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Perspectives into topical issues in society and ways to support political decision making.

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Socio-economic impact of space activities in Finland

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Space-based services are an integral part of modern society and its infrastructure

Space-based services and data are utilized widely in government decision making, planning and provision of public services. Satellite navigation systems, time signal, satellite-based earth observation and satellite communications are examples of space-based technologies that are utilized in provision of various public services, e.g., emergency services, public safety as well as environmental protection and enforcement. Similarly, many industry and business related applications are dependent on space-based technologies e.g., energy and telecom networks, commerce, financial and insurance services, transports and logistics. Additionally, many services depend on space-based services, data, and technology. In effect, space-based services are critical to the modern society.

Space-based activities bring many improvements to the society

Space-based services are improving efficacy of numerous everyday activities. Many are familiar with satellite navigation through mobile phone map applications. A significant share of international telecommunications is routed through satellite connection. Satellite images and sensor data are used in several research and information applications, e.g., weather forecasts and atmospheric research, monitoring forests, water quality, agriculture, or snow cover and to assist in winter navigation at sea. Space technology is also present in consumer products, as many materials that are used in for example in clothes and other everyday items originate from various space programs.

Space activities are undergoing a period of strong global growth. The estimated volume of the space industry's turnover is between 360 and 470 billion USD¹ globally and it is expected to double or triple and break the trillion Dollar mark in the next decade².

Objective of the study

The socio-economic impact of space activities in Finland (AVARTAVA) -study examined the current state of space uptake and future possibilities and challenges in developing and adopting new space-based services and solutions in Finland. The study answered the following research questions:

- How and what space-based systems and services are used in government decision making, particularly related to execution of the government program and furthering other societal goals?

¹ Cf. Space Foundation, The Space Report 2021 Q2, Q4; Weinzierl & Sarang, 2021" The Commercial Space Age is Here, Harvard Business Review; OECD 2019, The Space Economy in Figures: How Space Contributes to the Global Economy; Morgan-Stanley, "The Space Economy's Next Giant Leap" Available: <https://www.morganstanley.com/Themes/global-space-economy>

² Morgan-Stanley, "The Space Economy's Next Giant Leap" Available: <https://www.morganstanley.com/Themes/global-space-economy>

- In which sectors space uptake has enhanced the precision, effectiveness and timeliness of activities, research, monitoring and planning in Finland?
- Which sectors are still lagging behind in space uptake? Which factors or bottlenecks hinder further application of space-based services and data?
- What kind of outcomes different interruptions or disturbances in space-based services could have for the society and its different functions?
- How should Finland/Finnish actors collaborate and position themselves to enable best use of European space programs (e.g., European Space Agency, EU and other European collaborations)?

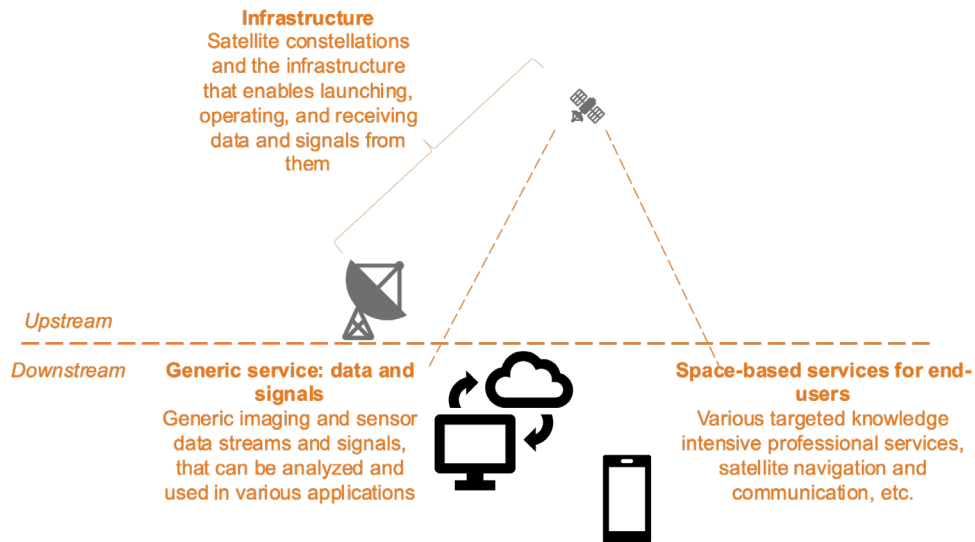
The project was executed between March 2021 and March 2022 by 4FRONT Ltd and VTT Ltd. The project focused in examining the impact logic of space uptake in various areas of society, focusing specifically on the contribution of space to attainment of the goals set in the Government program.

What does space uptake mean and what are space-based services?

The study relied on the OECD definition³, which splits space activities into three tiers: *upstream* comprises space flight and operations in the orbit, as well as operating ground stations and technology development and manufacturing related to upstream activities, *downstream* includes the use and application of the signals, data and services provided by upstream activities and infrastructure and *space-derived* activities utilize space technology in other fields. This study focused primarily on the first two tiers.

In lay terms, satellites produce various signals and data streams that are received at ground stations and recorded for further analysis and application. Most end-user services utilize the signals and raw data as an intermediate product. The final products may, for example, take form as a map, a weather forecast, a satellite phone call or other data service on the end users' device or screen. (See picture)

³ OECD 2012, The OECD Handbook on Measuring the Space Economy, OECD, Paris



Key findings and conclusions

Space uptake is broad in various government sectors and space-based services are instrumental for decision making and operations

Space-based services have a variety of roles in multiple government sectors and at different levels. The implementation of the Government program benefits from space uptake in a variety of ways. However, the role of space activities and services is often unacknowledged in government or society at large. Some specific examples from case studies are presented in the following table.

The Finnish government, public sector and business are engaged in downstream space activity and have a host of developed applications of space-based services. New applications are constantly being developed. The roles of space activities differ from government sector to sector:

- *Space activities inform high level policy making:* EO and satellite-based remote sensing is used in research that inform high level environmental policy and international policy
- *Space-based services support governance:* EO contributes to monitoring the environment, agriculture and forestry, enforcing regulation, as

well as collecting data and reporting. Traffic and transport system planning, monitoring and upkeep planning is based on location information.

- *Space activities are a part of operative work:* situational awareness and operative command of flight control, marine traffic control, and public safety and emergency response are dependent on GNSS and location information. Additionally, satellite/route navigation and SATCOMs are used in countless application around the public sector.

Case	Space application	Contribution of space uptake	Impact of space uptake
Navigation satellite systems (GNSS) in transport sector	Location information is used in development of transport infrastructure, GNSS are essential for traffic automation and other intelligent transport and mobility services.	Intelligent transport systems and infrastructure improves the efficiency of transport and logistics at the systems level, enables better control of traffic flow and road safety, and by extension improves sustainability of transport.	Location and navigation services are already used extensively. Without them, the functioning of the traffic system would be disrupted and travel/delivery time and reliability would suffer, congestion would become more prevalent etc. The impact of space uptake is a broad improvement in productivity.
Time synchronization using navigations satellite systems	GNSS are used for time synchronization and time stamping routinely in banking, finance, insurance, commerce, as well as various networks and process equipment and instruments.	Time stamping is an important trust service for finance and commerce, and synchronization is important for telecom and electric networks, and various industrial processes and laboratories.	GNSS enables more effective, trust worthier and faster high-accuracy time stamping and synchronization than other technologies. Therefore, it also facilitates more effective and productive commerce and industrial processes.
Earth Observation (EO) in agriculture	Satellite-based remote sensing data is used in combination with on-ground samples and growth models to optimize sowing, irrigation, fertilization and other actions	EO is an important enabler for precision farming, which enables better crop yields by optimizing use of land, fertilizer and pesticides.	Precision farming benefits the industry, farmers and consumers and contributes to better food security.
Space uptake in public safety	Public safety uses EO, GNSS and SATCOMs in a variety of ways.	Space-based services enable better planning, preparedness, risk analysis and avoidance and better team awareness during field operations. It also makes working environments safer and more effective for firefighters, emergency medical technicians, police and other public safety officers.	Spaces-based services enable better preparedness, proactive planning and response, shorter response times and safer operation in emergency response.

Case	Space application	Contribution of space uptake	Impact of space uptake
Earth observation in climate and environmental sector	EO produces continuous data streams about the earth's atmosphere, seas and land-mass.	EO enables reliable continuous data collection that covers the globe and captures changes in atmosphere, seas and land.	EO increases data quality, coverage and decreases cost for individual researchers in accessing high quality data.

Space uptake improves efficiency, effectiveness and productivity by offering better data, situational awareness and solutions for real-time process control and optimization. Space-based services are used in various business sectors:

- *Agriculture and forestry*: satellite-based remote sensing enables more timely data collection and covering larger areas with better accuracy than *in-situ* sampling, thus enabling more comprehensive and accurate natural resource inventories and growth forecasts and optimization of fertilizer and pesticide use.
- *Energy and industry*: GNSSs enable synchronization of telecom, data, and energy networks and various process equipment. It enables for example better energy network balancing, stability, resilience and integration of local and intermittent power generation.
- *Transport and logistics*: flight and maritime navigation and traffic control depend on satellite navigation for real time control and efficiency. GNSS service improve overall efficiency and safety of traffic, transport and logistics.
- *Finance and commerce*: GNSSs enable accurate trusted timestamping of transactions, contracts, and other legal documents. EO enables better evaluation of insurance claims.
- *Services*: Various mobility and courier services rely on satellite navigation in their business model and pricing.

Further space uptake is hindered by lack of resources and knowledge about opportunities

Further space uptake has the potential to offer further benefits for both public sector and industry. One of the major bottlenecks for further utilization of space-based services is structural. Both in government and business, typical organization units are relatively small and have limited R&D resources. This limits both engaging with downstream space activities and developing new products and services. Another related

challenge is that adoption and application of space technology and data are associated in practice with organizational development, process engineering and digitalization projects, which all require their own expertise and resources.

Interruption in space-based services can have major effects for functioning of society

Service interruptions may be caused for example by space weather and associated solar activity, space debris, malfunctions in satellites or terrestrial infrastructure or intentional interference, jamming or spoofing. The service interruption can be local or broad and vary in length.

Especially broad and prolonged interruptions may have serious effect in infrastructure and normal functioning of the society. For example, energy and telecom network service quality will suffer and interruption in time synchronization may affect network balance and cause blackouts. Transport and logistics as well as public safety services also largely depend on GNSSs, and interruptions in service may threaten supply security and public safety.

Recommendations

As whole, Finland is utilizing space technologies relatively broadly. The recommendations are focusing on how Finland can maximize the benefits in both public sector and businesses.

Recommendation 1: Knowledge of space-based services and understanding of the possibilities should be strengthened in government and general population

Space-based services are little known compared to their importance to normal functioning of society. Space awareness should be built and integrated to regulation and sectoral strategies also outside the space community.

Recommendation 2: The strategic management of Finnish space activities should be reinforced

The national space strategy sets a relevant framework and vision for further development and application of space technology and services. There is a need for a joint strategic program that attaches to government sectors' strategies, as well as RDI and industrial policy to make the vision concrete and achievable.

Recommendation 3: Further actions and investments in developing space uptake and the national ecosystems should be based on recognizing the most potential and relevant technology and application areas

The national focus areas should be decided based on national strategic importance and global demand, and to reflect national capabilities and competence, to channel investments to the most potential areas of activity. (cf. recommendation 2)

Recommendation 4: Greater value capture from European space programs requires better coordination and proactive preparation by national actors

Capturing the full benefits of the European programs demands proactive national strategizing, lobbying, programming, and both public and private investments in capacity building. (cf. recommendations 2 and 3)

Recommendation 5: The government and ministries should use pre-commercial procurement more effectively in enabling space uptake

When preparing to use pre-commercial procurement, organizations and purchasing units should have the necessary capability for procurement, requirements engineering, developing and using the solutions to realize the expected outcomes.

Further information:

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Government's analysis, assessment and research activities

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