, and labour market conditions.
9. **Infrastructure and Asset Procurement Funding:** Securing funding for necessary infrastructure development and asset procurement.
10. **Navigating Industry-Specific Problems:** Addressing various industry-specific challenges, ensuring technologies and approaches are recognised within the space industry.

Preparation for Changes and Challenges

1. **Skill Development and Training**: Several entities focus on internal skill development, such as "on-the-job" training, to meet the evolving requirements of the aerospace and defence sectors.
2. **Hiring Specialized Personnel**: There's a trend towards hiring more specialized personnel in areas like RF Engineering, FPGA/Embedded Systems Engineering, Material Science, Test Technicians, and Assemblers.
3. **Cybersecurity Focus**: Some companies are actively seeking professionals with strong cybersecurity profiles, highlighting the growing importance of security in space communications and technology.
4. **Economic and Business Skills**: Plans to hire economics graduates or professionals with business acumen are noted.
5. **Collaboration with Larger Primes**: Collaborating with larger, more established companies is a strategy for some smaller entities.
6. **Expansion of Capabilities**: Companies are expanding their capabilities in specific areas, such as CubeSats and Nanosatellites, to better adapt to market needs.

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7. **Investment in Advanced Technologies**: Investment in advanced technologies like Earth Observation and AI tools is identified.
8. **Focusing on R&D for Market Trends**: A focus on R&D to keep up with technological trends and market demands is evident.
9. **Flexible and Responsive Operational Strategies**: Implementing strategies to stay flexible and responsive to the dynamic market, including navigating bureaucratic and sourcing challenges, is a key focus for some companies.
10. **Developing Polyvalent R&D Facilities**: The development of autonomous, versatile R&D facilities and teams to adapt to market needs is noted.
11. **Addressing Industry-Specific Challenges**: Efforts to ensure that the voices and technologies of companies are recognized in the space industry, and addressing various industry-specific challenges, are part of the preparation strategies.

2.4.5 Section 5: Open Discussion

Open text format: Please share any additional thoughts or comments related to the survey's topic.

- Some respondents advised continuing to support the findings after the completion of the report, but rather continue by actively supporting the development of the findings.

- Some respondents noted that SMEs seeking financing between 1 to 5 million Euros face challenges, as banks find the risk too high and the amount too low for venture capitalists.

- A respondent mentioned that their production facility is close to Dendermonde, Belgium, and invited others to visit and see how the parts are made.

- Some respondents suggested reducing the weight of non-technical aspects in HE space application forms, similar to ESA's tender application structures, to lessen administrative burdens. They also recommended enhancing the Public-Private Partnership approach by allocating more funds to specific European Industry space PPPs, like the S.P.A.C.E. partnership, and further supporting SMEs by lowering supply chain entry barriers.

2.5 Statistics

From the above results, some interesting demographic statistics are provided. The analysis of these results will be included in the final version of the deliverable.

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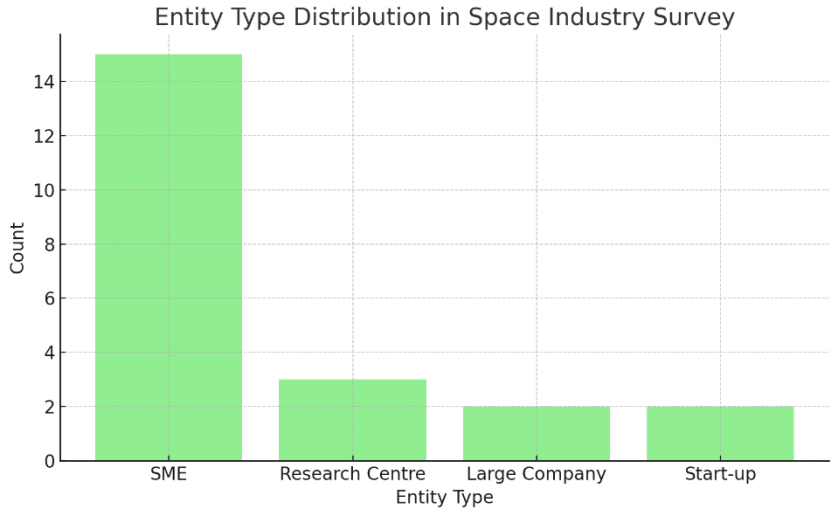

Figure 3: Entity type distribution in Space Industry ASTRAIOS Survey

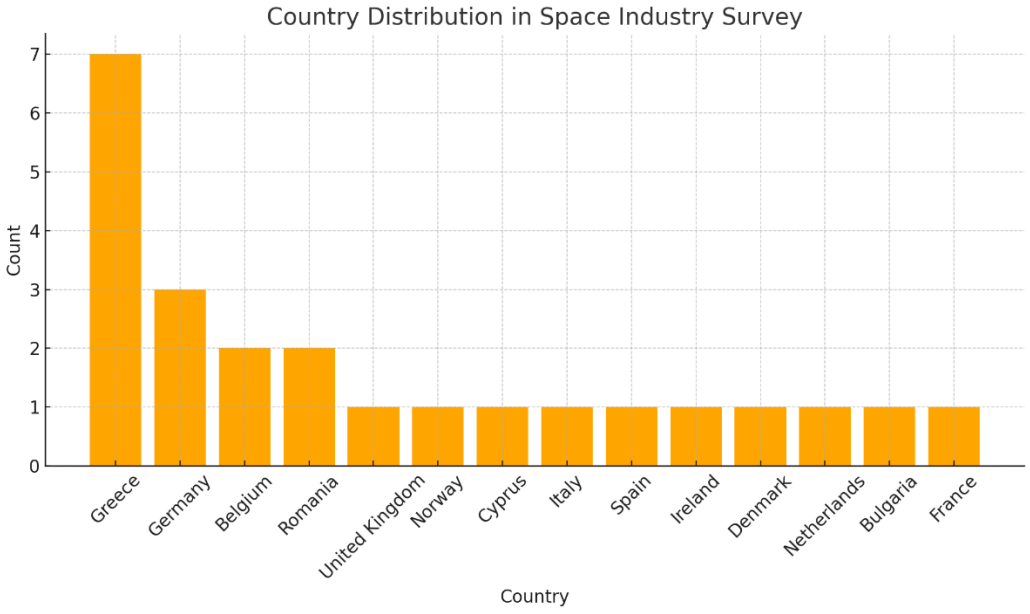

Figure 4: Country Distribution in the ASTRAIOS space industry survey

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3. ACTIVITY 2: DESKTOP RESEARCH

3.1 Introduction

This chapter forms a crucial segment of a broader **in-depth analysis**, created by PwC, of the space services and businesses sector, developed under the framework of D2.1 Overview of the Trends and Challenges for the European Space Industry. However, part of the study was also devoted to the area of skills needs and current applications, services and supporting technologies of the sector.

In this chapter, we focus on examining the current offer on **EU-provided space programmes**, specifically on each sector along with **market dynamics**, including **both demand and supply trends**, and map in the format of **a catalogue the emerging and future applications, services and supporting technologies** of the space sector. Additionally, for each domain, we map out emerging technologies, services, and applications.

The domains covered in this analysis include:

1. Earth Observation
2. Satellite Communication
3. Satellite Navigation
4. Access to Space and Launch Systems
5. Space Safety

The detailed report that includes the full references and sources is attached in Appendix B.

3.1.1 Focus Domain: Earth Observation (EO)

3.1.1.1 Overview

Earth Observation (EO) is a rapidly evolving domain that leverages satellite technology to monitor and collect data about the Earth's surface, atmosphere, and oceans. This field **plays a critical role in a wide range of applications**, from environmental monitoring and disaster management to urban planning and agricultural development. With the advent of advanced satellite systems and sensors, the **granularity and accuracy of data have improved** significantly, enabling more precise analyses and actionable insights.

One of the most noteworthy aspects of the Earth Observation domain is its diverse development landscape, which includes both institutional programmes and private actors. Key programmes such as Copernicus, EO4SD, and LANDSAT, **backed by governmental or international organisations**, have become cornerstones in the Earth Observation landscape. These programmes provide a multitude of data sets that include temperature, humidity, land use, and even air quality.

Simultaneously, the private sector has become increasingly active in Earth Observation, launching their own satellites and offering specialized services. **Companies are innovating in data analytics, machine learning**

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models, and real-time monitoring services, thereby **complementing the data and services provided by institutional programs**. This synergy between public and private entities is enriching the EO ecosystem, making it more dynamic and responsive to market needs.

The market dynamics in the Earth Observation domain are complex yet promising. On one hand, there is a growing demand for real-time, high-resolution and high-quality data for various applications. On the other hand, there is a surge in the supply side with more satellites being launched and more companies entering the EO services market. This interplay between supply and demand is supporting innovation and investment, making Earth Observation **a pivotal domain with significant economic and societal impact**.

3.1.1.2 Earth Observation programmes

3.1.1.2.1 Copernicus

The **Copernicus** programme is one of the **largest EO programmes** ever created in terms of satellites and in terms of data generated. It is directed by the European Union, through the European Commission and is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for MediumRange Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.

The EO satellites providing the Copernicus data are split into two groups of missions:

- **The Sentinels**, which are developed for the specific needs of the Copernicus programme.
- **The Contributing Missions**, which are operated by National, European or International organisations.

The Sentinel-1, Sentinel-2, Sentinel-5P, and Sentinel-3 land missions are all operated by the European Space Agency (ESA), which is also in charge of developing the Copernicus program's space segment. EUMETSAT oversees operations of the Sentinel-3 satellites, completing the marine mission, and operating and delivering the Sentinel-4, Sentinel-5, and Sentinel-6 satellites' instruments.

List of current Sentinel satellites:

- **Sentinel-1A and 1B**, launched in 2014 and 2016, provide all-weather, day and night radar imagery for land and ocean services
- **Sentinel-2A and 2B**, launched in 2015 and 2017, have a multispectral optical sensor for land services
- **Sentinel-3A and 3B**, launched in 2016 and 2018, carry a suite of optical, radar, and altimetry instruments for land and marine applications
- **Sentinel-4** is a payload devoted to atmospheric monitoring that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit
- **Sentinel-5** Precursor or Sentinel-5P, launched in 2017, is the forerunner of Sentinel-5 to provide timely data on a multitude of trace gases for atmospheric service

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- **Sentinel-5** is a payload that monitors the atmosphere from polar orbit aboard a MetOp Second Generation satellite
- **Sentinel-6** carries a radar altimeter to measure global sea-surface height, primarily for operational oceanography and for climate studies

3.1.1.2.2 LANDSAT

The **Landsat** program is a series of EO satellite missions that were jointly developed by the United States Geological Survey (USGS) and National Aeronautics and Space Administration (NASA). The primary mission of the Landsat program is to collect and provide **high-quality, reliable, and consistent data** about the Earth's natural resources and the planet's surface. The Landsat program has been operational since 1972, making it **the longest-running program of its kind**.

The data collected by the Landsat satellites is transmitted to ground stations located around the world, where it is processed and archived by the USGS. The USGS makes this data available to the public free of charge, allowing researchers, policymakers, and the general public to **access and use it for a wide range of purposes**. The data applications include development of information for monitoring and management of forests, water, agricultural land, urban areas, ecosystems, fire, disasters, climate, energy, and human health.

3.1.1.3 Market Dynamics, Demand and Supply Trends in Earth Observation (EO)

3.1.1.4 Market Dynamics

The EO market encompasses two primary revenue streams: **EO data revenues** and **value-added service revenues**. EO data revenues result from financial transactions between EO data providers and users, while value-added service revenues are generated further along the value chain, involving transactions between EO products and services or information providers and end-users.

3.1.1.5 Demand trends

The democratisation of Earth Observation (EO) technology is ushering in a new era where both experts and non-experts, from small enterprises to policymakers, are leveraging EO data for diverse applications. As EO technology becomes **increasingly user-friendly**, its benefits are being recognized across a multitude of fields. This has led to greater engagement from various stakeholders, who are now utilising **EO data for research, decision-making, and societal benefits.** The shift towards broader accessibility is not just a technological trend but a societal movement, enabling more precise resource management, community-based research, and informed policymaking.

In summary, the democratisation and technological advancement of EO data are leading to its widespread application across different sectors, including policymaking, specialised industry solutions, military strategy, emerging analytics markets, and regulatory compliance. Specifically:

Democratisation of EO Data Use: There is an increasing trend of both experts and non-experts, encompassing small enterprises, citizen scientists, educators, and policymakers, utilising Earth Observation

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(EO) data. The user-friendliness of this technology is broadening its application **across various fields for research, decision-making, and societal benefits.**

EO Data in Policy Making: Policymakers are progressively using EO data for informed decision-making in areas such as urban planning, disaster management, and climate change mitigation. This data assists in **land use analysis, population density assessment, and disaster response planning**.

Specialised EO Products and Analytics: With the advancement of EO technology, there's a shift towards developing **vertically specialised products** and insights for specific industries like **agriculture, forestry, and urban planning.** This approach leads to more precise resource management and informed operational decisions.

Military Applications of Advanced EO Analytics: Military organisations are leveraging advanced EO analytics for mission planning, situational awareness, and broader defence strategies. Integration with AI and ML enhances these capabilities.

Emerging EO Analytics Markets: The integration of AI with EO is opening new analytics markets, improving data analysis for various applications such as climate modelling, natural resource management, and disaster prediction.

Non-Imagery EO Data: Interest is expanding beyond traditional imagery to include radar, LiDAR, and hyperspectral imaging, providing diverse insights into various Earth phenomena and improving decision-making across multiple industries.

Regulation and Reporting Requirements: The Corporate Sustainability Reporting Directive (CSRD) by the EU necessitates public companies to include climate risk and ESG analysis in their reports, increasing demand for EO and satellite data for supply chain tracking and compliance.

3.1.1.6 Supply Trends

Overall, the EO industry is evolving with trends like vertical integration, satellite miniaturisation, constellations, industry consolidation, diversification into non-imagery data, 'as-a-service' models, commercial weather satellites, and sovereign EO initiatives. These developments are shaping the future supply and application of EO data and services. Specifically:

Trend Towards Vertical Integration and Satellite Miniaturisation: The EO industry is experiencing **a move towards vertical integration**, combining various elements like **satellite production, data collection, processing, and value-added services** within single organisations. This approach enhances efficiency and control. Concurrently, there's a trend towards creating smaller, lighter satellites, facilitating more flexible and affordable EO data collection and allowing for frequent revisits. These developments are expanding the availability and diversity of EO data, opening new opportunities across industries.

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Constellations as the New Standard: Many EO market players are adopting satellite constellations, which are arrays of multiple satellites working together. Benefits include higher revisit frequency, global coverage, and enhanced data collection capabilities, thus providing comprehensive Earth observations and better monitoring of dynamic events.

Expected Industry Consolidation via SPACs: In 2021, key EO companies like Spire, BlackSky, Planet, and Satellogic engaged in SPAC deals, capturing significant market shares. This consolidation trend, fuelled by strategic partnerships and acquisitions, signifies a maturing industry poised to meet increasing demand for EO data and services.

Rise of Major Non-Imagery Players: While imagery data has traditionally dominated, there's growing interest in non-imagery data types like hyperspectral, thermal infrared, and microwave sensing. Companies specialising in these areas are diversifying the market with their unique services and data products.

Emergence of 'As-a-Service' Models: 'Space-as-a-service' models are emerging, where governments can contribute critical payload components while outsourcing other aspects of the space segment to commercial companies. This approach allows governments to access premade satellites while retaining ownership.

Commercial Weather Satellites: The commercial weather sector within the EO industry is gaining prominence in climate adaptation and resilience technology development. Private companies are increasingly involved in enhancing sensors, modelling, processing, and transmitting weather data.

Sovereign Earth Observation Initiatives: Some countries, responding to geopolitical shifts and data independence needs, are investing in EO constellations and supporting commercial EO companies to align with national data policies. These initiatives also aim to develop the EO sector locally, offering skill progression and job opportunities.

3.1.1.7 Catalogue of EO technologies, services, and applications

The table below shows a variety of **cutting-edge technologies and applications** in the upstream, midstream, and downstream segments of the EO value chain. Sentinel-4, Sentinel-5, and hyperspectral imagery represent upstream developments that promise improved data collection capabilities. Data processing and analysis are being shaped in the midstream by innovations like the Copernicus Marine Data Store and AI-driven tools like generative adversarial networks. The diverse range of downstream applications—which include improving agriculture to assisting the European Green Deal—illustrates the crucial role that **EO plays in tackling today's challenges in a variety of fields**. These developments highlight the growing significance of EO in responding to global and regional needs.

Catalogue of all the listed Technologies, Applications and Services and Supporting Technologies can be found on Appendix C.

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Table 1: Upstream and Midstream EO Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Upstream & Midstream	Meteosat Third Generation Sounder (MTG-S) satellite (Sentinel-4)	Hourly data on tropospheric constituents over Europe for air quality	Weather and atmosphere monitoring
	46 MPixels sensors with video acquisition	High resolution video of an extremely wide scene	Video observation
	32 small satellites fleet constellation	Very high resolution and rapid revisit	Real-time commercial data products
	Hyperspectral imagery	Broad spectral range and narrow sampling	Multipurpose hyperspectral data
	Bicubic-down sampled low resolution image-guided generative adversarial network	Super resolution imagery	Remote sensing image enhancement solutions
	Efficient hybrid conditional diffusion model1	Data processing onboard spacecraft	Remote sensing image enhancement solutions
	Onboard AI		Efficient data transmission with reduced ground-based processing

Table 2: Downstream EO Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Downstream	Integrated AI, cloud, and EO capabilities	Digital model of the Earth	Climate monitoring and change prediction
	Geo-augmented reality	Mobile display tools	Advanced situational awareness and location information
	Copernicus Marine Data Store	Cloud-based open access Sentinels data storage	Free marine data and metadata tools, downloads, and post-processing
	Sentinel Hub QGIS plugin	Graphical interface within Copernicus browser	Sentinel data search, integration, and visualization

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3.1.2 Focus Domain: Satellite Communication (Satcom)

3.1.2.1 Overview

The satcom value chain is composed of **three key segments -upstream, midstream & downstream**. Each of these phases plays a significant role in the development, delivery, and optimisation of satellite communication services to end users. The figure illustrated below showcase this value-chain.

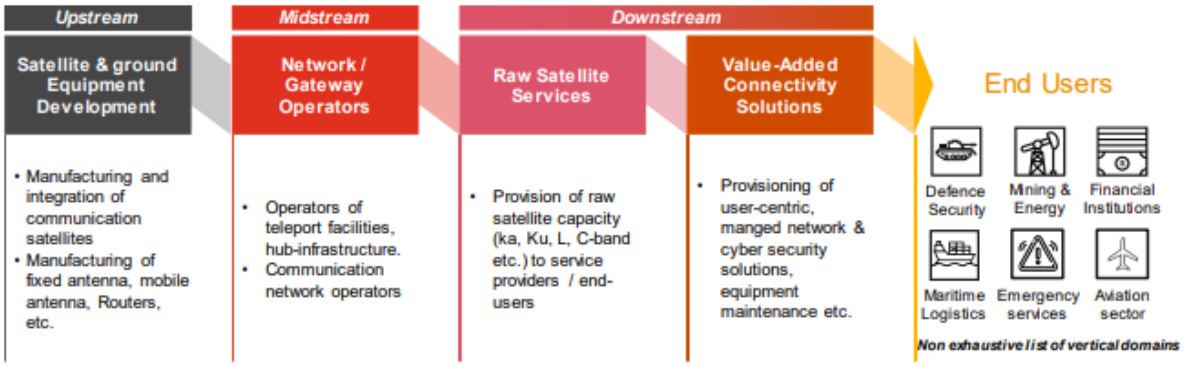

Figure 5: Satcom Value Chain (by PwC)

3.1.2.2 Satellite Communication programmes

The European institutional satcom framework is anchored by **three critical programmes**: the Advanced Research in Telecommunication Systems (**ARTES**), the Government Satellite Communication (**GOVSATCOM**), and the Infrastructure for Resilience, Interconnectivity, and Security by Satellite (**IRIS²**). Each catering to distinct motives and objectives.

3.1.2.2.1.1 ARTES: Advanced Research in Telecommunications Systems

Currently, the ARTES programme has evolved into ARTES 4.0, overseen by the **ESA's Telecommunications and Integrated Applications (TIA) directorate**. A detailed breakdown of ARTES 4.0 is shown in the figure below, highlighting four generic program lines as well as the three strategic programmes lines.

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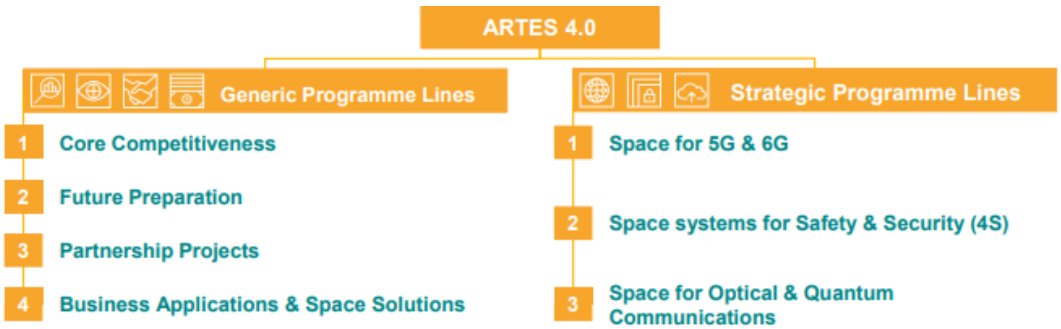

Figure 6: Overview of ARTES 4.0 Programme Lines (by PwC)

Table 3: Detailed overview of ARTES 4.0 Programme Lines

Generic Programme Lines	Strategic programme Lines
▪ **Core Competitiveness:** This programme line focuses on both market pull and technology push initiatives. The market pull Focus aims to support technologies and products tailored to current market needs, with proposals originating from the industry. ▪ **Future preparation**: The primary goal through this program line is to identify upcoming technologies and their associated market opportunities across the satcom value-chain. ▪ **Partnership projects**: Enabling environment for the satcom industry to roll out innovative commercial solutions, and foster collaboration for large scale programmes with both the private and public sector entities. ▪ **Business Applications & Space Solutions (BASS):** This programme line supports a wide range of businesses, including start-ups and SMEs, by offering access to tools like ESA Business Incubation Centres.	▪ **Space for 5G and 6G:** This initiative focuses on harmonising terrestrial networks, both existing and emerging, with space-based communication systems. ▪ **Space Systems for Safety & Security (4S):** Through this program line, ESA promotes the creation of secure satellite communication systems compatible with public and private terrestrial networks. ▪ **Space for Optical & Quantum Communications:** Through this programme line ESA strives to remain at the forefront, this includes optical communications that amplify network throughput and the advancement of quantum communication technologies, for security measures.

3.1.2.2.1.2 GOVSATCOM

In December 2013, the European Council highlighted satellite communication as a priority during its first thematic defence debate. They urged collaboration among Member States, the European Commission, and

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the European Space Agency for the **next-gen Governmental Satellite Communication**. Starting 2014, the European Commission spearheaded the EU GOVSATCOM program to ensure European autonomy in satellite communications. This effort continues, and the 2021-2027 EU Space Programme has incorporated EU **GOVSATCOM** as one of its four main elements.

The GOVSATCOM initiative is built on **three key objectives**. Firstly, address the **fragmentation of European governmental satellite systems** by creating a unified pool of capabilities, services, and users. Secondly, **ensure Europe's strategic independence** in technology and services, enhancing the effectiveness of humanitarian and civil protection efforts both regionally and globally. Thirdly, **develop cost-effective communication solutions** for EU defence and government users, ensuring timely access, and protection against unauthorized access. Building on these foundational objectives, the broader implications of GOVSATCOM initiative are expected to be instrumental in various EU policy areas, notably the EU Arctic Policy, and the EU Cyber Defence Policy Framework, as well as the EU Maritime Security Strategy.

Given the recent extension of the GOVSATCOM initiative until November 2025, the initiative plans to **leverage existing national space assets** and engage with **accredited private operators via interconnected operational hubs**. These hubs are designed to act as streamlined networking nodes, directing traffic among them to guarantee secure and reliable communication that satisfies end-user Quality of Service (QoS) requirements. Furthermore, in remote areas lacking terrestrial systems or in scenarios where such systems are compromised due to natural disasters or malicious acts, these hubs will be crucial in maintaining secure communication links.

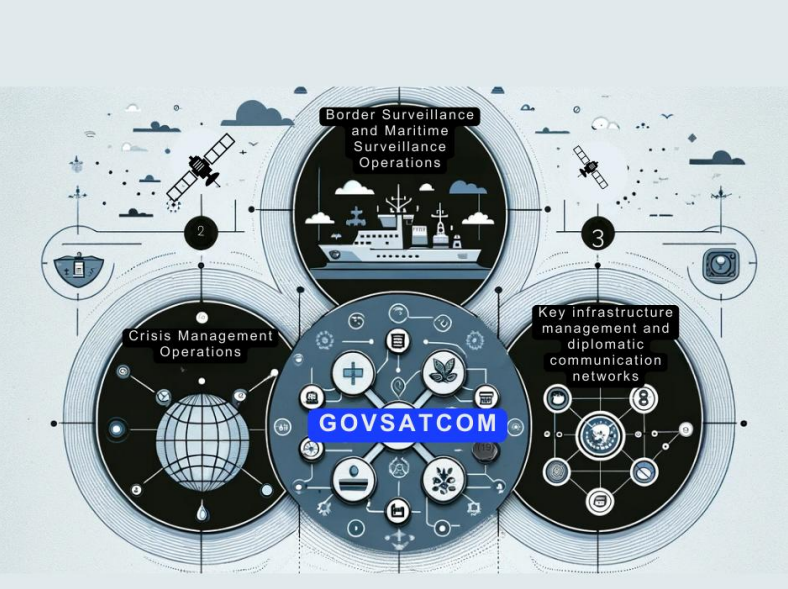

Figure 7: Three main applications of GOVSATCOM

3.1.2.2.1.3 IRIS²: Infrastructure for Resilience, Interconnectivity and Security by Satellite

IRIS² is the most recent programme announced by the European commission, the objectives of which are two-fold, first to **curb competition arriving from non-European commercial LEO constellations** such as

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OneWeb, Starlink, Telesat, and Project Kuiper, as well as institutional constellations such as China's Guowang and the United States' Proliferated Warfighter Space Architecture (PWSA). Secondly**, to ensure sovereign global access to secure, reliable and resilient communication links**. This second aspect is more so crucial and has been under discussion for almost a decade.

The programme has already completed its first phase towards the formation of an open consortium, governed by Airbus Defence and Space, Eutelsat, Hispasat, SES and Thales Alenia Space. While also relying on core expertise from companies such as Deutsche Telekom, OHB, Orange, Hisdesat, Telespazio, and Thales. This **consortium is expected to design a multi-orbital satellite constellation**, with interoperable features linking the terrestrial networks too. Moreover, the consortium is also expected develop relationships and partnerships with the greater satcom and telco community, that is composed of start-ups and SME's.

Currently **the programme is under phase 2**, whereby the consortium members submit their preliminary proposals. These proposals include details regarding the project design, cost, schedule as well as gauging the financial involvement of the private sector. Additionally, phase 2 also aims to comprehend the supply chain that shall be necessary to deliver the constellation, **including the involvement of start-ups and SMEs**. Overall, this phase is expected to be completed by 2024. The implementation of IRIS2 will follow an incremental approach with the ambition to **deliver initial services in 2025** to reach full operational capability by mid-2027. it is noteworthy to mention its EUR 2.4B of EU funding over several years is about 1% compared to the $50B annually of public space funding for security and defence globally.

3.1.2.3 Market Dynamics

The global satcom market is anticipated to grow at a CAGR of 9.5%, increasing from $12.1B in 2021 to an estimated $30B by 2031. This overall growth, however, varies dramatically across verticals. Much like the global landscape, the European market is experiencing widespread erosion in capacity prices. **This trend spans both High Throughput Satellite (HTS) and Fixed Satellite Services (FSS) solutions** and is visible across all verticals.

Currently, Non-GEO constellations such as SES (O3B), and especially **Starlink have significantly disrupted the market by offering solutions that are on an average 2.6 times more cost effective than those offered by GEO** HTS operators with the widest gap emerging in the Commercial Mobility vertical, where non-GEO HTS operators are almost 3.5 times less expensive than GEO HTS operators.

By 2031, the price differential is expected to widen even further for specific verticals. For the Government/Military (Gov/Mil) and Enterprise Data segments, non-GEO HTS offerings are projected to be nearly 10 times and 4.5 times more economic, respectively, compared to GEO HTS services. In addition, for other sectors like Commercial Mobility, Backhaul & Trunking, and Broadband Access, Non-GEO HTS is anticipated to continue its cost advantage, being 2.1 times, 1.4 times, and 1.1 times less expensive than the GEO HTS options.

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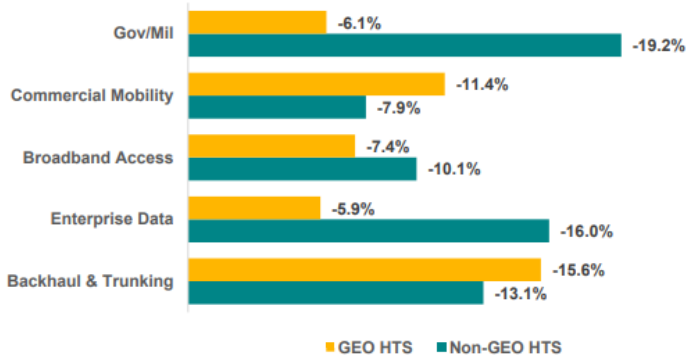

Figure 8: GEO HTS & Non-GEO HTS European Capacity Pricing CAGR, 2021-2031 (by PwC)

3.1.2.4 Demand Trends

The broadband and telecommunication landscape is witnessing significant shifts. Starlink is at the forefront of this change, offering flexible and affordable consumer broadband services that starkly contrast with the inflexibility and hidden restrictions of traditional packages. This has led to an **increased demand for broadband in Europe**. Concurrently, the demand for traditional video services is waning in Western Europe due to the growing popularity of **Over-The-Top (OTT) platforms** and a shift towards **terrestrial and fiber solutions over satellite-based ones**. However, this trend is less pronounced in Central and Eastern Europe. Moreover, the telecommunications sector is poised for **further growth with the integration of advanced technologies like optical communication links** and **the adoption of 5G standards**, which are expected to drive increased demand across various data-centric industries. These developments collectively indicate a dynamic evolution in consumer preferences and technological capabilities in the broadband and telecommunication sectors. Specifically:

Starlink's Impact on Broadband Demand

- Traditional broadband requires two-year commitments with hidden data caps.
- Starlink offers no long-term commitments, 100-220 Mbps speeds, and flexible terminal purchase/rent options.
- Competitive pricing in Europe: €40/month, with additional global mobility option for €190/month.
- Starlink's model boosts broadband demand in Europe due to its affordability and high-speed.

Decline in Video Services Demand in Western Europe

- Providers like Deutsche Telekom and Sky UK lose ground to OTT platforms (e.g., Netflix, Amazon Prime).
- Shift from satellite to fibre for content distribution, reducing satellite reliance.
- Decline in video service demand is less in Central and Eastern Europe.

Boost from Optical Communication Links and 5G

- Inter-satellite links and 5G standards improve network optimization.
- Expected to increase demand in data-centric sectors, both fixed and mobile.

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3.1.2.5 Supply Trends

The satellite communication (satcom) market in Europe is undergoing significant changes, characterised by three main trends:

- **HTS Capacity Oversupply**: The European market is facing an oversupply of High-Throughput Satellite (HTS) capacity, with a projected increase from 321 Gbps in 2021 to 34 Tbps by 2031. Non-GEO HTS constellations are growing significantly, expected to contribute 92% of total capacity by 2031.

- **Government Satellite Programs Resurgence**: There's a shift from commercial satellite communication (COMSATCOM) to government-led satellite programs like China's Guowang and the US's PWSA, affecting market supply dynamics.

- **Market Consolidation via M&As**: The satcom market is consolidating through mergers and acquisitions, both vertically (companies expanding services) and horizontally (significant deals like Viasat's acquisition of Inmarsat for an estimated $7.3 billion USD).

3.1.2.6 Catalogue of Satcom technologies, services, and applications

The table below shows a variety of cutting-edge technologies and applications in the upstream, midstream, and downstream segments of the Satcom value chain.

Table 4: Upstream and Midstream Satcom Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Upstream & Midstream	Optical communication/inter-satellite communication	Space & ground network optimization (example: managing/diverting traffic between network nodes	Consumer broadband In-flight entertainment & connectivity (IFEC) Maritime infrastructure & crew connectivity Data-relay
	Electronically steered antenna	Mobile connectivity (commercial, civil government & military assets	Electronically steered) Communication on the move (COTM) Aeronautical connectivity (passenger jets, business jets, etc.) Maritime connectivity

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			(merchant vessels, fishing vessels, cruise ships etc.)
	Flexible satellites	Independent beam steering, digital channelizer, alter beam characteristics and power/spectrum profile	Communication on the move (COTM) Flexible landing of traffic (backhaul, cloud services, etc.) Crisis management (offer communications during momentary traffic burst events, example, natural disasters) Government/military communication services (flexibility to support different service level agreements (SLAs))
	Very High Throughput Satellites (VHTS)	Broadband and mobile connectivity	Broadband access Commercial mobility Enterprise data Government/military mobility Backhaul & trunking
	Satellites based on Quantum Key Distribution (QKD)	Secure & encrypted communications Quantum communication network	Cryptographic key delivery services Secure data centric services (broadband access, enterprise data, etc.) Secure managed network services

Table 5: Downstream Satcom Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Downstream	Optimised video software solutions	High-precision, high compression, geo-tagged live video content & streaming over satellite	Fixed & mobile services: intelligence, surveillance, and reconnaissance (ISR), search & rescue, remote inspection, drone services
	DVB-S2 (Digital Video Broadcasting -Satellite)28 and HEVC standards (High Efficiency Video Coding)	Video applications (DTH, broadcasting, OUTV)	Satellite TV (transmission of UHD channels, and live UHD channels)
	5g Non-Terrestrial Network (NTN) & Orthogonal Frequency Division	Interconnectivity with terrestrial 5g networks Satellite-enabled devices	Satellite backhaul for 5g Satellite broadband

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	multiplexing (OFDM)	Direct-to-device communication	services Interoperability and roaming between networks
	Multi carrier satellite gateway	End-to-End multimedia integrated support, including OTT integration Multi-stream reception and transmission	Direct To-Home (DTH) video delivery Direct-To-Tower (DTT) video & audio delivery live, on-demand OTT distribution
	Edge computing both in-space & on ground	In-orbit data processing Real-time and autonomous identification of efficient/best-fit communication links across multipleorbits, & terrestrial networks	Edge computing both in-End-to-End managed network services for enterprise, consumer broadband, & mobility market

3.1.3 Focus Domain: Satellite Navigation

3.1.3.1 Overview

Satellite navigation is used in various sectors beyond its original military purpose. It is now common in cars, smartphones, as well as in farming and shipping. The market for these systems is growing, **driven by both public and private sectors**. It's not just about the physical devices; services like **mapping and real-time tracking** are also in demand.

New technologies like the **Internet of Things (IoT)** and **5G** are expected to increase the need for more advanced navigation systems. However, the market faces challenges such as data privacy concerns, signal interference, and the complexity of international regulations. This section will provide a detailed look at the current state, demands and trends of the satellite navigation market.

3.1.3.2 Satellite Navigation programmes

Several GNSS constellations and satellite-based augmentation systems provide navigation capabilities around the globe. At present, there are four main systems providing service globally:

- **Global Positioning System** (GPS) by the United States
- **Global Orbiting Navigation Satellite System** (GLONASS) by Russia
- **Galileo** and the **European Geostationary Navigation Overlay Service** (EGNOS) by Europe
- BeiDou by China

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3.1.3.2.1 Galileo

Galileo is Europe's GNSS civil programme, providing a highly accurate, **guaranteed, global positioning service**
for the public and private use of European and global entities. Moreover, the programme is compatible and interoperable with GPS, GLONASS and BeiDou. **ESA leads the design and development of the space and ground systems**, as well as procuring launches. **EUSPA acts as the service provider of Galileo**, overseeing the market and application needs and closing the loop with users.

Currently, there are **28 satellites in orbit and 10 further Galileo satellites** due to be launched, after which the
first of the Galileo Second Generation (G2) satellites with enhanced capabilities are expected to be added in coming years.

3.1.3.2.2 EGNOS

The European Geostationary Navigation Overlay Service (**EGNOS**) is Europe's regional satellite-based augmentation system (SBAS) that is used to **improve accuracy of GNSS**, while also ensuring continuity and availability of a signal.

Three services are provided by EGNOS:

- **Open Service** (free and open to the public for common user applications)
- **Safety of Life Service** (targets a range of safety-critical transport applications such as aviation, maritime, rail and road; more applications are expected in inland waters and agricultural domains)
- **EGNOS Data Access Service** (provides a controlled ground access through the Internet to customers requiring enhanced performance for professional use)

3.1.3.2.3 ESA programmes: FutureNAV, NAVISP, Moonlight

ESA has an increasing funding for satellite navigation programs, and currently has three running initiatives which will be described below.

FutureNAV

The FutureNAV programme will be composed of several missions to adequately respond to the rapidly growing navigation needs. The first mission consists of an initial in-orbit demonstration, small constellation of **LEO-PNT satellites** complimenting **Galileo MEO satellites**. Thus, the mission will test a new multi-level 'system of systems' approach in delivering navigation service. The next mission will map the **contours of planet Earth** more accurately than ever before, thus contributing to the precision improvement of multiple navigation and Earth science applications. The mission also includes creation of a combined **single platform satellite navigation** with laser and radio-ranging, as well as very long baseline interferometry.

NAVISP

NAVISP is ESA's Navigation Innovation and Support Programme, which facilitates **development of new technologies in PNT**, and has supported already **more than 200 innovative projects** by opening a set of

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tenders offering funding, consultancy, and network opportunities for developers. Further calls within the programme are expected to focus on the applications for green and digital mobility on land and on sea.

Moonlight
Moonlight initiative aims to **extend satellite navigation and telecommunications coverage to the Moon** and its orbit ensuring **sustainable earth-lunar connectivity**. The first receiver to operate in lunar orbit was already delivered to the UK company Surrey which will further integrate it in the ESA Lunar Pathfinder relay satellite, which is expected to be launched in late 2025.

3.1.3.3 Market dynamics

The GNSS market encompasses a wide array of activities where GNSS-based positioning, navigation, and timing play a pivotal role in enabling various functionalities. This market includes revenues derived from augmentation and additional value-added services attributed to GNSS technology.

Augmentation services comprise software products, digital maps, and GNSS augmentation subscriptions, while added-value services cover revenue **generated from data transmitted over cellular networks for location-based applications**, income from **smartphone apps with GNSS functionality**, subscriptions for **fleet management services**, and earnings from **drone services** across diverse industries, among other sources. Over the next decade, **GNSS demand is projected by EUSPA** to exhibit significant growth, both within the European Union and globally.

In the European Union, from 2021 to 2031, **device revenues are expected to increase from 12.1 billion euros** to 21.6 billion euros, while services revenue is anticipated to rise from 27.4 billion euros to 53.7 billion euros. On a global scale, the GNSS market is set to expand considerably, with device revenues projected to grow from 48.4 billion euros in 2021 to 87.0 billion euros in 2031, and services revenue surging from 150.5 billion euros to 405.2 billion euros over the same period. This outlook emphasises the **fundamental role GNSS technology** plays in a wide range of industries and underscores its enduring importance in the foreseeable future. With a foundational understanding of the market dynamics in place, the following sections will describe the demand and supply trends within the GNSS domain.

Table 6: European GNSS Market Growth 2021-2031 (by PwC)

Revenue streams	2021 revenues	2031 projected
GNSS devices revenues	€12,1B	€21,6B
GNSS services revenues	€27,4B	€53,7B
Total	€39,5B	€75,3B

3.1.3.4 Demand Trends

The **Global Navigation Satellite Systems (GNSS)** market is experiencing **significant evolution**, driven by the expanding indispensability of location-based services (LBS) in both emergency response and everyday

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activities. The military sector's growing demand for resilient and secure GNSS solutions is noteworthy, reflecting the high stakes involved in critical operations.

The **road sector remains the dominant consumer of GNSS technologies**, spurred by digitalisation and legislative mandates, particularly in Europe with the adoption of the Galileo system. Public engagement with LBS, facilitated by widespread internet-capable devices like smartphones and fitness trackers, has led to diverse applications across business, health, and leisure.

Moreover, the formation of the **Open Positioning, Navigation, and Timing (PNT) Alliance** highlights a collaborative effort towards developing robust navigation systems, ensuring operational integrity even in challenging scenarios. This collective trend towards **advanced and versatile GNSS usage** underscores its integral role in shaping future technological landscapes and societal functionalities. In a nutshell:

Evolving GNSS Market Trends:

- Growing need for LBS in emergencies and daily activities.
- Increased use of GNSS in military for resilience and security.
- Road sector as the top GNSS consumer, driven by digital shifts and laws.

Broad Application of LBS:

- LBS driving economic activity across various sectors.
- Crucial in managing emergencies like floods and natural disasters.
- Mandatory for civil operations in many countries.
- Popular in public use via smartphones and other devices in diverse areas.

Routine Uses of LBS:

- Key in urban planning, traffic management, and weather forecasting.
- Supports various programs like traffic systems and disaster response.

GNSS in Military: Resilience and Security:

- Demand for robust GNSS in critical military tasks.
- Advances in technology for security and anti-jamming.
- Open PNT Alliance formed for resilient navigation solutions.

GNSS in Road Sector:

- Largest GNSS market segment.

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- Transition to GNSS-based tolling systems.
- EU promoting Galileo system for road safety and services.

3.1.3.5 Supply trends

The Global Navigation Satellite Systems (**GNSS**) industry is advancing with **major trends towards greater accuracy and innovative technologies**. Key developments include **multi-constellation receivers** for enhanced precision, the introduction of **Galileo's High Accuracy Service**, and the rise of **Low Earth Orbit (LEO) constellations** by companies like Xona and TrustPoint. Additionally, the next generation of GNSS spacecraft is focusing on **improved security features and resistance to spoofing and jamming**, significantly enhancing the reliability and versatility of satellite navigation systems. In a nutshell:

Greater Accuracy in GNSS:

- Trend towards higher accuracy in GNSS.
- Introduction of multi-constellation receivers for enhanced reliability and precision.
- Galileo High Accuracy Service (HAS) started in 2023, boosting precision in various sectors.

LEO-Based GNSS Constellations:

- Rise in Low Earth Orbit (LEO) constellation concepts.
- Companies like Xona, TrustPoint, DDK Positioning, and Satelles focusing on LEO-based solutions.
- China's BeiDou exploring LEO constellation addition.
- LEO constellations offer diversified, resilient navigation solutions for multiple sectors.

Next-Generation Spacecraft Performance:

- Advancements in resistance to spoofing and jamming.
- Galileo's Open Service Navigation Message Authentication (OSNMA) for secure messages.
- European Geostationary Navigation Overlay Service (EGNOS) V3 upgrade enhances accuracy and integrity.
- Improved search and rescue capabilities in Galileo and BeiDou systems since 2021.

3.1.3.6 Catalogue of Satellite Navigation technologies, services, and applications

Within the GNSS domain, the subsequent table maps specific projects focusing **on innovative technologies, applications, and services** across each segment of the GNSS value chain. The table demonstrates key developments in satellite **navigation technology and its downstream applications**. Upstream, innovations in

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DFMC **Navigation modes, Galileo Second Generation, and low-cost dual-frequency GNSS systems** are set to revolutionise the GNSS capabilities. In the **midstream, advancements encompass GBAS services**, **navigation message authentication, high accuracy services, and cybersecurity measures**, ensuring the reliability of satellite navigation systems. **Downstream applications** span a wide spectrum, **including precision agriculture, climate modelling, rail command and control, and disaster management**, illustrating the profound impact satellite navigation has on various sectors, enhancing safety, efficiency, and resilience across diverse applications.

Table 7: Upstream and Midstream Satellite Navigation Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Upstream & Midstream	Dual frequency (L1/L5 and E1/E5a) GPS + Galileo receiver	Enhanced navigation capabilities	Positioning integrity for safety-critical sectors
	Use of 6 atomic clocks	Galileo Second	Generation Enhanced civil satellite navigation
	Dual frequency smart GNSS receivers	Positioning accuracy at the centimetre level	Low-cost high positioning accuracy for land surveying
	GBAS Approach Service Type F (GAST F)	Robustness against ionosphere and radio disturbances in multifrequency GNSS environment	Aircraft precision approach operations
	L1C	GPS interoperability with other GNSS	High-precision surveying
	M-Code GPS signal	Encrypted signal for military receivers	Secure cryptography architecture

Table 8: Downstream Satellite Navigation Emerging Technologies, Applications, Services

Value chain segment	Technologies	Applications	Services
Downstream	GNSS-blockchain integration	Geolocation software	Platforms with automated verification of data trustworthiness
	GNSS chip equipped	Emergency alert	Emergency Warning

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	smartphones	transmission	Satellite Service
	Certifiable on-board localization unit in the railway environment	GNSS-based multi-sensor fusion architecture	Train control system

3.1.4 Focus Domain: Access to Space and Launch Systems

3.1.4.1 Overview

Access to space is a key enabler of the whole sector and is itself an indispensable element in the overall space value chain. To deliver variety of space mission payloads, different types of launchers have been used, such as heavy-lift (>10,000 kg to LEO), medium-lift (4,000-10,000 kg to LEO), light-lift (500-4,000 kg to LEO), and micro-lift (<500 kg to LEO), as per European classification used by Arianespace and ESA for the classification of launch vehicles.

The value chain of the access to space domain, as presented in the figure below, is usually divided in three (**3) types of key activities:**

Launcher development: includes all activities related to the Research & Innovation actions and technologies initiatives (e.g. demonstrators) **supporting the development of future launchers**, including continuous incremental upgrades on launch vehicles. In Europe, prime contractors and key-subsystems manufacturers include ArianeGroup, Avio, MT Aerospace, PLD Space, Air Liquide Advanced Technologies. European public entities involved in launchers development include space agencies (ESA, ASI, CNES, DLR), research agencies (ONERA, DGA), academic institutions.

Launcher manufacturing: includes **activities from the launch vehicle integrators** (also referred to "prime integrators"), components and material suppliers (e.g. raw materials, micro-electronics) and sub-systems suppliers (e.g. engines, faring etc.). Prime contractors in the European region include ArianeGroup, Avio, and Europropulsion (ArianeGroup/Avio joint venture). Sub-systems manufacturers are MT Aerospace, Nammo, RUAG, SABCA.

Launch operations: include all the **activities performed during launch campaigns** such as the **transport of the launcher** to the **launch site**, **storage** of the satellites in clean rooms prior their integration on top of the launcher, **fuelling of the launch vehicle on the pads**, **monitoring of the launch** until the delivery of the satellite for the customer to the right orbit. In Europe, operations are performed by ArianeGroup, Avio, ESA, CNES (safety of the launch site).

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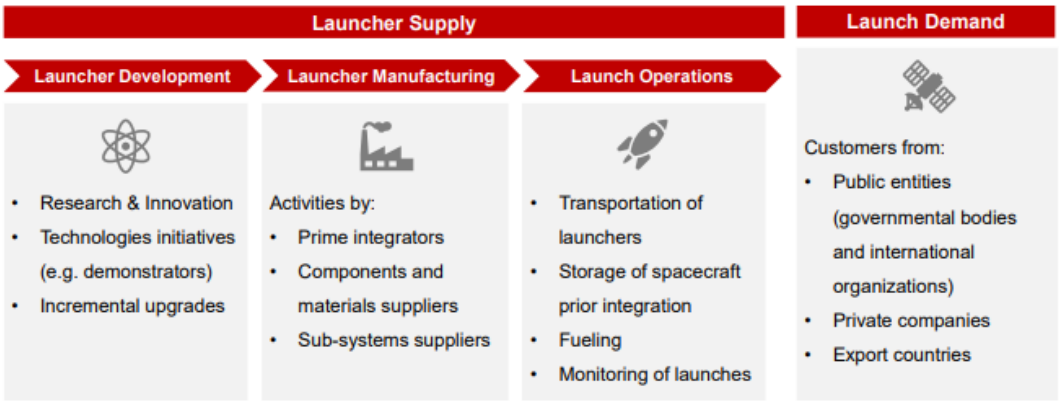

Figure 9: Access to Space Value Chain (by PwC)

Figure 10: Map of Spaceports in Europe (by PwC)

3.1.4.1.1 Launch system programmes

3.1.4.1.1.1.1 European Union access to space projects

The **EU space policy**, as set out in the **Space Strategy for Europe**, focuses **on ensuring independent access to space**, vital for deploying infrastructures like Galileo, Copernicus, and EGNOS, crucial for the economy and societal security. **The Horizon Europe Programme,** succeeding Horizon 2020, supports the EU industry in developing space access solutions, overseen by bodies such as **HaDEA, EUSPA, ESA, and the European Commission**. Key initiatives include the creation of launchers for small satellites and the **EIC Horizon Prize** for low-cost space launch, awarded to Germany's Isar Aerospace. As of 2022, Horizon Europe has funded 16 space access projects, totalling €56.7 million. **The European space transportation sector employs around 11,000 professionals across 16 countries.**

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3.1.4.1.1.1.2 European Space Agency access to space projects

The European Space Agency (ESA) has been working on **developing a commercially viable micro-launcher** since 2003, independent of public funding. The Future Launchers Preparatory Programme aims to create environmentally friendly, cost-effective, and competitive launcher technologies. ESA's recent project focuses on supporting European privately developed mini/micro launchers for small payloads, enhancing the industry's competitiveness. This includes financial support of up to €300,000 for qualified launch providers, covering testing, quality control, and compliance with regulations.

3.1.4.2 Market dynamics

The market for space launch services has expanded significantly in recent years. **The need for better communication, navigation, and Earth observation tools**, as well as for **scientific study and exploration**, is likely to push the demand for spacecraft launches to keep rising. Thus, the size of the global market for space launch services, which was estimated to be worth $13.9 billion in 2022, is expected to increase to $47.3 billion by 2032, rising at a CAGR of 13.4% between 2023 and 2032. Moreover, a number of **start-ups are creating cutting-edge launch technologies and tactics**, paving the way for new players to enter the industry.

Table 9: List of companies generating micro-launchers in Europe.

Established Companies	Small/Dedicated Companies	Start-ups
ArianeGroup	Dawn Aerospace	Hylmpulse
MT Aerospace	Zero2Infinity	Rocket Factory Augsburg
Avio	PLD Space	Pangea Aerospace
Nammo	Horizon Space Technologies	Smallspark Space Systems
Deimos Space	LS Sidereus	Space Dynamics
Celestia Aerospace	Orbex Space	HyPrSpace
Swedish Space Corporation	Tranquility Aerospace	MaiaSpace
Orbital Access	Isar Aerospace	Skyrora

3.1.4.3 Demand Trends

In summary, the space industry is experiencing significant shifts towards **domestic prioritisation, environmental sustainability, and the integration of small satellites (Small-sats) into larger constellation projects.** These changes reflect the industry's dynamic nature and its adaptation to new challenges and opportunities. In more depth:

Institutional Payload Protectionism: Major space-faring nations like the US, China, Japan, and Russia are prioritising their domestic space industries by **restricting foreign launch services for their institutional payloads**, aiming to **boost their own industries**, **ensure national security**, and **maintain control**. In contrast, Germany, a major European player, sometimes uses non-European launch services for reasons like cost,

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technology, and diplomatic ties. Recent agreements between Germany and France aim to **strengthen European launch services**, especially for Ariane 6 and Vega launches.

Push for Non-Dependency: Europe's space capabilities, particularly with the Ariane 6 and Vega-C rockets, are crucial for independent space access. Setbacks in these programs could make Europe reliant on foreign launch providers. Geopolitical tensions, affect the supply chain for space components**, highlighting the need for Europe to adapt and possibly reevaluate its sourcing strategies.**

Environmentally Sustainable Access to Space: There's a growing emphasis on developing environmentally friendly space access technologies, with a focus on sustainable rocket propellants and spacecraft materials. This shift is driven by global environmental consciousness and the potential for regulatory mandates on green benchmarks.

Emergence of Small Satellites and Micro-Launchers: The rise of Small-sats has created a demand for micro-launcher services. These smallsats offer cost-efficiency, versatility, and rapid deployment, leading to the development of micro-launchers tailored for lighter payloads and more flexible launch schedules.

Decrease in Single-Mission Small-sat Launches: The next decade is expected to see a decline in individual non-constellation Small-sat launches, overshadowed by the rise of constellations and mega-constellations in communications and Earth observation. This shift is due to the economies of scale and technological advancements offered by constellations, reducing the need for standalone technology demonstration Small-sats.

3.1.4.4 Supply trends

The space launch systems industry is undergoing significant changes, highlighted by key developments:

Reusable Rocket Technology: The industry is moving away from constructing new rockets for each launch towards reusable rockets, reducing costs and material wastage. Companies like SpaceX and Blue Origin are leading in this area, with SpaceX's Falcon 9 and Blue Origin's New Shepard showcasing successful reuse.

Green Propellants: There's a shift towards environmentally friendly propellants, particularly methane, which offers better performance and reduced environmental impact.

European Micro-Launchers: Europe is pivoting towards micro-launchers to cater to the growing small satellite market. Companies like Orbex, PLD Space, and ISAR Aerospace are developing smaller rockets, with support from European governments and agencies. The challenge lies in balancing infrastructure development with market demands.

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Adapted Infrastructures for Micro-Launchers: European countries are adapting existing launch sites and regulatory frameworks to accommodate micro-launchers, aiming to become attractive hubs for these services. The sustainability of this burgeoning industry, however, hinges on the alignment of supply and demand.

New Manufacturing Processes: Digitalization and new manufacturing technologies like 3D printing are revolutionizing the production of rockets, offering cost and time efficiencies. This is exemplified by companies like Relativity Space in the US, which uses large-scale 3D printing for major components.

3.1.4.5 Catalogue of Access to Space technologies, services, and applications

Table 10: Launcher supply Technologies and Demands

Technologies	Applications	Demand Pulls
Super Heavy Launch Vehicles	Orbital and planetary launch with increased volume and capacity	Launch of flocks of satellites constellations, planetary missions
Kinetic Launch System	LEO launch	Cost effective and environmentally sustainable launches
Ariane 6	Commercial, institutional, exploration missions	European autonomy
Reusability Concepts	Orbital launch with increased frequency and decreased cost	Sustainability and cost-efficiency
3D Printing	Launcher structures development and manufacturing	Acceleration of the development phase
Stratospheric Balloons	Rocket carriers and launches from a “near-space” environment	Reduction of operation costs
Hypersonic Spaceplane	Defence, cargo, ultra-high speed transportation, suborbital flight	Routine access to space
erospike Engines	Single-stage-to-orbit launch vehicles	Increasing the payload capacity while decreasing the rocket mass
Methalox Propellant	Reusable rockets propulsion	High energy density with clean combustion products
Rotating Detonation Rocket Engine	Light-weight rocket’s upper stage	Achieve increased propulsion efficiency while reducing fuel consumption
Reusable Rocket Engine	European launch vehicles	Low-cost rocket engine

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Carbon-fiber – Reinforced Plastic	Rocket tanks manufacturing	Rocket weight reduction

Table 11: Launch Demands

Technologies	Applications	Demand Pulls
Anticipated developments		Higher frequency of launches and dedicated small lift launchers Commercial use of space resources Space tourism

3.1.5 Focus Domain: Space Safety

3.1.5.1 Overview

As of September 2023, there are **8672 satellites in orbit** around the Earth, overtaking **historical rates of the launch traffic** in all mass and type classes. The increase in launch traffic and permanence of space debris events in Low Earth orbit leads a significant conjunction risk in the most congested Earth orbits. The extrapolation of the current changing use of orbits and launch traffic, combined with continued fragmentations and limited post mission disposal success rate **could lead to a cascade of collision events** over the next centuries. To date, more than **30 000 pieces of space debris have been recorded** and are regularly tracked by space surveillance networks.

The provision of **Space Situational Awareness (SSA)** services is the cornerstone of space safety and is a **foundation for establishing Space Traffic Management (STM) system** which builds on SSA data. Such data encompasses Space Surveillance and Tracking (SST), Space Weather (SWE) and Near-Earth Objects (NEO). It refers to the capability of **detecting and tracking man-made and natural threats** (e.g. space debris, geomagnetic storms, asteroids), **predicting and assessing the involved risks** (e.g. collision risk, storm intensity
risk) and **providing services** (e.g. conjunction warnings, storm forecasts and alerts) **and related products** (e.g. tailoring data and information to the specific type of institutional or commercial users).

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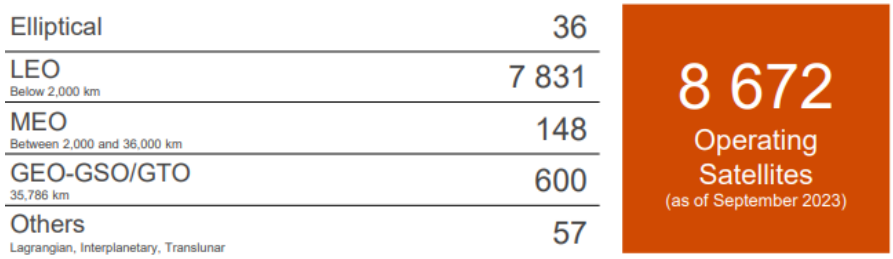

Figure 11: Distribution of active and operating satellites (September 2023 by PwC))

3.1.5.2 Space Safety programmes

The EU and ESA have initiated several programmes to enhance space safety:

3.1.5.2.1.1 Space Surveillance and Tracking (SST)

Part of the Space Situational Awareness (SSA) component of the **EU Space Programme**, developed with the **SST Partnership and EUSPA**. It offers services like **collision avoidance, re-entry analysis, and fragmentation analysis** to EU Member States and various public and private entities. The participating Member States are Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Latvia, the Netherlands, Poland, Portugal, Romania, Spain, and Sweden.

3.1.5.2.1.2 Horizon 2020 Projects

European Space Traffic Management for the 21st Century (EUSTM): Aimed at defining the future European space traffic management capability.

European Ways Forward for Space Traffic Management (SPACEWAYS): Established a common understanding of rules and standards for an EU STM concept.

3.1.5.2.1.3 ESA SSA Programme

The ESA SSA Programme, supported by 19 Member States, focuses on **R&D for Space Weather, Near Earth Objects, and SST**, with funding increasing from EUR 95 Million (2017-2020) to EUR 432 Million (2020-2024). It collaborates with European and international organizations and relies on data from the US Department of Defence, emphasising the importance of global cooperation in space situational awareness.

3.1.5.3 Market dynamics

The domain of Space Safety is witnessing a **flourishing market and economy**, particularly in the area of **space situational awareness.** As the number of satellites and space debris increases, the **demand for accurate and real-time data for tracking and management is growing exponentially**. This uptick in demand is creating new economic opportunities for companies specializing in data access and management, thereby shaping a promising market landscape in Space Safety.

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3.1.5.4 Demand Trends

The demand trends in space safety are characterized by several key developments:

Growing Space Debris: The increasing amount of space debris in Earth's orbit poses significant challenges for satellite operators. The need for precise collision data is growing, emphasizing the importance of enhanced space situational awareness and the development of advanced tracking and monitoring technologies.

Need for Automation and AI: With the overwhelming volume of data on potential space debris collisions, satellite operators are turning towards automation and AI for efficient data processing. AI's capabilities in pattern recognition and predictive analytics are crucial for assessing collision threats and improving the safety and efficiency of satellite operations.

Rising International Collaboration: There is an increasing trend of international partnerships in Space Situational Awareness (SSA). Key collaborations include the United States' SSA partnerships with countries like India and those in the Asia-Pacific region. These partnerships, extending beyond space to include security, economic, and educational aspects, reflect a broader recognition of the need for collective stewardship in space exploration and safety.

3.1.5.5 Supply Trends

The supply trends in space safety are characterised by the implementation of new technologies, the growth of commercial SSA services, and governance challenges:

New Technologies: High-performance computational systems, AI, and machine learning are increasingly used in Space Situational Awareness (SSA) for processing **vast data sets and predicting satellite movements with high accuracy**. Additionally, developments in optical, radar, and laser technologies enhance the tracking and management of space debris, providing more timely and accurate information for satellite operators.

Commercial SSA Services Growth: The SSA market is witnessing a significant influx of private companies, diversifying SSA service offerings with innovative and adaptable solutions. These commercial entities face challenges in meeting the **specific demands of satellite operators** and securing long-term contracts. However, the rise of Mega constellations necessitates specialized SSA services, potentially increasing the importance of these commercial providers.

Governance Challenges: The current regulatory framework for space safety is relatively limited, with broad international obligations and non-binding guidelines. Initiatives like the **Space Safety Coalition** are promoting responsible space safety practices, but there's little consensus on the structure of international Space Traffic Management (STM).

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3.1.5.6 Catalogue of Satcom technologies, services, and applications

Table 12: Space Safety Current Applications and Services

Applications	Services	Comments
Solar Activity Observation	Space weather forecasts	Predicts solar flares, CMEs, and other events impacting Earth's systems. Vital for protecting spacecraft, satellites, and power grids.
Radiofrequency Monitoring	Spectrum analysis, Orbit determination, RFI notifications	Data on object orbits and movements; notifications about RFI sources for reliable satellite communication and navigation.
Onboard Propulsion	Drag devices, Disposal/end-of-life support	Facilitates controlled deorbit manoeuvres or reentry, preventing space debris accumulation and reducing collision risks.
Ground-based Radar Systems	Launch detection, Space object identification, Breakups and separation detection, Space debris tracking, Orbit determination, Conjunction assessment	Timely launch notifications; data on debris objects; predictions of spacecraft and debris positions; collision probability assessment.
Atmospheric Modelling	Radar tracking, Re-entry forecasts, On-orbit conjunction assessment	Precise re-entry time and location predictions by analysing orbital parameters and atmospheric conditions.
Laser Ranging	Space objects' precise position measurement	Uses short laser pulses to determine the distance, velocity, and orbit of space objects with millimetre precision.
Machine Learning & Artificial Intelligence	Predictive analysis, Passive space surveillance	Processes vast real-time datasets from multiple observation systems for efficient space surveillance.

Table 13: Space Safety Technologies with its relevant Applications, Services and Benefits

Technologies	Applications & Features	Services & Benefits
Tow Truck Spacecraft Enabled with Vision-Based AI	AI-enhanced capturing mechanism targeting uncooperative space objects	Active debris removal; reduces risk of space collisions
Revaluation of Spacecraft Battery	Advanced design standards reducing	Debris mitigation; promotes longevity

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Standards	risk of onboard battery malfunctions	and safety of spacecrafts
Combination of SSA Software and Spacecraft Propulsion Control	Unified platform for situational awareness and instantaneous response	Integrated space mobility subscription; streamlined space traffic management
Open-Architecture Data Repository (OADR)	Centralized database promoting transparency and seamless data sharing	Warning system for public operators; enhances global coordination
AI/ML-Based Prioritisation and Classification of Alerts	Advanced algorithms discerning threat levels for potential collisions	'Smart' STM; enables more precise and efficient space traffic management
Advanced Radar and Telescope System	Superior tracking with global coverage and real-time updates	Autonomous EU SST; improves detection and monitoring of space objects
Multi-Agent Deep Reinforcement Learning	Collaborative AI agents optimizing sensing strategies for object detection	Space sensor tasking; ensures comprehensive and efficient object tracking
Space/Ground-Based Laser Nudge	Precise nudging mechanisms to safely redirect space debris trajectories	Active debris removal; offers non-contact means to manage space debris
Tethered-Net Removal	Flexible and adaptive technology suitable for capturing various space debris sizes	Active debris removal; provides a scalable solution to manage different debris sizes
Removal Docking Plate Bus Equipment	Modular platform facilitating easy attachment and de-orbiting procedures	Active debris removal; standardizes de-orbiting operations
Extra-Vehicular General-Purpose Robotic Arm and Hand	Multi-purpose robotic mechanism with high adaptability for various space operations	Active debris removal; versatile tool for both debris management and other in-orbit servicing requirements

3.2 Space Hubs: Mapping, Analysis and Characterization in the EU

The analysis provided herein was conducted by PwC and is shared under the framework of the ASTRAIOS project.

The European space sector is facing increasing global competition, as well as significant technological challenges in the context of the New Space economy. The EU space flagship programmes, including EGNOS, Galileo and Copernicus, are key assets to deliver on the EU's future objectives in areas such as sustainability, safety and security, prosperity, cultural development and geostrategic outreach. To face these challenges, Europe needs to maintain and strengthen its world-class capacity to conceive, develop, launch, operate and exploit cutting-edge space systems, by relying on a more risk prone and innovative space industry. In this regard, the Space Strategy for Europe underlines the need to encourage a business and innovation-friendly ecosystem at the European, regional and national levels by establishing space hubs that bring together the

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space, digital and user sectors - Section 2.2 of the communication on a “Space Strategy for Europe” (COM (2016) 705).

Space Hubs in the EU

The Space Strategy for Europe lays out a plan to establish and support “space hubs” at regional, national and European levels by using the emergence of business and innovation-friendly ecosystem. The term “Space Hub” refers to a sub-category of clusters which, as the name suggests, specializes in space-related activities. In particular, a cluster has been defined by economist Michael Porter as a group of “similar and related firms concentrated in a small geographic area.” Clusters specifically dedicated to space-related activities in Europe have been able to gather the interests of ICT entrepreneurs, often including national space agencies.

Contribution of Hubs to the Space Ecosystem in the EU

Using “space hubs”, the Commission aims to bring together space and non-space sectors leading to crossfertilization technologies and ideas in sectors such as ICT, energy, transport, thereby creating mutually beneficial technologies and business approaches. Through an environment that encourages collaborations and symbiotic relationships, “space hubs” are expected to stimulate joint projects between entrepreneurs, industries and universities. In essence, “space hubs” will be vital in fostering an integrated supply chain within the space sector and also explore synergies with non-space sectors. Finally, “space hubs” would facilitate funding activities and make sure that the EU initiatives for the space ecosystem, reaches the intended audience.

In **2019**, PwC has conducted a study whose objective was to to map and analyse the different space hub activities and ecosystem in the EU and provide recommendations to foster the emergence and development of European space hubs through the following tasks:

- Task 1: Mapping and analysis of current space hubs’ activities and ecosystem in the EU
- Task 2: Identification of strengths, weaknesses and best practices of public and private actors of the European space hubs ecosystem
- Task 3: Provision of recommendations to foster the emergence and development of European space hubs

3.2.1.1 Methodology of the study

Stakeholder consultation was the major source of data for the analysis conducted in the study, complemented by desk research. Consultation, carried out through online questionnaires, telephonic conversations and faceto-face interviews, was critical in gaining insights about the functioning and

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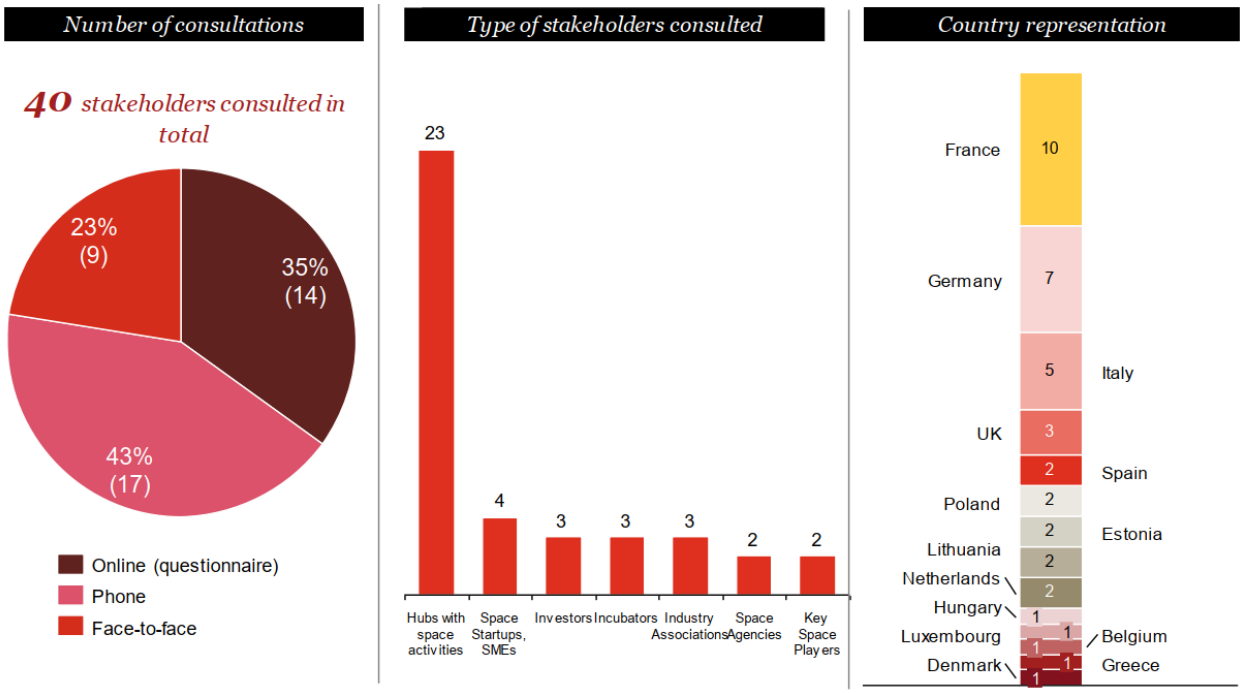
operations of the hubs. Apart from interviewing the hubs themselves, key actors part of the space ecosystem in the EU were also consulted. These included small and medium sized space companies, large companies, investors, accelerators and incubators, space agencies and other public bodies. The 40 stakeholders, who were consulted through the described means, represented 14 Member States, thus providing a strong geographic distribution in the EU. A summary of stakeholders consulted can be seen in Figure below.



Stakeholder consultation

3.2.1.2 Stakeholders of the European Space Ecosystem

The European space ecosystem is comprised of five main groups of stakeholders. “Space Hubs” are in essence, considered to be the core component of these stakeholders, thereby benefitting the entire space ecosystem in the EU.

Private Sector: This group comprises of the large corporations including the key space players in the European space industry along with the small and medium sized enterprises and start-ups.

Governmental Bodies: The governing bodies on the regional, national and European levels define the policy aspects of the space ecosystem in the EU.

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Academic & Research Institutions: This group of entities consist of all the European educational institutions who are responsible for creating a skilled workforce and qualified researchers.

Space Agencies: Including both the European Space Agency (ESA) and the national space agencies of some Member States, this group of actors operate as relays of governmental policies for the space sector.

Enabling Organisations: This group include the investor community and other organisations such as space incubators and accelerators who play a key role in the overall space ecosystem

3.2.1.3 Trends in the Development of Hubs with Space Activities

Before analysing and characterising hubs with space activities, it is significant to understand how hubs developed and are currently being developed in the EU, along with inferring how potential hubs might form.

Hubs based on aerospace activities

Some hubs develop based on the heritage of the Member State with aeronautics eventually being host to entities that start pursuing space activities, thanks to the industrial linkage between the two industries. Typically, these hubs are hosted in Member States with established space capacity such as France, Germany and Italy.

Hubs based on space activities

A noticeable trend is the creation of hubs focused on space activities, particularly in Member States with emerging space capacity in order to enhance their space capabilities. This includes hubs hosted in Member States such as Luxembourg, Hungary, Romania and Greece among others.

Hubs based on EU digital space initiatives

Initiatives from the Commission play a vital role in forming hubs with space activities, particularly focused on the downstream sector. Hubs part of the Copernicus Relay Network have been significant in acting as dissemination entities especially with respect to earth observation data and its digital uses.

Hubs based on initiatives from space agencies and Member States

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The Business Incubation Centres from ESA play a key role in forming hubs working on space activities, particularly encouraging the innovation ecosystem. Initiatives from Member States also play a vital role on a national scale in organising hubs such as the COSPACE Booster initiative from France.

Potential hubs with less relevance on geographical proximity

The advancements in the digital industry combined with the increasing uptake of downstream space activities means that some potential hubs could form with less relevance on geographical proximity, thanks to virtual collaboration opportunities.

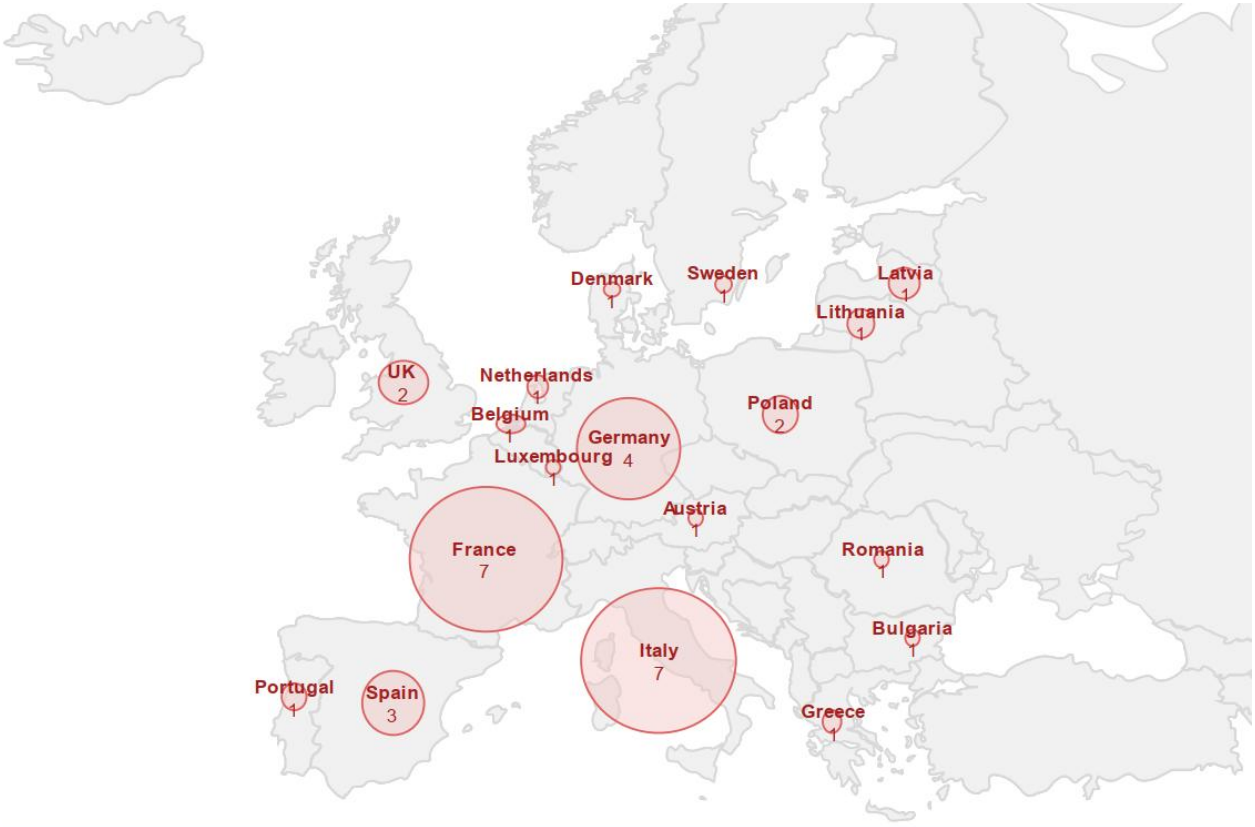

Figure 12: Distribution of Hubs with Space Activities in the EU

3.2.1.4 Analysis of 16 Space Hubs in Europe

For the purpose of a deep-dive analysis to map and characterise the hubs, a set of 16 hubs with space activities were shortlisted from the 38 hubs identified previously. This shortlisting process involved a high-level analysis of the relevance of space activities within the hub along with the degree of representation of a Member State such that the hubs selected for deep-dive analysis covered those that were present across

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different Member States, on various stages of development. The following table lists the 16 hubs selected for further analysis.

Table 14: List of 16 Space Hubs Shortlisted for Analysis

Name	Location	Member State
AED Portugal	Lisboa	Portugal
Aerospace Valley	Occitanie	France
ASTech	Ile de France	France
Aviation Valley	Podkarpackie	Poland
BavAIRia e.V	Bavaria	Germany
CASTRA	Yugozapaden	Bulgaria
CenSec	Midtjylland	Denmark
Harwell Space Cluster	Oxfordshire	United Kingdom
Hunspace	Northern Hungary	Hungary
Lithuanian Aerospace Association	Lithuania	Lithuania
Lazio Connect	Lazio	Italy
Lombardia Aerospace	Lombardia	Italy
Luft- und Raumfahrt Baden-Württemberg	Baden-Württemberg	Germany
Madrid Aerospace Cluster	Community of Madrid	Spain
si-Cluster	Attica	Greece
Space Business Incubation Centre (SBIC)	South Holland	Netherlands

3.2.1.5 Hub Assessment Framework

The hub assessment framework involved a set of 11 categories of KPIs that were used to assess the hub based on both factors external to the hub and those that are internal to the hub operations.

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Table 15: KPIs Included in the Analysis of Hubs

KPIs External to the Hub	Internal Hub KPIs
Country Macroeconomic Indicators	Governance
Country Spending on Space	Funding
Region Attractiveness	Academia & Research Potential
Country Public Policy Development	Diversity of Hub members
Degree of Upstream Space Activities	
Degree of Downstream Space Activities	
Potential for Non-space Synergies	

3.2.1.6 Key Barriers Identified

Based on the analysis and through the various stakeholder consultations conducted, the following are identified as the key barriers and challenges for the establishment and development of "space hubs" in the EU.

Lack of awareness of EU related initiatives in the space sector

Although there are numerous initiatives from the European Commission for the space sector, there is still a lack of awareness from the target audience and a multiplication of initiatives leading to difficulties in having a readable corpus of initiatives

Lack of established synergies among different funding schemes

Over 80 percent of the consulted believe that access to finance is their biggest barrier and this is more so the case for hubs located in Member States with emerging space capacity. Scarcity of equivalent space funding from the regional and national bodies means that the space ecosystem is entirely dependent on grants and schemes from the EU.

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Lack of systematic technology transfer activities

A number of research projects in both the upstream and the downstream sector have the potential to turn in to start-up ideas. However, the lack of tools to transform such projects into business endeavours coupled with the aforementioned difficulty in access to finance become a critical challenge in developing in the innovation ecosystem in the EU.

Lack of organisational structure for collocated entities and capacities

There is a consensus among the hubs community that, the larger they grow, the more difficult it gets for them to manage them as a vast majority of them do not have an organisational structure in place. The lack of substantial financing means that hiring new personnel is impossible and hence, the understaffed management team is faced with the arduous task of both managing day-to-day activities and setting strategy roadmaps for the hub.

Lack of means to exploit the multidisciplinary synergies of the space sector

Space being a multidisciplinary sector, there is a huge potential for "space hubs" to work with non-space actors to uncover new opportunities and work on new initiatives. However, there is lack of an efficient co-ordination mechanism that could facilitate the entities in the space sector to identify and work on activities that could exploit the multidisciplinary potential of the space sector.

Lack of a mechanism to transfer best practices towards emerging actors

The lack of a centralised platform for hubs to network makes it harder for the smaller, developing hubs in countries that do not have a huge participation to European space activities to be aware of recent trends and challenges. As such, it also make it more difficult for the upcoming space-focused hubs to form partnerships with the larger, more established hubs.

3.2.1.7 Recommendations

Based on the analysis conducted, the following recommendations are provided for the Commission to foster the development of "space hubs" in the EU. Recommendations are divided into policy actions per building block.

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Recommendation 1: Establish a "Space Hubs Coordination Office" to organise and manage the **network of "space hubs" in the EU**

It is crucial for the "space hubs" to be able to benefit from an EU-supported centralized entity, providing a unique entry point to "space hubs" in the EU. Apart from identifying guidelines and best practices for "spacehubs", the proposed "Space Hubs Coordination Office" shall perform the following activities, which were identified based on the analysis in the study, corresponding to each building block.

Table 16: Recommendations per Building Block

Building Block	Corresponding Recommendations
Vision	The "Space Hubs Coordination Office" could develop an EU Space Hub Competency and Capability Matrix which will be useful in creating a space ecosystem map and help "space hubs" to improve its scope.Build and maintain a scoreboard measuring performance of space hubs by monitoring key KPIs.
Operational Capability	Establish a forum to promote networking among "space Hubs" as well as with other space and non-space entitiesIdentify and propose, on an ongoing basis, improvements to the operational model of "space hubs."
Activities	Encourage the participation of members, both professional and academic, within "space hubs" to the provision of trainings to other actors within the hub in order to foster cross-fertilization opportunities.Enable the participation of "space hubs" in KIC initiatives to stimulate the synergies of space and non-space sectors.
Financial Capability	Gather best practices on financial sustainability from high performing hubs and develop financial guidelines.Provide, through the proposed "Space Hub Coordination Office", a training in fund management to the hubs in need to enhance their financial management capability.
Facilities	Develop guidelines for testing and digital processing facilities available in the "space hubs" and recommend areas of investment for improvements and new facilities.

Recommendation 2: Promote synergies among different funding opportunities

The Financial Capability of a "space hub" is a pivotal building block and is directly related to the functioning and activities of the hub. Although hubs are expected to fund their day-to-day operations, hubs are still dependent on external funding either through public grants or private funds, in order to carry out their

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activities. The upcoming InvestEU programme is an attempt towards creating unified EU funding system bringing all grants under one roof. Two approaches to attaining and promoting synergies among available funding opportunities are listed below:

- Implement actions such as production of communication material and conducting awareness sessions and workshops to promote the synergies of space and non-space sectors and attract private investors from different domains.

- Leverage existing grants and direct them towards funding the activities carried out within "space hubs", as the Commission could have a clear picture of the European space ecosystem through the "Space Hubs Coordination Office."

- Develop, in collaboration with the proposed "Space Hubs Coordination Office", a mapping of public and private funds available for each hub, such that "space hubs" have a simpler and more efficient way of getting to know about access to funding opportunities in the space sector.

Recommendation 3: Pursue activities ranging from education to innovation and market uptake

Increasing awareness for the space sector is vital in increasing the uptake of space technologies and applications in the EU. "Space hubs" provide an ideal opportunity for promoting space education, increasing space awareness and thereby, boosting the overall space environment in the EU by improving the overall participation in space research and innovation across the EU. The following recommendations are proposed to the Commission to ensure the development of the space ecosystem in Europe and to encourage market uptake.

Table 17: Recommendation 3: Recommendations per Building Block

Building Block	Corresponding Recommendations
Vision	Encourage "space hubs" to pursue innovation and entrepreneurship activities to enhance market uptake.
Operational Capability	Expand the participation of academic & research institutions within the "space hubs" to EU funding dedicated to research underlying space activities.
Activities	Implement educational schemes to enable hands-on learning courses on upstream space activities at academic institutions in emerging space nations.

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6. APPENDIX A – DESKTOP RESEARCH CATALOGUE

Below is a detailed compilation of 130 applications, services, and technologies spanning areas such as Earth Observation, Satellite Communication, Satellite Navigation, Access to Space and Launch Systems, and Space Safety. This list includes a wide array of categories, encompassing items such as advanced satellite technologies, high-resolution imaging systems, environmental monitoring tools, cutting-edge artificial intelligence applications, comprehensive

Domain	Value Chain Segm	Area	Item	General Skill	ESCO Skill Type
EO	Upstream	Technology	Meteosat Third Generation Sounder (MTG-S) satellite	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Upstream	Technology	46 MPixels sensors with video acquisition	Sensor Design	S7 – constructing
EO	Upstream	Technology	32 small satellites fleet constellation	Space Systems Engineering	S7 – constructing
EO	Upstream	Technology	Hyperspectral imagery	Hyperspectral Imager Design	S7 – constructing
EO	Downstream	Application	Hourly data on tropospheric constituents over Europe for air quality	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Application	Daily global mapping of atmospheric gases	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Application	High resolution video of an extremely wide scene	Image Processing Expertise	S2 - information skills
EO	Upstream	Technology	Very high resolution and rapid revisit RS	Space Systems Engineering	S7 – constructing
EO	Downstream	Service	Weather and atmosphere monitoring	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Video observation	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Real-time commercial data products	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Multipurpose hyperspectral data	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Midstream	Technology	Bicubic-downsampled low-resolution image-guided generative adversarial network	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Technology	Efficient hybrid conditional diffusion model	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Technology	Onboard AI	Machine Learning Expertise	S5 - working with computers
EO	Downstream	Technology	Super resolution imagery	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Application	Data processing onboard spacecraft	Data Processing Expertise	S2 - information skills
EO	Midstream	Service	Remote sensing image enhancement solutions	Image Processing Expertise	S2 - information skills
EO	Midstream	Service	Efficient data transmission with reduced ground-based processing	Data Optimization Expertise	S2 - information skills
EO	Downstream	Application	Integrated AI, cloud, and EO capabilities	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Geo-augmented reality	AR-GIS Integration	S5 - working with computers
EO	Downstream	Technology	Copernicus Marine Data Store	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Technology	Sentinel Hub QGIS plugin	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Digital model of the Earth	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Mobile display tools	Geospatial Data Visualization	S2 - information skills
EO	Downstream	Application	Cloud-based open access Sentinels data storage	Data Optimization Expertise	S2 - information skills
EO	Downstream	Application	Graphical interface within Copernicus browser	Geospatial Data Visualization	S2 - information skills

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Domain	Value Chain Segm	Area	Item	General Skill	ESCO Skill Type
EO	Upstream	Technology	Meteosat Third Generation Sounder (MTG-S) satellite	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Upstream	Technology	46 MPixels sensors with video acquisition	Sensor Design	S7 – constructing
EO	Upstream	Technology	32 small satellites fleet constellation	Space Systems Engineering	S7 – constructing
EO	Upstream	Technology	Hyperspectral imagery	Hyperspectral Imager Design	S7 – constructing
EO	Downstream	Application	Hourly data on tropospheric constituents over Europe for air quality	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Application	Daily global mapping of atmospheric gases	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Application	High resolution video of an extremely wide scene	Image Processing Expertise	S2 - information skills
EO	Upstream	Technology	Very high resolution and rapid revisit RS	Space Systems Engineering	S7 – constructing
EO	Downstream	Service	Weather and atmosphere monitoring	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Video observation	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Real-time commercial data products	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Multipurpose hyperspectral data	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Midstream	Technology	Bicubic-downsampled low-resolution image-guided generative adversarial network	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Technology	Efficient hybrid conditional diffusion model	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Technology	Onboard AI	Machine Learning Expertise	S5 - working with computers
EO	Downstream	Technology	Super resolution imagery	Deep Learning Expertise	S5 - working with computers
EO	Midstream	Application	Data processing onboard spacecraft	Data Processing Expertise	S2 - information skills
EO	Midstream	Service	Remote sensing image enhancement solutions	Image Processing Expertise	S2 - information skills
EO	Midstream	Service	Efficient data transmission with reduced ground-based processing	Data Optimization Expertise	S2 - information skills
EO	Downstream	Application	Integrated AI, cloud, and EO capabilities	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Geo-augmented reality	AR-GIS Integration	S5 - working with computers
EO	Downstream	Technology	Copernicus Marine Data Store	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Technology	Sentinel Hub QGIS plugin	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Digital model of the Earth	Data Fusion Expertise	S2 - information skills
EO	Downstream	Application	Mobile display tools	Geospatial Data Visualization	S2 - information skills
EO	Downstream	Application	Cloud-based open access Sentinels data storage	Data Optimization Expertise	S2 - information skills
EO	Downstream	Application	Graphical interface within Copernicus browser	Geospatial Data Visualization	S2 - information skills

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EO	Downstream	Service	Climate monitoring and change prediction	Remote Sensing Data Analysis and Interpretation	S2 - information skills
EO	Downstream	Service	Advanced situational awareness and location information	Geospatial Analysis	S2 - information skills
EO	Downstream	Service	Free marine data and metadata tools, downloads, and post-processing	Data Processing Expertise	S2 - information skills
EO	Downstream	Service	Sentinel data search, integration, and visualization	Sentinel Data Interpretation	S2 - information skills
SatCom	Upstream	Technology	Optical communication/inter-satellite communication	Optical Communication Systems Design	S1 - communication/collaboration/creativity
SatCom	Upstream	Technology	Flexible satellites	Spacecraft Design, Manufacturing, Testing	S7 – constructing
SatCom	Upstream	Technology	Electronically steered antenna	Spacecraft Subsystems Design, Manufacturing, Testing	S1 - communication/collaboration/creativity
SatCom	Upstream	Technology	Very High Throughput Satellites (VHTS)	Spacecraft Design, Manufacturing, Testing	S7 – constructing
SatCom	Upstream	Technology	Satellites based on Quantum Key Distribution (QKD)	Quantum Communication Systems Design	S1 - communication/collaboration/creativity
SatCom	Midstream	Application	Space & ground network optimization	Optimizing Space and Ground Network Connectivity	S1 - communication/collaboration/creativity
SatCom	Downstream	Application	Broadband and mobile connectivity	Radio Frequency Engineering	S1 - communication/collaboration/creativity
SatCom	Upstream	Technology	Adaptive digital beamforming and channelization with power and spectrum control	Adaptive Digital Beamforming and Channelization Expertise	S5 - working with computers
SatCom	Upstream	Technology	Quantum communication network	Quantum Communication Systems Design	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	In-flight entertainment & connectivity (IFEC)	IFEC Systems Integration	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Maritime infrastructure & crew connectivity	Maritime Satellite Communication Systems Integration	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Data-relay	Inter-satellite Network Management	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Communication on the move (COTM)	COTM Systems Integratoin	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Aeronautical connectivity	Aeronautical Network Management	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Crisis management	Satellite Network Resource Allocation	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Government/military communication	Secure Communications Protocols and Encryption	S1 - communication/collaboration/creativity
SatCom	Midstream	Technology	Optimized video software solutions	Development of Optimized Video Software	S5 - working with computers
SatCom	Midstream	Technology	DVB-S2 (Digital Video Broadcasting -Satellite) and HEVC standards (High Efficiency Video Coding)	HEVC Expertise	S5 - working with computers
SatCom	Midstream	Technology	5g Non-Terrestrial Network (NTN) & Orthogonal Frequency Division Multiplexing (OFDM)	5G NTN Network Architecture	S1 - communication/collaboration/creativity
SatCom	Midstream	Application	Satellite-based high-precision geo-tagged live video compression and streaming	Data Processing Expertise	S2 - information skills
SatCom	Midstream	Application	Video applications (DTH, broadcasting, OUTV)	Satellite Broadcasting Expertise	S1 - communication/collaboration/creativity
SatCom	Midstream	Application	Interconnectivity with terrestrial 5g networks	5G NTN Network Architecture	S8 - working with machinery and specialised equipment
SatCom	Midstream	Application	Satellite-enabled devices	Satellite-enabled Devices Design, Manufacturing, Testing	S8 - working with machinery and specialised equipment
SatCom	Midstream	Application	Direct-to-device communication	Direct-to-device Network Architecture	S8 - working with machinery and specialised equipment
SatCom	Downstream	Service	Satellite TV (UHD)	Satellite Broadcasting Expertise	S1 - communication/collaboration/creativity
SatCom	Midstream	Service	Satellite backhaul for 5g	5G NTN Network Architecture	S8 - working with machinery and specialised equipment

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SatCom	Midstream	Service	Satellite broadband services	Satellite Internet Expertise	S1 - communication/collaboration/creativity
SatCom	Midstream	Service	Interoperability and roaming between networks	Satellite Communications Protocols and Standardization Expertise	S1 - communication/collaboration/creativity
SatCom	Midstream	Technology	Multi carrier satellite gateway	Multi-Carrier Satellite Gateway Integration	S1 - communication/collaboration/creativity
SatCom	Midstream	Technology	Edge computing both in-space & on ground	Edge Computing Expertise	S5 - working with computers
SatCom	Midstream	Application	End-to-End multimedia integrated support, including OTT integration	End-to-End Multimedia Integration	S1 - communication/collaboration/creativity
SatCom	Midstream	Application	Multi-stream reception and transmission	Multi-Stream Satellite Communication Network Management	S1 - communication/collaboration/creativity
SatCom	Midstream	Application	In-orbit data processing	In-orbit Data Processing Expertise	S2 - information skills
SatCom	Midstream	Application	Real-time and autonomous identification of efficient/best-fit communication links across multiple-orbits & terrestrial networks	Machine Learning Expertise	S5 - working with computers
SatCom	Downstream	Service	Direct To-Home (DTH) video delivery	Satellite Broadcasting Expertise	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Direct-To-Tower (DTT) video & audio delivery	Satellite Broadcasting Expertise	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	Live, on-demand OTT distribution	Satellite Broadcasting Expertise	S1 - communication/collaboration/creativity
SatCom	Downstream	Service	End-to-End managed network services	End-to-End Network Management	S8 - working with machinery and specialised equipment
SatNav	Upstream	Technology	Dual frequency (L1/L5 and E1/E5a) GPS + Galileo receiver	GNSS Receivers Design, Manufacturing, Testing	S7 – constructing
SatNav	Upstream	Technology	Use of 6 atomic clocks	Precise Time Reference Expertise	S8 - working with machinery and specialised equipment
SatNav	Upstream	Technology	Dual frequency smart GNSS receivers	GNSS Receivers Design, Manufacturing, Testing	S7 – constructing
SatNav	Upstream	Technology	Galileo Second Generation	GNSS Spacecraft Design, Manufacturing, Testing	S7 – constructing
SatNav	Downstream	Application	Positioning accuracy at the centimetre level	Precise Point Positioning Expertise	S2 - information skills
SatNav	Downstream	Service	Positioning integrity for safety-critical sectors	Safety-Critical Positioning Expertise	S2 - information skills
SatNav	Downstream	Service	Low-cost high positioning accuracy for land surveying	Precision Mapping and Surveying Expertise	S2 - information skills
SatNav	Midstream	Technology	GBAS Approach Service Type F (GAST F)	GBAS Approach Service Type F (GAST F) Expertise	S8 - working with machinery and specialised equipment
SatNav	Midstream	Technology	L1C	GNSS Signals Expertise	S8 - working with machinery and specialised equipment
SatNav	Midstream	Technology	M-Code GPS signal	GNSS Signals Expertise	S8 - working with machinery and specialised equipment
SatNav	Midstream	Application	Robustness against ionosphere and radio disturbances in multifrequency GNSS environment	Multi-frequency GNSS Signal Processing Expertise	S8 - working with machinery and specialised equipment
SatNav	Midstream	Application	GPS interoperability with other GNSS constellations	GNSS Signals Expertise	S8 - working with machinery and specialised equipment
SatNav	Midstream	Application	Encrypted signal for military receivers	GNSS Signals Protocols and Encryption	S8 - working with machinery and specialised equipment
SatNav	Midstream	Service	Aircraft precision approach operations	Precision Approach Expertise	S2 - information skills
SatNav	Midstream	Service	High-precision surveying	Precision Mapping and Surveying Expertise	S2 - information skills
SatNav	Midstream	Service	Secure cryptography architecture	GNSS Signals Protocols and Encryption	S8 - working with machinery and specialised equipment
SatNav	Downstream	Technology	GNSS-blockchain integration	GNSS-Blockchain Integration Expertise	S5 - working with computers
SatNav	Downstream	Technology	GNSS chip equipped smartphones	GNSS-enabled Devices Design, Manufacturing, Testing	S7 – constructing
SatNav	Downstream	Technology	Certifiable on-board localization unit in the railway environment	GNSS Railway Integration	S8 - working with machinery and specialised equipment

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SatNav	Downstream	Application	Geolocation software	Geolocation Software Development	S5 - working with computers
SatNav	Downstream	Application	Emergency alert transmission	Emergency Geospatial Positioning Expertise	S2 - information skills
SatNav	Upstream	Technology	GNSS-based multi-sensor fusion architecture	Multi-sensor Fusion Positioning and Navigation System Design	S1 - communication/collaboration/creativity
SatNav	Downstream	Service	Platforms with automated verification of data trustworthiness	Data Authentification Expertise	S2 - information skills
SatNav	Downstream	Service	Emergency Warning Satellite Service	Emergency Geospatial Positioning Expertise	S2 - information skills
SatNav	Downstream	Service	Train control system	GNSS Railway Integration	S8 - working with machinery and specialised equipment
Access to Space	Upstream	Technology	Super heavy launch vehicles	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Kinetic launch system	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	European launch autonomy	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	LEO launch	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Reusable launchers	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	3D-printed launcher structures	Additive Manufacturing For Space	S8 - working with machinery and specialised equipment
Access to Space	Upstream	Technology	Stratospheric balloons	Stratospheric Balloons Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Hypersonic spaceplane	Hypersonic Spaceplane Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Aerospike engines	Rocket Engines Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Methalox propellant	Rocket Propulsion Expertise	S8 - working with machinery and specialised equipment
Access to Space	Upstream	Technology	Rotating detonation rocket engine	Rocket Engines Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Technology	Carbon-fiber–reinforced plastic	Composite Materials Expertise	S7 – constructing
Access to Space	Upstream	Technology	Reusable rocket engine	Rocket Engines Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	Rocket carriers and launches from a “near-space” environment	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	Suborbital flight & ultra-hight speed transportation	Suborbital Vehicles Design, Manufacturing, Testing	S7 – constructing

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Access to Space	Upstream	Technology	Single-stage-to-orbit launch vehicles	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	Reusable rockets' propulsion	Rocket Propulsion Expertise	S8 - working with machinery and specialised equipment
Access to Space	Upstream	Application	Light-weight rocket's upper stage	Launcher Design, Manufacturing, Testing	S7 – constructing
Access to Space	Upstream	Application	Space tourism	Space Tourism Infrastructure Planning	S4 - management skills
Space Safety	Upstream	Technology	Tow truck spacecraft enabled with vision-based AI	Space Debris Capturing Spacecraft Design, Manufacturing, Testing	S7 – constructing
Space Safety	Midstream	Technology	Combination of SSA software and spacecraft propulsion control	Space Situational Awareness Expertise	S2 - information skills
Space Safety	Downstream	Technology	Open-Architecture Data Repository (OADR)	Open-Architecture Data Repository (OADR) Development and Management	S2 - information skills
Space Safety	Downstream	Technology	AI/ML-based prioritisation and classification of alerts	Artificial Intelligence and Machine Learning Expertise	S5 - working with computers
Space Safety	Upstream	Technology	Advanced radar and telescope system	Radar and Telescope System Design, Manufacturing, Testing	S7 – constructing
Space Safety	Upstream	Technology	Advanced design standards reducing risk of onboard battery malfunctions	Spacecraft Propulsion Expertise	S8 - working with machinery and specialised equipment
Space Safety	Midstream	Technology	Collaborative AI agents optimizing sensing strategies for object detection	Artificial Intelligence Expertise	S5 - working with computers
Space Safety	Midstream	Technology	Space/ground-based laser nudging mechanisms to safely redirect space debris trajectories	Space and Ground-based Laser Nudging System Development	S7 – constructing
Space Safety	Upstream	Technology	Tethered-Net Removal	Space Debris Capturing Spacecraft Design, Manufacturing, Testing	S7 – constructing
Space Safety	Upstream	Technology	Removal docking plate bus equipment	De-orbiting Mechanisms Design, Manufacturing, Testing	S7 – constructing
Space Safety	Upstream	Technology	Extra-vehicular general-purpose robotic arm and hand	Robotic Arm and Hand Design, Manufacturing, Testing	S7 – constructing
Space Safety	Downstream	Service	Integrated space mobility subscription	Space Mobility Expertise	S8 - working with machinery and specialised equipment
Space Safety	Downstream	Service	Streamlined space traffic management	Space Traffic Management Expertise	S4 - management skills
Space Safety	Downstream	Service	Warning system for public operators	Space Safety Alert System Development	S1 - communication/collaboration/creativity
Space Safety	Midstream	Application	Advanced algorithms discerning threat levels for potential collisions	Machine Learning Expertise	S5 - working with computers
Space Safety	Midstream	Application	Autonomous EU SST	Space Situational Awareness Expertise	S2 - information skills
Space Safety	Midstream	Application	Space sensor tasking	Space Sensor Tasking Expertise	S8 - working with machinery and specialised equipment

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7. APPENDIX B – DESKTOP RESEARCH REPORT

For completeness, this section is also included in Deliverable D2.1, which contributes to the same initiative aimed at mapping the skills needs of the space sector over the next 10-15 years.

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