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Our service offering for the Space sector

Our expertise and service offering dedicated to public and private organisations evolving in the Space sector

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Foreword

Growing demands for global connectivity and environmental monitoring are challenges that can be met by appropriate exploitation of space-based assets. Beyond the community of institutional and private stakeholders directly involved in the sector, the wider space economy includes a larger intermediate and end user base, with a reach that extends to numerous industrial sectors.

Luigi Scatteia
PwC Space Practice Leader

Space is widely recognised as a highly strategic sector for governments, businesses and citizens because it is vital to a wide array of services and applications across numerous economic sectors.

Historically, existing and expected benefits from investment in space have led to a steady demand for space assets. Several nations have responded by launching initiatives to pool resources and develop capabilities in space system production, operation and exploitation, and in the last few decades, private investors have also shown significant interest in space sector domains that have traditionally been driven by public spending, such as space transportation and Earth observation. In order to maximise the return on investment in space assets, the sector's stakeholders need to adapt to an environment that in recent years has experienced profound change. At each level of the value chain, from space asset development to end-user exploitation, an understanding of the evolving landscape is pivotal to creating a successful strategy.

The sector's transformation offers fresh opportunities to well-established companies and new players, both from within and from outside the space sector. Seizing these opportunities is indispensable to remaining competitive.

The profound changes in the space sector also offer institutions and policy makers the chance to create the most appropriate conditions for market expansion, and to successfully develop technology-driven national and regional economies.

With its dedicated Space Team, PwC offers tailored support to public and private entities in space policy, technology road-mapping, market assessment, strategy and economic impact assessment, to assist in their decision-making processes and approaches to developing space-related activities.

The team leverages a cross-domain sectorial expertise that is paramount when operating in a sector like Space, characterised by a one-of-a-kind market and institutional dynamics and specificities.

This document describes how PwC's expertise and service offering addresses the needs of the wider space community. PwC is committed to providing effective support to organisations and companies across the entire space value chain, by working closely with our clients to define and implement appropriate and profitable strategies that enable them to thrive in a rapidly evolving sector.

The figures presented in this document are based on available data as of September 2016, and are subject to change over time. The monetary values are shown in euros and, when necessary, were converted based on the average annual exchange rate.

Space as a holistic sector: *From infrastructure to services*

Overview of the space sector

Definition

The space sector includes all public and private entities involved in the development, manufacturing, operation and exploitation of space systems and related infrastructure, from innovative research activities to the supply of products and services to end users. It therefore includes "pure" space players such as space agencies and space technology companies but also companies with a different core expertise (IT, electronics, media, etc.) that rely directly on space infrastructure.

The space sector is traditionally divided into the following main domains:

- Communications
- Earth observation
- Navigation
- Space transportation
- Space Situation Awareness and Tracking
- Science and human spaceflight

Depending on its purpose or application, space infrastructure can be operated by civil or military institutions, or by private entities.

Space as a growth driver for national economies

Through the products and services provided to ground industries, space is an economic contributor to many sectors such as natural resource management, transport, health, agriculture, education, meteorology, disaster management, insurance and banking. Beyond these economic benefits, space is also an enabler of social development and environmental protection. Space applications have a strategic impact on the sustainable development of urban areas, preventing the spread of pollution and soil erosion, optimising ground transportation, measuring the effectiveness of environmental policies, enabling communication in remote areas, improving the safety of air transportation and more.

Space activities today

Space activity has experienced significant growth since 2012. Orbital launches have increased by 22% during the period, reaching 95 in 2017, operated mainly by Russia, the United States, China and Europe. The number of spacecraft launches excluding nanosatellites (<10kg) has increased by more than 50% and launches including nanosatellites have more than tripled, skyrocketing from less than 30 in 2012 to more than 260 in 2017. As a result of this activity, it is estimated that around 1,700 satellites were in operation in 2017. Over the past two years, half of the payloads delivered into space were of Earth observation instruments, followed by technology payloads (tests and demonstrations) and communication satellites. Despite representing less than 5% of the launch events operated in 2016 and 2017, cargo and crewed missions to the International Space Station still accounted for around 30% of the total payload mass launched into space.

Space as an enabler

The importance of the space sector is not in the data or imagery transmitted through spacecraft, but rather the industries and markets that they enable. Airlines, marine transport companies, oil & gas or mining operations, agriculture, environment, forestry and naturally the military sector are all becoming increasingly reliant on space infrastructure. Data sets including satellite imagery and positioning signals provide valuable insights for applications as varied as agriculture, transport, smart city planning and emergency response.

In 2018, as the age of autonomous vehicles, pervasive AI, data analytics and fusion rapidly advances, the relevance of the space sector is becoming more and more apparent. As the only solution that can provide reliable, inexpensive global coverage, the commercial space age is only just beginning.

The value of the global space economy in 2016 was estimated at around:

€307 bn ($340 bn)

Representing +12% compared to 2012

Segmentation of the value chain

The transformation of the space landscape has pushed operators in the sector to adopt a holistic approach, from space infrastructure down to end-user products and services. The competitive environment has changed and companies are adapting by expanding their footprint across the value chain through a series of horizontal and vertical integrations.

2016 Figures of the space economy per stream – CAGR calculated between 2012 and 2016

Upstream (CAGR +1%)	Midstream (CAGR +2%)	Downstream (CAGR +2%)
€92 bn / $102 bn	**€28 bn / $31 bn**	**€187 bn / $207 bn**
Commercial satellite market **€12 / $14 bn** (CAGR -8 %) Launch market **€5 / $5.5 bn** (CAGR -7%) Institutional budgets **€74 / $82 bn** (CAGR +3%	Operators revenues **€19 / $21 bn** (CAGR +2%) Ground infra. and op. **€9 / $10 bn** (CAGR +1%)	Space services **€95 / $105 bn** (CAGR +3%) Consumer equipment **€92 / $102 bn** (CAGR +2%)

The structure of the space value chain

The space value chain is traditionally composed of three activity streams:

"Upstream" includes activities that contribute to an operational space system. It comprises the manufacture of space infrastructure and related subsystems and components, as well as launch services, programme management and additional activities provided by space agencies.

"Midstream" includes activities related to satellite operation and the lease or sale of satellite capacity and data. It also includes support activities, such as user equipment manufacturing (i.e., dishes, satphones, etc.), network management, and associated services that exploit space systems, such as data storage, processing and dissemination.

"Downstream" includes activities related to space-infrastructure exploitation and the provision of space-based products and services to end users.

The role of institutional entities

Historically, the space sector has been almost exclusively driven by institutional demand, mainly by space agency spending. In the 1990s, the privatisation of satellite telecommunication operators initiated the raise of commercial space activities, and although in 2016 more than 80% of financial investment still came from public institutions, since then the role of private companies has expanded substantially. New private investment sources are more and more involved, and greater responsibility is transferred to the industry (e.g., for launchers). Nevertheless, institutional entities are expected to remain influential as they continue to represent a substantial revenue source for privately owned organisations.

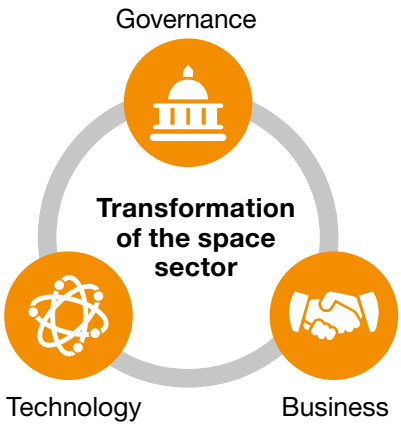
NewSpace: a recent paradigm shift

The last few years have been marked by the emergence of various private initiatives with innovative business models that are targeting the entire value chain from upstream to downstream. These NewSpace players are characterised by their tendency to move away from the traditional approach of large, high performance spacecraft with strong risk mitigation, manufactured, operated and exploited by different entities towards low-cost, easily replaceable satellites, launched in constellations. This vertically integrated approach enables these players to focus on the downstream segment and data exploitation to create value.

These lower risk, shorter cycle initiatives attract venture capital funds and non-space companies, which are investing heavily in the space sector and stimulating dynamic growth.

A sector undergoing profound transformation

The space sector is at the crossroads of significant governance, business and technological change and is being challenged more than ever at every level of the value chain and in every market. In this rapidly evolving environment, the space sector is entering a period of profound transformation.



Governance

International, European and national space policies are set to undergo gradual but profound change in the years to come, particularly in the delineation and distribution of public responsibilities and new areas of action, including the expected adoption of "application-driven" or "user-oriented" policies. Examples include standardisation, market regulation of space products and services, and cooperation frameworks. Public institutions are already formulating innovative programmes to achieve new strategic objectives in the sector. These programmes will shape future space markets. The growing involvement of regional and local players in space policies is increasingly accepted, particularly in an effort to facilitate economic development.

Business

Innovative NewSpace business models and projects are a source of both enthusiasm and doubt in Europe, but most stakeholders believe that they represent an opportunity that should not be underestimated. Historical players are increasingly being challenged in various markets by non-traditional competitors with innovative business models and support from venture capital funds and non-space companies. Application-driven markets are a growing segment for space industry players looking to maximise the benefits of their investment by expanding their customer base. Newly developed terrestrial technologies, such as in-flight connectivity, M^2M networks, location-based services on smartphones, or new Earth observation data applications, are opening up promising new markets for players in the space sector.

Technology

The space sector is highly dependent on technological innovation but is also keen to preserve its technical heritage and know-how. However, innovative projects, such as mega-constellations or expendable Earth observation satellites, are pushing established industries to reconsider their high-quality and low-risk engineering and production models and adopt new design-to-cost and "good enough" risk acceptance models. Such profound changes impact every level of an organisation, from programme management and quality systems to production line modernisation and staff structure. Sectors that prioritise quality, such as the automotive and aeronautics industry, have already started implementing new manufacturing technologies (e.g., additive layer manufacturing) and moving towards Industry 4.0. Stakeholders in the space sector are closely monitoring this global trend that will soon become a driver of greater competitiveness in the industry.

Our service offering

We are part of a global team of over 2,000 industry professionals focusing on the Aeronautics Space & Defence sectors

We are able to leverage our Global Aerospace & Defence network in major space nations in Europe, the United States, the Middle East and Asia

Our offer is based on five pillars tailored for each of the space domains

Strategy

With a 100-year legacy in strategy consulting, PwC Strategy& offers a unique "capabilities-driven strategy" approach to maximise its clients' chances of success. Whether we are supporting government agencies and public institutions, satellite operators, service providers or industrial players, we provide our clients with confidence that their strategies, policies, investments, and organic capabilities will coherently combine to achieve the desired results.

- Market characterisation (sizing, trends, competitive landscape, etc.)
- Evaluation of business cases and revenue projections
- Definition and assessment of diversification strategies
- Gap analyses and evaluation of market opportunities and barriers
- Assessment of policy options and institutional actions for market development

Socio-economic impact assessment

PwC has developed a comprehensive suite of methodologies to cover the whole spectrum of socio-economic impact assessments. The approach, which has been used and validated on numerous occasions, can be applied to large-scale public or private investments in infrastructure or space programmes. The assessments rely on commonly accepted methodologies and taxonomies to produce results that can be used to support effective decision making and policy design.

- GDP impact assessments
- Catalytic and non-monetary impact assessments
- Cost-Benefit Analyses (CBA)
- Assessment of intangible societal and strategic impacts

Governance and Operations

We support institutional bodies, space agencies and private customers involved in major space programmes in the analysis of governance, organisational structure and management of human capital. We look at different organisational, operating, and outsourcing models to target governance and operational excellence.

- Analysis of national and regional space policies
- Identification of funding schemes to support the development of space capabilities
- Audit of space programmes and space agencies governance structures to maximise economic development

Regulatory

We have supported public bodies to analyse regulations impacting the space sector from upstream to downstream. Our team includes legally trained consultants, supported for in-depth assessments by PwC Société d'Avocats, PwC France's legal services arm, which operates in the global network of PwC lawyers. This allows for timely relevant expertise that is invaluable in cases requiring an understanding of legal challenges with a regional or global reach.

- Analysis of the impact of export regulations in satellites and launcher activities
- Assessment of the warranty and liability safeguards of Earth Observation and Navigation data
- Analysis of IPR, Personal Data Protection and Export Control related to digital solutions and services derived from space data

Data analytics

Our team works closely with the PwC Advanced Solutions Development team and PwC Geo Analytics teams. Together, we have supported companies in the technical evaluation and development of their digital services offering, capitalising on data fusion from both space and non-space data. Our team of skilled data scientists can also capitalise on the global PwC network, which counts more than 7,000 data & analytics experts.

- Analysis and identification of data-driven business models derived from the exploitation of space data
- Design of new digital products and services based on space data via a customer-driven approach (use case-based)
- Development of Proofs Of Concept with PwC software teams using scalable and open sources tools
- Creation of products and econometric models based on geospatial data

Our expertise in each space sector domain

Satellites play a vital role in global communications. Although the market is relatively established, the sector is still subject to changes in demand from private and institutional end users that require the development and application of new business models and technologies.

Communications

472
Estimated number of communication satellites in operation in 2017

€119 bn ($126 bn)
Estimated global market for satcoms, from upstream to downstream in 2016

80%
Share of revenues of the satcom market generated downstream in 2015

Satcoms: the primary use for space assets

Over the past 50 years, use of satellite communications (satcoms) has skyrocketed to become the most important space sector domain based on various indicators, such as mass launched into orbit or revenue generated by satcom players. In the midstream, each of the top 3 fixed-satellite service (FSS) operators generated more than €1 billion (global market of $107 billion) in revenue. Services derived from telecommunication satellites, from internet via satellite to television, are among the most lucrative of all the space sector domains.

The importance of satellite communication for the global economy

Satcoms are critical to a wide range of business, government and leisure activities. Compared to terrestrial infrastructure, satcoms provide an unmatched level of availability, coverage, confidentiality and resilience. The numerous applications derived from communication satellites provide public and private stakeholders with solutions for continuity, safety and accessibility.

Many promising markets still to be developed

The development of human activity in both urban and rural areas is resulting in a growing need for an Information and Communication Technology (ICT) infrastructure. Satcoms are increasingly identified as strategic infrastructure for the development of communication networks, often interfaced with terrestrial solutions. In addition, new markets, such as M²M, in-flight connectivity or Ultra HD, are expected to sustain the satcom market.

A market open to global competition

Historically, governments controlled the satellite telecommunication sector through public intergovernmental organisations. The sector was largely privatised in North America and Europe and today, private operators control most of the satcom market. Although local operators are still controlled by the government in Asia, South America, the Middle East and Africa, most of the global market remains open, in contrast to the captive domestic public markets that normally exist in other segments of the space sector.

Business and technological challenges derived from a growing demand for bandwidth

The international business environment of the satellite telecommunication sector is relatively stable with a few leaders holding the majority of market shares.

However, big established players are locked in intense competition to enhance their leadership at the expense of their main competitors. Global connectivity needs are the major driver for the growing demand for bandwidth, pushing operators to expand the capacity of their satellites (e.g., by increasing the number of transponders) and to introduce technological innovations (e.g., high throughput satellites).

Our specialised service offering

Strategy

- Evaluation of business cases for innovative satellite operator go-to-market strategies
- Evaluation of business cases for satellite constellations
- Analyses of satcom operator aftermarket segment potential
- Assessment of the external growth potential of satellite players resulting from diversification strategies

Socio-economic impact assessments

- Assessments of the potential impact on the satcom manufacturing industry of new platforms, such as high altitude drones and balloons
- Impact assessments of governmental satcom programmes

Governance & Operations

- Technical and economic product portfolio performance evaluation and optimisation
- Deployment of design-to-cost best practices
- Implementation of "good-enough" engineering models
- System engineering through requirement and configuration management
- Definition of levers to foster collaboration between satellite operators and capacity buyers
- Impact analyses of the use of digital tools to support mega-constellation series production

Selected credentials

Assessment of the satellite communication capacity requirements of emergency services

PwC worked with the European Commission on its assessment of the needs, design and implementation of the GOVSATCOM programme dedicated to satellite communications for emergency service organisations (maritime, police, civil protection, humanitarian aid and external action services). Our conclusions led to a strategy based on scenarios involving proprietary satellites, satellite constellations, the leasing of capacity or services, and pooling between European countries.

Business case and strategy evaluation for OEM vertical integration to SATCOM services

PwC Strategy& conducted a detailed market assessment to determine how a globally leading satellite manufacturer might enhance its position across the value chain. We compared alternative strategies and associated business cases to determine which would offer the greatest returns with lowest risk to the existing manufacturing business. We combined the firm's strategy, operations, corporate finance and digital capabilities to evaluate the full implications of the opportunities, which directly influenced the client's corporate strategy decisions.

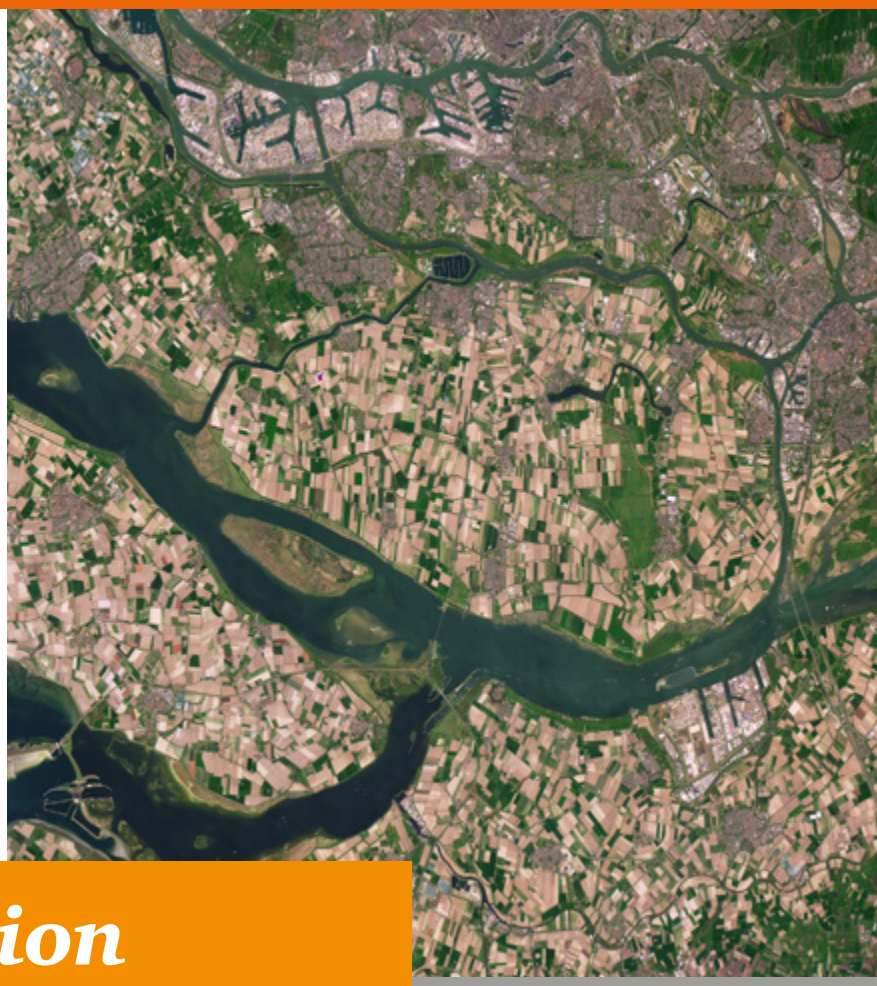
India market entry

PwC has supported both Tier-1 space systems suppliers andseeking to enter the Indian market. This involved the evaluation of numerous use cases, competitive positioning, and playbooks to inform entry strategies.

Middle East / North Africa new SATCOM operator

PwC Strategy& developed the green field business case to start up a new operator serving the Middle East/North Africa region. We engaged with institutional and commercial stakeholders on market dynamics, business strategy, operations, and technical details.

Earth observation (EO) is a promising, fast-growing field boosted by a wide range of applications across various economic sectors, including precision farming, civil protection, insurance, natural resource monitoring, oil and gas exploration, meteorology and urban monitoring.



Earth observation

Growth potential of Earth observation

The EO data exploitation market (data sales and value-added services) benefits from the highest annual growth of all the space exploitation markets, with an average rate above 13%. The need for EO data in geo-information products and the increasingly central role of Big Data reinforce the development potential of commercial activities, making the young EO market particularly promising for the years to come.

A market with profound changes in business models and technology

The recent emergence of low-cost small satellite technology enabled EO companies to revolutionise their business models, based on near real-time low resolution images, such as those provided by the Dove satellites operated by Planet (formerly PlanetLabs) or the ICEYE radar satellite constellation. Combined with the growing and promising EO market, these low infrastructure cost projects prompted private investment in space ventures, especially in North America, from venture capital funds, private equity firms or non-space angel investors. In addition, the tremendous amount of data generated by EO satellites stands as both a challenge for EO companies and an opportunity for large ICT players, such as Google and Amazon, which are fitted to tackle Big Data issues and willing to cross-fertilise their IT capabilities. PwC considers that stimulating private initiatives on the European EO market, supporting more vertically integrated innovative models, developing user-oriented data access platforms based on new design-thinking approaches and ensuring synergies between EO and ICT are crucial to maintaining a competitive and inspiring European EO sector.

237
Earth Observation satellites in operation in 2015

€7 bn ($7.5 bn)
Global Earth Observation market in 2015

15%
Average annual growth rate of Earth Observation value added services over 2014-2019

Governance trends

Institutional spending on EO programmes has increased over the years and the deployment of Copernicus assets that began in 2014 will intensify. However, national policy differences and a lack of standardisation between frameworks may prove to be an obstacle to the efficient use of EO services.

Technological trends

The use of microsatellite constellations means that new business models can be developed, while payload performances continue to improve.

Commercial off-the-shelf components for satellite manufacturing and miniaturisation are reducing satellite costs.

Business trends

The emergence of private business ventures and new sources of private financing, especially in the United States, should result in riskier projects being pursued. However, the significant amount of EO data will prove challenging for Big Data and efficient data dissemination, as substantial investment will be required to cover the infrastructure costs.

Changes in demand

The demand for EO satellites is growing as markets for applications become increasingly diversified. Furthermore, demand from emerging economies is expanding rapidly. Satellite imagery services could however be challenged by drone-based remote sensing offerings, which could be considered more suitable in certain markets.

Our specialised service offering

Strategy

- Analyses of EO downstream market technology, governance, business and demand trends
- Benchmarking of existing platforms' cloud computing capabilities and user interfaces
- Gap analyses between end-user needs and EO market offerings

Socio-economic impact assessments

- GDP impact assessments of institutional EO programmes
- Assessments of socio-economic benefits on the EO downstream and end-user markets
- Cost-Benefit Analyses (CBA) of EO programmes

Governance & Operations

- Analyses of intermediate and end-user requirements for platforms and data manipulation interfaces
- Diagnoses of data dissemination processes
- Big Data capability requirements and opportunity analyses for EO downstream companies

Regulatory

- Analysis of warranty and liability safeguards embedded in Earth Observation programmes

Selected credentials

PwC has a breadth of both private and public sector experience in EO technology across regions. In particular, PwC has been regularly involved in supporting the European EO flagship programme, Copernicus, since the first satellite entered into service in 2014 with more than 10 dedicated assignments.

Socio-economic impact assessments of the Copernicus programme

PwC was mandated by the European Commission to undertake several targeted impact assessment on the EO downstream and end-user markets, including an ex-post downstream assessment of the market impact of Copernicus along 8 selected value chains, in consultation with more than 100 stakeholders, a large scale ex-ante societal impact assessment of the programme, and a GDP impact of the spending in the Copernicus upstream.

Assessment of the Earth observation market and characterisation of new business models

PwC carried out a characterisation of the EO market for a private investment fund, with expected market evolution, industry dynamics, emerging business models and investment opportunities.

Review of the Big Data vision for Copernicus

PwC defined an approach to facing Big Data challenges and exploiting its potential in the field of public EO data. The results should help the European Commission to develop its vision for the Copernicus dissemination platform.

Other governance and policy studies

PwC was also entrusted with performing the Copernicus programme mid-term review, the assessments of the governance schemes of the Copernicus entrusted entities, and an evaluation of open data policy impacts. Finally, our team carried out a feasibility assessment on two potential new Copernicus products aimed at Ground Motion Monitoring and Cultural Heritage Monitoring.

4

GNSS constellations providing global signals: GPS, Glonass, Galileo and Beidou-2 satellites are being progressively deployed

82

Global and regional navigation satellites in operation in 2018

€ 94.8 bn (~$110 bn)

Estimated global navigation market revenues in 2015

Navigation

Navigation satellites provide positioning and timing data to an ever-expanding user base. Today, they represent one of the most widely used space assets, through navigation and smart-phone terminals or government applications.

A ubiquitous asset in our society, providing safety, performance and leisure capabilities

Today, navigation satellites are omnipresent in our society. They provide information about positions, routes, speed and timing, and are used by an extremely wide range of users in every economic sector, such as precision farming, transport, banking systems, mobile applications, emergency services, etc. Navigation signals are freely emitted by public entities, and their exploitation drives significant economic activity including the manufacture of chipsets and devices, as well as sales of services and applications, which generated global market revenues estimated at €94.8 billion (~$110 billion) in 2015.

Different navigation systems, improving the existing infrastructure

The first Global Navigation Satellite System (GNSS) available for civilian use was the US Global Positioning System (GPS), which is exploited by most of the navigation signal applications commonly used today.

Since then, other GNSS have been deployed, such as the Russian Glonass, the Chinese Beidou-2 (former Compass) and the European Galileo, which is currently ramping up to reach operational capability at the end of the decade.

Other satellite constellations like the Japanese Quasi-Zenith Satellite System (QZSS) and the Indian Regional Navigation Satellite System (IRNSS) provide regional signals. In addition, regional augmentation systems, such as the WAAS in the United States or EGNOS in Europe, are improving the accuracy and reliability of the signal: these are used for demanding applications (e.g., air transportation).

The GNSS market and the legal framework

With the development of GNSS devices and services, providers are exposed to liability risks in terms of privacy, frequency management, or legal responsibility for satellite guided vehicles. Regulations such as the eCall for European cars, combined with the availability of the Galileo Commercial Service (CS) high precision signal, should lead to greater adoption of navigation services.

Pushing for greater accuracy

The development of multi-constellation receivers (compatible with multiple GNSS signals) is expected to result in greater uptake by end users and enhance performance in terms of accuracy and integrity. In addition, navigation signals will have to resist jamming and spoofing threats.

Capitalising on existing markets

Location-Based Services (LBS) and in-vehicle equipment are undergoing significant development, with LBS benefiting from the fast growing apps market. GNSS-enabled businesses (device manufacturers and service providers) are not expected to change greatly in the years to come.

Changes in demand

End-user demand is expected to grow in the years to come, especially for high-precision and indoor positioning. Augmented signals enable cross-market applications such as precision farming, oil and gas exploration or fleet management. Emerging economies represent fast-growing markets with resource management and weather monitoring needs.

Our specialised service offering

Strategy

- Market assessments of critical GNSS component supply chains
- Assessments of market opportunities for regional augmentation system deployment
- Assessments of high-precision signal exploitation business models

Socio-economic impact assessments

- GDP impact assessments of GNSS programmes
- Impact assessments of risks associated with signal spamming and spoofing
- Socio-economic impact of EU navigation activities

Governance & Operations

- Support for critical project and programme recovery
- Organisational and operational efficiency evaluation and optimisation
- System life-cycle assessments and management
- System architecting

Regulatory

- Assessments of regulatory impacts on GNSS markets
- Impact of budget changes on a GNSS programme

Selected credentials

System prime for second generation Galileo satellites

With the implementation of the Galileo Second Generation in 2021 in sight, PwC identified a set of possible prime management options for the development and procurement phases. The recommendations were based on a strengths & weaknesses analysis, development of implementation options, establishment of roadmaps, and estimation of implementation and transition costs.

Evaluation of future GPS disruption for US terminal/system manufacturer

As commercial and military navigation is changing at such a fast pace, our client recognised that its own GPS-enabled navigation systems may be at risk for disruption. PwC Strategy& evaluated the gamut of current and projected changes to future navigation technologies and their potential to disrupt our client's technology, allowing our client to begin positioning itself accordingly.

Market assessment of strategic GNSS components

Given the critical role played by Atomic Frequency Standards (AFS) in GNSS, PwC was mandated by the European Commission to provide policy action recommendations to reduce atomic clock supply chain risks and implement double sourcing for critical Galileo AFS components. PwC conducted several analyses including a technological analysis and a market assessment to provide information for a risk analysis, a GPS case study with US experts, and a gap assessment for the creation of a fully European supply chain.

Market entry for the Middle East/ North Africa

PwC assisted a satellite company in its goals to deploy a satcom and navigation system covering the Middle East and North Africa. We evaluated market conditions and technical and procurement requirements.

Spacefaring nations support their domestic launch sector to guarantee independent access to space. In an increasingly competitive global market, spacefaring nations need to adapt the economic model of their launcher industry in order to remain competitive.

Launchers

Strategic assets for spacefaring nations

Independent access to space not only depends on being autonomous in terms of technology and infrastructure (i.e., the industrial base and spaceports). With new market entrants increasing competition on launch costs, independent access to space is now also dependent on the economic sustainability of the launch sector.

New industrial setups and practices, as well as modularity or innovative technologies, such as micro-launchers and reusable rockets, will drive the competitiveness of the launch sector.

Growing competition on the open launch market

Competition in the launch sector has traditionally been between fully or partially state-owned industries. As the delivery of certain payloads is important to the national security of launching countries, a significant part of launch services is not open to private companies. On the open market, newly created private companies and non-historical spacefaring nations have been disrupting the established norms. As a result of the increasing competition, spacefaring nations have promoted their domestic launch systems through dedicated policies and measures, and also pushed their national companies to improve or develop new launch vehicles.

Number of launch events for major spacefaring nations between 2011 and 2017

€8 bn ($8.6 bn)

Global launch services market in 2017

Innovation as a strategic advantage

Launcher integrators and launch service providers are aiming at expanding their scope of activities through innovation and vertical and horizontal integration. Technological innovations, such as partial or full launcher reusability, methane propulsion or additive layer manufacturing, are expected to bring a strategic advantage on the launch market. In addition, business model innovations, such as sharing the risks of satellite launches with operators, are also being reviewed by launch companies.

Launch companies need to increase their customer base

Despite being subsidised by governments due to its strategic importance, the launch sector is expected to face stable or declining government financing for flagship space programmes. As a consequence, launch companies will have to evolve and examine new markets. Historical launcher manufacturers and their associated service providers are considering new kinds of services, such as using micro-launchers for the flexible delivery of small satellites deployed as part of large satellite constellation programmes.

Our specialised service offering

Strategy

- Revenue projections of global competitors
- Customer surveys on LSP selection factors
- Analysis of the market potential of micro-launchers
- Analysis of diversification strategies for launch vehicle manufacturers

Socio-economic impact assessments

- Impact assessments of new satellites players on the launch services market
- Scenario analyses of the market impact of reusable launchers

Governance & Operations

- Analysis of the governance between public and private actors to maximize competitiveness of launcher operations
- Definition of levers to foster collaboration between scientific and industrial communities
- Analyses of investor satisfaction in scientific and human spaceflight programmes
- Elaboration of an integrated supply chain interfacing with external suppliers
- Deployment support for «digital twin» approaches to provide real-time monitoring of production assets and launch infrastructure

Selected credentials

Benchmarking of the major space nations' launch capabilities and policies

PwC was mandated by the European Commission to perform benchmarking on the policies of major spacefaring nations and their impact on their launch capabilities, their industrial landscape, and national and global launch markets. The analysis included an assessment of the launch market and a high-level forecast using identified trends and their impact on supply and demand. An analysis of the governance and cost structures of global launch systems was also performed. Using our results, we were able to provide the European Commission with strategic recommendations for the definition of the European launcher space strategy. Those recommendations were later assessed through a socio-economic impact assessment.

Socio-economic impact assessment of Ariane5 and Vega programmes

PwC assessed the GDP impact of European Space Agency investments in Ariane5 and Vega launch activities. Social and non-quantifiable benefits associated with the programmes were extrapolated using in-depth analyses of the launcher supply chains, and the European launch operation capabilities.

Market adjacency strategy for leading US launch system manufacturers and launch providers

PwC Strategy& has supported the full value chain of the launch industry, from inorganic strategies in rocket components to strategic positioning for propulsion and cost takeout for launch services.

Global launch market forecast for European rocket propellant provider and space hardware manufacturer

Our team assisted a large rocket propellant provider in identifying emerging markets and opportunities for the development of their business worldwide including launch sand test sites. PwC also identified potential opportunities for the development of launch vehicle sub systems.

18,300

Estimated number of debris larger than 10cm orbiting in Low Earth Orbit. These debris can cause critical damage to any kind of spacecraft.

5

Number of Member States (FR, DE, ES, UK, IT) composing the European Union SST Consortium which pools national surveillance and tracking capabilities.

$1.6 bn (€1.3 bn)

Estimated cost of the American Space Fence surveillance system operational in 2019 and capable of tracking objects of 1cm in LEO regime.

Space Situational Awareness

Space Situational Awareness (SSA) refers to the capability of detecting and tracking man-made and natural threats, predicting and assessing the risks involved, and providing services enabling the implementation of appropriate mitigation measures aiming at protecting space and ground assets.

A threefold activity

The use of space has helped enhance the global economy, provide social benefits, support environmental protection activities and ensure strategic sovereignty. Therefore, many sectors and activities rely on the protection of space assets against threats such as man-made space objects, space weather events and near-Earth objects. To mitigate these threats, three solutions have been instigated through sub-programmes. Space Surveillance and Tracking (SST) is the monitoring, cataloguing and analysis of changes in space objects. Space Weather (SWE) activities encompass the study and analysis of the activities of the Sun and its effects on solar wind, as well as Earth's magnetosphere, ionosphere, and neutral atmosphere. Near Earth Objects (NEO) activities have the purpose of observing, cataloguing and anticipating changes in natural objects in the solar system that might cross paths with Earth.

An international network of capabilities

SSA architecture involves a set of nationally owned sensors, such as radars, telescopes and laser stations as well as space-based assets in the case of the US. These are used to detect and track space objects, solar events and NEOs, and provide key data to SSA data centres, where it is analysed by specialists. The data is channelled into providing essential services, such as conjunction assessment warnings, re-entry warnings and fragmentation analysis in the case of SST, which is utilised mainly by satellite operators and other civil protection and industry users. Even though SSA assets are owned and operated at national level, international cooperation reinforces the delivery of reliable and timely SSA services. As such, the EU and its Member States are developing a network of SST assets aiming to enhance European SST capabilities and contribute at a global level to the protection of space assets. The network is completed by strong cooperation with the United States, which provides a substantial volume of SST data.

Increased need for observation capabilities

Even though best practices aiming at limiting the creation of additional space debris are encouraged among the global space community, the debris population is expected to increase due to an upsurge of space activities in the coming years with the potential deployment of mega-constellations primarily instigated by commercial players who benefit from cheaper and simplified access to space solutions. This trend testifies to the fact that traditional barriers to entry, which are specific to the space sector, are being diminished, opening the sector to new entrants which are not necessarily aware and sensitive to debris release mitigation best practices.

Strategic importance of SSA activities

The purpose of SST sensors is to observe and track all types of space objects orbiting around Earth. As such, SST capabilities play a dual role by tracking passive threats such as debris and by observing operated space objects that can act in an aggressive or unfriendly manner. Furthermore, in order to limit the spread of debris, the regulation measures must be reinforced and their effective application must be controlled and verified. In that sense, SST sensors enable better knowledge of the nature and origin of space debris and can be used as a tool to support the enforcement of mitigation measures.

Emergence of a commercial market

It appears that several private entities have developed their own network of capabilities to provide SST services. However, the security and defense nature of space surveillance is a persistent concern and prevents private entities from entirely leading SST activities without the support, partnership and cooperation of public players. A sound development of future SST capabilities addressing space traffic management issues must be based on a relevant ecosystem and governance structure, ensuring service precision and efficiency, international cooperation and a thorough data policy.

Our specialised service offering

Strategy

- Assessments of market opportunities for the deployment of Surveillance and Tracking solutions
- Forecast of changes in space traffic
- Revenue projection for commercial use surveillance and tracking radar systems

Socio-economic impact assessments

- Identification and assessment of impacts resulting from the evolution of the European and global SSA landscape
- Assessment of costs and benefits implied by the implementation of a Space Situational Awareness programme

Governance & Operations

- Support to the design and characterisation of potential programme governance structures
- Evaluation of organisational and operational efficiency
- System architecting

Regulatory

- Support to the definition of data policy linked to the use space surveillance information

Selected credentials

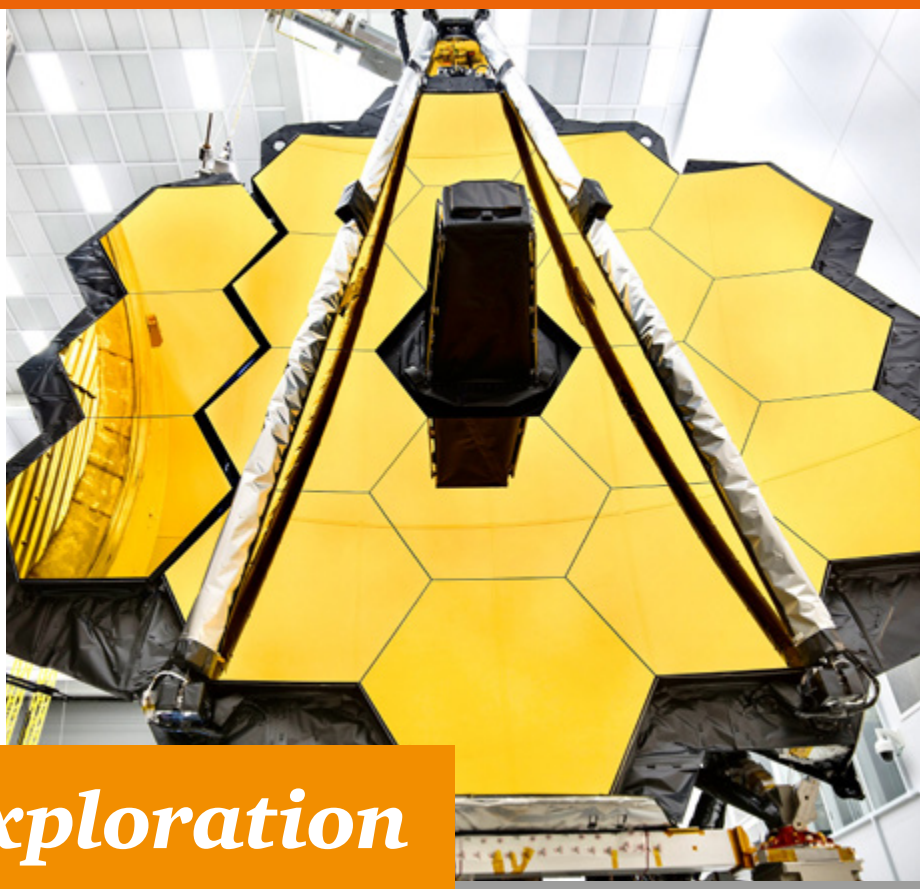
Ex-ante cost benefit analysis of the ESA SSA programme

The PwC space team has exhaustively assessed the impacts and benefits linked to the three areas of the European Space Agency (ESA) Space Situational Awareness programme: Space Weather, Near Earth Objects and Space Surveillance tracking. Through a cost-benefit analysis approach, the impacts and threats of a scenario in which no action is taken in the field of SSA were quantified and analysed. The results of this analysis led to the identification and understanding of key strategic aspects to take into consideration for the evolution of the SSA programme.

Study on the impacts of the EU space surveillance and tracking actions in the Space Strategy for Europe

In line with the focus of the Space Strategy for Europe, PwC has provided the European Commission with a study supporting the preparation of the decision-making process on the future of SSA activities at EU level. The study was designed to (i) evaluate the state of play in SSA at a global level, (ii) identify the full scope of impacts and benefits resulting from the set of potential development options at EU-programme level taken into account in the definition of the 2021-2027 Multi-Annual Financial Framework and (iii) provide a robust and clear comparative analysis of these options.

Human presence in space was made possible by extraordinary technological and scientific advances: material and physical science, propulsion, and much more.



Space exploration

20
Number of international partners contributing to the James Webb Telescope

€100 bn ($107 bn)
Cost of the International Space Station including development, assembly and running costs over 10 years

€3 bn ($3.2 bn)
Global science spacecraft market value in 2015 (includes satellites, interplanetary probes and resupply vehicles)

Science in space and international collaboration

Space exploration beyond Earth's orbit, including research into solar system formation and the search for Earth-like planets and exoplanets, leads to a better understanding of how our universe was formed and of fundamental scientific principles. National or regional initiatives like the Curiosity Rover or the European Extremely Large Telescope have already emerged. However, international collaboration is increasingly indispensable to sustain scientific programmes, for technological and economic reasons: ESA partnered with NASA for Jason and with ROSCOMOS for ExoMars; the US Orion spacecraft uses a service module from the European ATV; and the James Webb Telescope, designed to replace Hubble, involves 20 countries.

Suborbital flights

Suborbital flights are expected to travel at an altitude of around 100 km above sea level (Karman line). Though several private companies such as Virgin Galactic (VSS) or Blue Origin (New Shepard capsule) are currently testing suborbital flight vehicles, no inhabited flights (apart from SpaceShip 1, winner of the Ansari Prize in 2004) have yet been made. This technology looks promising, both to enable scientific experiments in microgravity and for space tourism. Legislative changes are currently being made in order to ensure the seamless introduction of these new methods.

Privatisation of the ISS

First launched into orbit in the late 2000s, five leading space agencies NASA, ROSCOSMOS, JAXA, ESA and CSA have invested more than €100bn in the ISS. Serving as a microgravity laboratory, the ISS has been the venue for experiments in biology, physics and astronomy. However, the private sector is gradually taking over the ownership and managing role of the station, previously the domain of space agencies. Certain activities have already been outsourced and new commercial activities are emerging: inflatable space habitats (Bigelow), deployment of cubesats (NanoRacks), hosting of external payloads (Bartholomeo), space manufacturing (Made in Space), etc. As the ISS is expected to retire by 2024-2028, the opportunities for private players to invest in this project are expanding.

Gradual involvement of commercial players and PPP

Exploration missions and space outpost maintenance are very expensive, and space agencies alone struggle to finance all their scientific programmes. Commercial players can thus be valuable partners to share investments and risks. Current potential opportunities for these types of synergies include the development of commercial space habitats under NASA's NextSTEP programme, the construction of infrastructure in microgravity, partnerships to be the first customers of commercial missions and, more generally, the allocation of competitive grants for the industry to develop equipment.

The Moon as a gateway for Deep Space exploration

The global space exploration roadmap shared by worldwide space agencies envisions ambitious missions to the Moon and Mars as the next steps. The Earth's gravity well raises strong space mechanics barriers, making these missions extremely expensive and challenging. The Lunar Orbit Platform Gateway, often presented as the "next ISS", would allow the agencies to overcome this challenge. In addition to being a science driver, it represents a new opportunity for global cooperation on an endeavour that will benefit all humankind.

Use of Space resources

The development of exploration activities will require more and more equipment to be transported, with strong constraints on mission feasibility in terms of both engineering and cost. The use of in-situ resources (volatiles and solids) for propellant and infrastructure manufacturing will be key to the success of this endeavour, with the first step being the enhancement of our knowledge of the elements available on the Moon and near-Earth asteroids, followed by the development of the necessary mining and processing technologies.

Our specialised service offering

Strategy

- Business case assessment and revenue projection for commercial exploitation of space stations
- Gap analysis and identification of market barriers for ISRU value chains
- Definition of technology roadmaps for future space exploration missions

Socio-economic impact assessments

- Assessment of market spillovers and technology spin-offs from ISRU development
- Impact assessment for Moon exploration programme and Global Exploration Roadmap

Governance & Operations

- Analyses of investor satisfaction in human spaceflight programmes
- Requirement and configuration management for multi-agency exploration programmes
- Definition of roadmap for additive manufacturing in micro and partial gravity environments

Regulatory

- Analysis of the legal framework for space mining

Selected credentials

Study on potential future markets and value chains of Space Resource Utilisation (SRU)

This study was undertaken to identify potential future markets and value chains associated with the exploitation of space resources. We examined the main challenges and gaps relating to knowledge of resources, sizing of demand, mission architectures and costs, as well as the relevant technologies. Our analysis covered each stage of the value chain, from prospection to mining, processing and manufacturing, with a timeframe extending up to 2040. It provided the Government of Luxembourg with an exhaustive picture of the areas that could benefit from public support and a quantification of the associated socio-economic benefits.

Socio-economic review of ESA's participation in the ISS programme

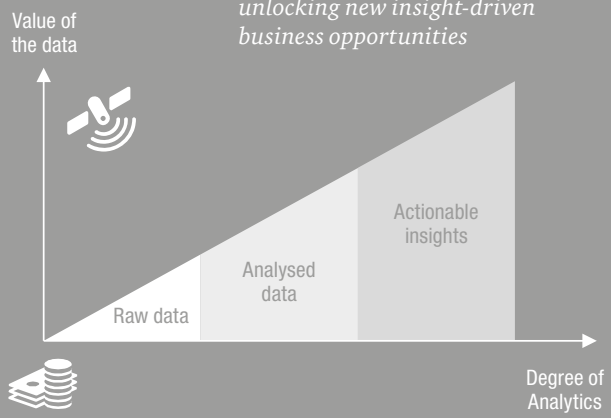
On behalf of ESA, PwC analysed the impact of ESA's investment in the ISS and the possible impacts of disengagement. A large-scale economic impact assessment was performed using ESA's data. Using the data derived from this assessment, we then created an economic model to produce GDP multipliers. We also conducted an assessment of the catalytic impacts and wider benefits for Member States, with different categories including space technology, fundamental and applied research, international cooperation and inspiration.

Ex-ante socio-economic assessment of ESA's new partnership proposals for space exploration

In the context of its position as a business partner to select private sector initiatives in the field of space exploration, ESA asked PwC to assess partnership proposals covering a wide range of topics including use of the ISS, exploitation of LEO and lunar exploration. We began by assessing the expected economic impact, to provide a high level review of the proposed business plans, and continued by evaluating major components used in negotiations (business model, financials). PwC also provided an ex-ante socio-economic impact assessment addressing wider impacts.

Insights from Space

The increasing availability of data gathered from space assets, coupled with advancements in cloud computing, automated analytics and data fusion, is unlocking new insight-driven business opportunities



Cross-domain integrated applications

Space industry stakeholders are realising that the value of their space assets lies not in the data but rather in the insights and value-added services derived from that data.

The Space value chain is becoming increasingly service-oriented

The traditional view of the space value chain – with a clear line between upstream and downstream – is rapidly evolving towards an integrated, service-oriented model. In domains like Earth Observation (EO), new entrants and incumbents at the upstream end of the chain are extending their reach towards service delivery, realising the value creation potential to be derived from full control of a customer-driven integrated offer.

The possibilities offered by the commoditisation of cloud storage and cloud computing services, together with advancements in data analytics and data fusion, will lead to enhanced exploitation of space-based data, towards cross-domain applications targeting a much larger user base than ever before.

Convergence of market dynamics

Cloud services from providers such as Amazon Web Services (AWS) offer high capacity storage and high performance computing on platforms at low cost, lowering significantly the barrier to entry for space-data exploitation. This, coupled with advancements in data analytics and data fusion, have effectively integrated the small and specialised space imagery-based market into the wider Big Data economy, offering unprecedented growth opportunities.

These opportunities are linked to customer-driven, use case-based cross-domain digital applications in a multitude of downstream sectors and target users not necessarily savvy about space and its potential, but with well defined needs in terms of insights and/or specific services.

New digital business models originating from EO

The delivery of new digital services requires ad-hoc business models and go-to-market approaches that break away from the conventional business models adopted so far in the space downstream.

With Big Data tools expected to become more and more commoditised and ubiquitous and access to data expected to become easier and cheaper for both open and commercial data, the main differentiators of market success will be the customer-centric, use case-driven application design approach and the business model associated with service delivery.

New opportunities for space and non-space companies

The disruption experienced in space data exploitation requires incumbents in the sector to adapt quickly while at the same time offering opportunities to established players, NewSpace companies and non-space companies with a reach in data exploitation.

A pull approach in service delivery

With the enabling capacity of the cloud, it's clear that the full potential of space data exploitation has yet to materialise from a market perspective. To fulfil this potential, a customer-driven, pull approach in service delivery has to replace the traditional push approach, by directly linking user needs and pain points to application development and delivery.

Our specialised service offering

In association with PwC Advanced Solutions Development, the PwC Space practice has pioneered the user-driven design of space-based digital services and definition of the associated business model

- Exploitation of space data to support decision-making through actionable insights based on advanced analytics and data fusion
- Analysis of portfolio and identification of data-driven business models
- Agile development of proof of concept of data-driven products and services leveraging on open-source components
- Audit and optimisation of big data pipeline of public and private organisations and optimisations
- Development of on-demand workspaces for data experts

Selected credentials

In the last 10 years, we have worked on more than 20 assignments directly related to satellite imagery and GIS data worldwide, covering the subject of the exploitation of space data from all angles. This has put us in good stead in terms of identifying new market dynamics and of effectively supporting our clients in the transformation of their digital offers.

Development of business models, positioning and go-to market for the new digital offer for a leader in the Defence & Space industry

The PwC Space Practice had conducted a comprehensive project on new digital business models related to large scale data fusion and automated analytics involving image intelligence and other sources of intelligence. The key differentiator for PwC was the unique integrated business, technical and legal expertise in geospatial, multi-intelligence, machine-learning and automated analytics. The project led to the development of a new offer and an associated go-to-market strategy for the client.

Feasibility study for a Nutrient Management Planning and Farm Sustainability Tool

PwC was contracted to develop a feasibility study related to the development and the implementation of a Nutrient Management Plan (NMP) tool at European Union level. This tool should be implemented in the next Common Agricultural Policy as an advisory support for farmers. The team analysed the global landscape of existing NMP initiatives, looking at both public and private initiatives, in order to assess the minimum viable features required to have a sustainable NMP tool for European Union Member States, and has at the same time produced a working technical demonstrator for the main features of the tool.

Building Big Data capabilities for a leader in agronomy and satellite remote sensing

The PwC Advanced Solutions Development team supported a major player in agronomy and remote sensing to assess the viability and maturity of Big Data technologies for its present and future business, anticipating the massive growth in data due to higher resolution sensors, new satellite missions and use of drones. Through a full audit, optimisation of the client's existing capabilities and a series of proofs of concept, PwC showed how Big Data technologies could support companies in on-demand insight for data-driven agriculture.

Reimagining Georgia's capital with data analytics and 3D

The Georgian city of Tbilisi sought to develop under-utilised land by engaging in major infrastructural changes for the benefit of the city through economic and touristic developments. Analysts from the PwC GeoAnalytics team combined hundreds of data components to pinpoint the optimal location of new tourist, hospitality, sporting and retail facilities, creating a comprehensive masterplan covering the construction of dozens of different initiatives across the Tbilisi Sea area, all with minimal environmental impact and offering a reasonable rate of return to investors.

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About the PwC Network

At PwC, our purpose is to build trust in society and solve important problems. We're a network of firms in 157 countries with more than 236,000 people who are committed to delivering the highest quality solutions.

About the PwC Space Practice

The PwC Space Practice is part of PwC Advisory and fully dedicated to the space sector. The core team based in Paris includes specialised professionals supported by additional contacts handling space consulting across the global PwC network.

Our expertise covers the entire space sector and spans the value chain, from upstream to downstream. We help entities, public and private, face their business, technological and governance challenges in constantly changing environments.