HTSM Roadmap Space 2020

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PREFACE

Space technology provides unique solutions to many societal challenges and is of increasing economic relevance. This roadmap provides the framework for R&D in the Netherlands in the area of advanced space technologies and space applications. In the high-tech, innovative space ecosystem, companies, knowledge institutes and government closely cooperate, which is key to success. The commercial market for space technologies and space applications witnesses an impressive uptake (although the effects of the COVID-19 crisis will most probably lead to a temporary setback), providing new opportunities for the Netherlands. International cooperation, specifically in Europe, is a key element of this roadmap, through ESA's programmes, the EU flagship programmes Copernicus and Galileo, the European Horizon Europe programme and through the European Defence Fund (EDF). Participation in these programs is of vital importance for a level playing field for the development of strategic technology in the dynamic international scene. Space is a critical enabler for innovation in many economical, scientific and societal fields of application and, as such, is a cross-sectorial activity in the 'Top sectors' of the Netherlands.

***Membership of ESA** is a key enabler for European collaboration and crucial for the presence of ESA's largest site (ESTEC) in the Netherlands. A continued loyal Dutch participation in the European Space Agency (ESA) is a prerequisite for competitiveness as it ensures the qualification of new technologies and products for the growing international markets. R&D through the ESA programme is a significant and essential part of this roadmap.*

Figure 1 Sentinel 5P / Tropomi products - Courtesy SRON

SOCIETAL CHALLENGES AND ECONOMIC RELEVANCE

Societal challenges

Space infrastructure is increasingly strategic and critical to economic growth. First of all the space infrastructure is part of vital processes nowadays since many applications in society depend on the continued availability of space infrastructure. Space infrastructure and space applications are enablers of solutions for many key societal challenges. Current space technology provides an understanding of the atmosphere better than ever before, gives unprecedented navigation capabilities and allows us to communicate with each other from any place on the world. Our growing economic dependence on space assets makes their protection against external threats an important new topic.

Space innovation contributes directly to four of the five major HTSM themes i.e. Climate, Sustainability, Security and Mobility. Space technology is essential for solving these challenges and consequently the use of space is one of the programmes in the **Knowledge and Innovation Agenda (KIA) "Sleuteltechnologieën"** and an enabling technology in others**.**

Space technology is invaluable for monitoring the state of "Spaceship Earth" in support of the **Sustainable Development Goals**. The pursuit of these goals will create a market for space-based solutions linked to the new data-ecosystem applying Big Data and Artificial Intelligence (AI), Big Science in an international setting and will lead to an expansion of commercial space initiatives ("New Space").

The national ambition in the **KIA "Veiligheid"** aims for an operational Dutch space capacity by 2030 that includes robust position, navigation and time-services (PNT), Space Situational Awareness (SSA), intelligence from space sensors, secure broadband communication and a national satellite capability.

Our national space policy (2019) has a clear connection with various societal challenges identified as well as with national innovation themes (energy & sustainability, agriculture & food & water, health, safety & security). In addition, this policy addresses the relevance of space, and especially space-based instruments, for science as part of the national agenda for science (Nationale Wetenschapsagenda, NWA)

Economic relevance

In 2018, the **world space economy** totalled around $380 billion for all countries and private enterprises combined. The forecast for the coming decades shows significant growth; many economists and private experts put the size of the space economy at $2 to $3 trillion in the next three decades. Satellite-related industry use takes up about 77% of the space economy ($ 277.4 billion). This number includes satellite manufacturing (around $19,5 billion), the launch industry (around $6,2 billion), satellite services - which represent the largest part of the space economy -

totalling almost $126,5 billion in 2018, closely followed by satellite-related ground equipment and devices ($125 billion). This is complemented by the non-industrial activities of national and intergovernmental space agencies (around $82,5 billion).[1] ,[2]

In the global space market, **institutional actors** (state agencies) provide the majority of funding in important areas, such as defence, science and space exploration. At the same time, private companies play an increasing and significant role. Especially in Europe and the US, state agencies collaborate with private industry in **public-private partnerships** to develop new technology, programmes and missions, a trend which is also developing in Japan, China and India where new space and privatisation of space industry is actively promoted. The private sector also develops private (commercial) activities, such as private satellite manufacturing and ownership (telecom, earth observation and tracking); private rocket development and satellite launch capabilities.

Dutch companies provide products and services as part of a generally **international value chain**, in the context of European and global developments in the institutional and commercial space market.

Finally, space programmes **drive technology and create spin-off**, enabled by the Top Sectors. Many technologies originally developed for specific space missions have found their way into other application domains, such as semiconductor equipment, security, industrial automation, aviation and medical technology. Many more space technologies offer similar potential. Since 2004 the ESA BIC Noordwijk program has supported around 8 start-ups per year which aim to use space-technology or data in non-space markets. The NL Space Campus in Noordwijk is developing a platform, with funding options to support these activities.

Furthermore, space is a huge source of inspiration for children and students to start a career in Science, Technology, Engineering and Mathematics.

Competitive position of the NL space ecosystem

A sustained policy of stimulating science and technology has created a well-developed Dutch space sector with strong, internationally recognised qualities. Intensifying these efforts can give the space sector a big push in the strongly growing commercial market of space systems and applications. In this context, we strongly recommend a NL contribution to ESA's optional programmes on par with the relevance of our space sector and the space infrastructure for our national economy. The current level of subscription in these programmes (1.5% at ESA's Ministerial Conference 2019 as opposed to an expected level of 4.6% based on our GDP) seriously hampers the realisation of the potential of the NL space sector and even endangers some of its previously established roles.

The space sector in the Netherlands currently generates a turnover of about €600 million. The Dutch space sector directly employs some 4000 – highly skilled – knowledge workers[3]. On top of that, ESA-

[1] source '2018 Global Space economy' and '2019 State of the Satellite Industry', by Bryce and Technology

[2] at the time of writing, the COVID-19 crisis already shows serious economic effects, also on the space industry. Eurospace estimates (June 2020) a reduction of 1.2 B€ in sales in 2020 and 1.7 € in order backlog in European Space Industry. It is not clear yet, whether we are confronted with a temporary decline or whether the effects will be more serious and persistent. It is clear however, that especially the need for space-based solutions such as secure digital communication is growing to a next level during this pandemic. This may also accelerate the pace of R&D in Space Systems.

[3] (in Dutch) Verkenning naar maatschappelijke kosten en baten van Ruimtevaart en het ruimtevaartbeleid, Dialogic / Decisio i.o.v het ministerie van Economische Zaken, april 2016. These numbers include indirect economic revenue of suppliers to space projects and of direct use of space systems. The investments presented in this roadmap are directed at space in the strict sense. A new evaluation is needed to re-estalish the size and growth of the space sector in its different segments.

ESTEC in Noordwijk is one of the largest R&D organizations in the Netherlands with around 3000 international experts of which 50% permanent staff.

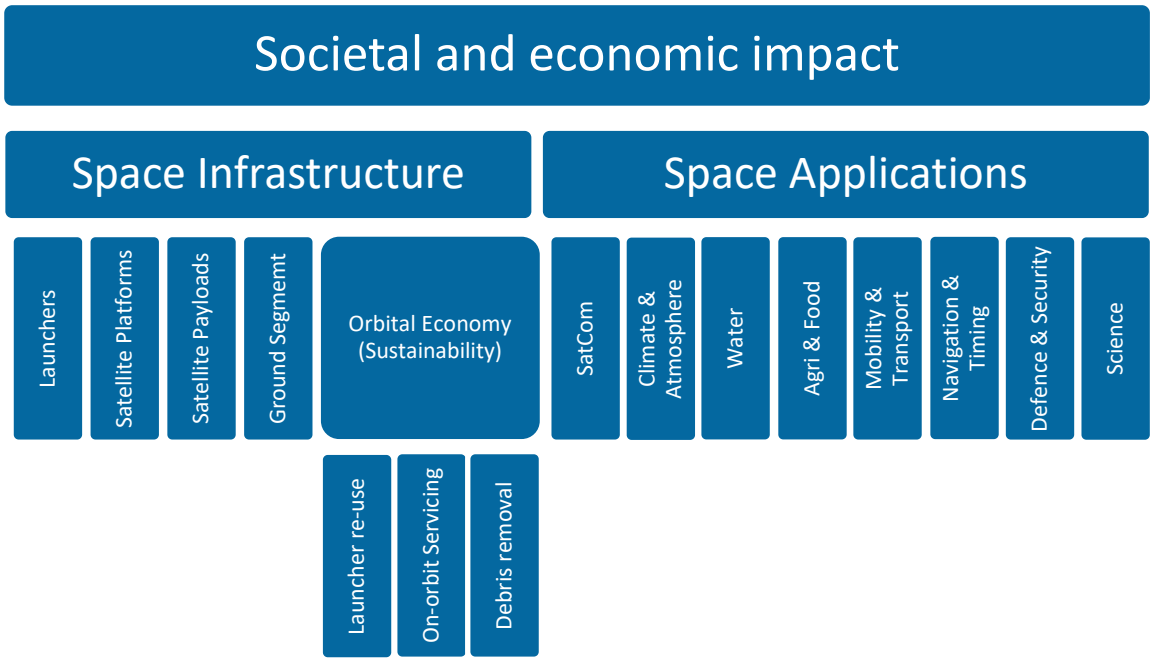
The Dutch space ecosystem is a strongly **interlinked network** of businesses (many of them SMEs and start-ups), knowledge institutes, schools and universities. It has achieved **scientific top positions** in domains such as astronomy and air quality & climate research, both in the field of instrument design and manufacturing and in applications and science. The resulting expertise is relevant to European developments, such as Copernicus and Galileo. The network and the high quality of academia and education provide a solid **foundation for innovation.** This attracts foreign investments as well. The space programmes driven by ESA-ESTEC and the space institutes provide an excellent basis to monetize on the **available know-how** and grow the **commercial space activities** both on space infrastructure (e.g. launchers, satellites and instruments for use in space) and space-based applications (e.g. satellite navigation, weather forecasting and monitoring methane emissions). The NL space sector aims at strong (double-digit) growth of commercial space activities.

Benefiting from the presence of ESA-ESTEC and a new International Meeting Facility (IMF) at ESA-ESTEC the NL Space Campus in Noordwijk will be a new meeting point for the international space sector. The Campus is one of the results of actions from the 2012 White Paper on ESA-ESTEC issued by the HTSM Top Team.

APPLICATIONS AND TECHNOLOGIES

State of the art review (industry and science)

The picture below schematizes areas of space technologies and applications.



The Dutch space sector has developed strong positions in various space value chains:

Space-borne instruments provide invaluable data for the big questions regarding **climate change and air quality**, feed applications for monitoring our efforts on these topics and allow for the global measurement of the effects of implemented mitigating measures. Building on a strong national effort in the past, the Netherlands now have a world-class position and are further developing atmospheric monitoring technology.

Food and food security are addressed through the Dutch participation in the Copernicus Programme and the EU's and ESA's associated R&D programme. Dedicated developments lead to the provision of value-added services in selected domains, such as soil moisture mapping and land surface temperature mapping from space, building on data generated by the fleet of Copernicus satellites and adding to it. Space infrastructure and space applications are indispensable for risk management in global food production and food security by providing independent monitoring available to all stakeholders in the food production chain.

Water and water quality is primarily addressed through participation in the EU's Copernicus programme for infrastructure through services on water quality. Space-borne sensors provide daily mapping of coastal structures, inundation and surface water quality on a global scale.

Mobility and transport in the air, road and maritime domains are supported by a broad spectrum of space-based systems and services, including satellite navigation, satellite communication and satellite-based earth observation. The European global navigation satellite system Galileo provides **secure and accurate navigation and timing**. The European GNSS Agency (GSA) that is responsible for

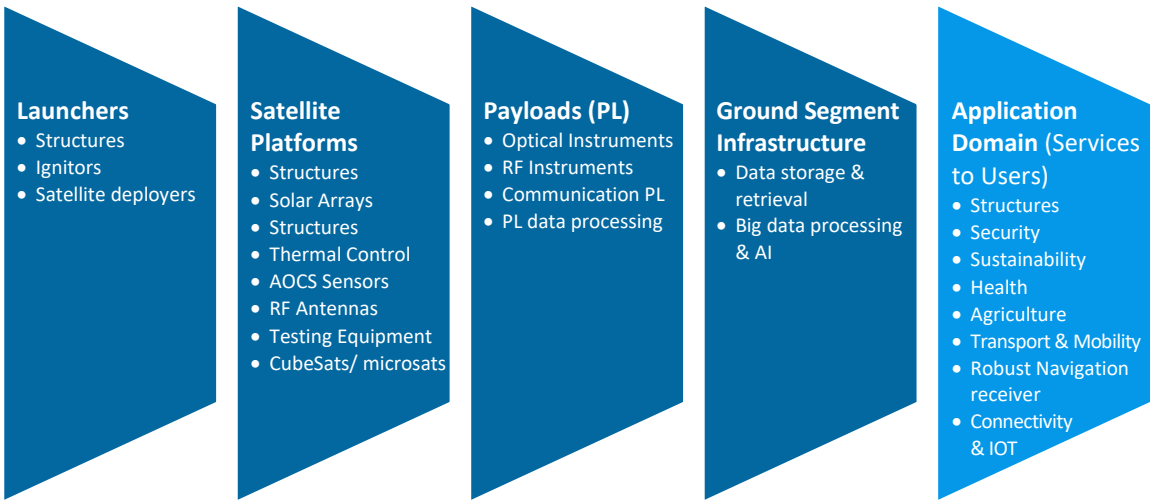
operation of the Galileo infrastructure is embarking on an ambitious investment program to boost the development of Galileo end user applications both for civil and military use which will drive growth in the EU. Space infrastructure and space applications are fully embedded in virtually all forms of transportation. They are essential for the use of systems all across the globe and key for the development of autonomous transport systems. The knowledge base on satellite navigation and timing technologies available in The Netherlands will stimulate and monetize on the trend towards autonomous transport applications and to make them operational in our society.

Next generation space infrastructure will provide essential services such as **secure broadband communication** using optical links and quantum key distribution with communication coverage in remote areas. In this domain, the development of NL technology is (still) ahead of global competitors, and programmes are being set up (together with European partners) to stay ahead of the competition with the prospect of building a multi-billion industry in The Netherlands.

Satellites provide a broad range of **monitoring and observation** capabilities using different sensing technologies across the electromagnetic spectrum. Space infrastructure and space applications are essential for making today's data-driven society reliable and secure.

Space is becoming an integral part of an information-driven **defence & security** approach. Netherlands defence & security space applications are reaching the in-orbit demonstration and validation stage for self-operated space infrastructure. Space can provide unique and valuable information, but also situational awareness of the space segment is key for this domain, as are position, navigation & time (PNT), and secure communication. NL maintains a solid knowledge base to act smart and exploit its technological position in this growing space application domain.

Scientific Instruments carried by satellites are fundamentally changing our knowledge of the Earth, our solar system and the universe. Space systems allow us to leave the Earth and explore the universe across the full electromagnetic spectrum, not hampered by the Earth's atmosphere, or to do measurements only possible from space such as the accurate determination of the Earth's gravity field or the detection of gravitational waves. New technologies developed for science create a backbone for commercial success in the space arena and beyond, today and in the future.
The Dutch space sector holds a number of strong positions in the market for **space infrastructure**, shown in the figure below. Technological innovations are essential in order to maintain a competitive role as supplier of systems, subsystems and/or components in the European and global space market as well as in the data-driven applications market.



The Technology Roadmaps established by SpaceNed and the Netherlands Space Office (NSO) describe the various product groups and associated technologies in more detail. These roadmaps are maintained and updated on a regular basis, in line with developments in the market i.e. both the institutional (ESA, EU) and commercial market.

Developments in present and future markets and societal themes

Applications build on both space and non-space technologies. Innovations in AI and Big Data Analytics enable new space-based services to user communities as well as new ways of operating and maintaining space Infrastructure.

Advances in miniaturisation and components make small satellites more powerful. The small satellite market (satellites in the range of 1 to 500 kg) is growing fast. In 2019, 79% of the 492 satellites launched[4] were smallsats, a 300% increase with respect to 2016. Within this segment, The Netherlands focuses on so-called CubeSats, quite small satellites (with a weight typically less than 25 kilograms) which represent about half the number of smallsats launched[5]. Today, the market size for smallsats is relatively modest (about 1% of the total value) at around $3.3 billion and is expected to grow with at least a 14% Compound Annual Growth Rate (CAGR) for the next decade. The forecast of the global market for small satellites shows a growth to $8.5 billion by 2025[6] (of which around $1.0 billion for the sub-segment of CubeSats, growing from an estimated market size of $364 million in 2016[7]).

Europe will continue to expand the Copernicus system for Earth Observation with new missions and with performance upgrades of existing satellites. The Galileo system will be fully deployed in 2020/2021 and will further develop with improved and additional services to the user (i.e Galileo Second Generation). Financed through ESA and through the EU, this provides a basis for further expansion of Dutch capabilities.

In the area of remote sensing governments study hybrid architectures of high-end space systems augmented with small satellite solutions that fill in specific gaps in the data streams or enhance existing data sets. ESA is studying various new remote sensing concepts within the Future Earth Observation programme element, most of which feature miniaturized instruments integrated in small satellite systems to work in conjunction with the next generation of large space systems within the Copernicus programme. In the area of security and defence, a similar hybrid trend is visible where the governments are both looking to deploy the next generation of large-scale space systems as well as enhancing these backbone systems with novel small satellite architectures that are more agile in deployment. Within the US, the Blackjack programme is the most prominent of such initiatives, where networks of small satellites partially replace large space systems for ballistic missile warning systems.

A large amount of new initiatives disrupts the satcom market, vying for new mobile broadband satcom business (e.g. aviation and international voyages by ship). Traditional fixed satellite services are under pressure from regulatory change and competition from terrestrial alternatives. New

[4] Source: '2019 Orbital Launches – Year in Review", by Bryce Space and Technology
[5] Source: 'Smallsats by the Numbers – 2020', by Bryce Space and Technology
[6] Source: 'Global Small Satellite Market: Analysis and Forecast, 2019-2030', by BIS Research
[7] Source: 'Global CubeSat Market: Analysis and Forecast, 2018-2022', by BIS Research

satcom solutions are emerging, such as low earth orbit constellations to provide 'internet in the sky'. A broad array of parties is involved, ranging from disruptive players like SpaceX and Blue Origin to the incumbents Intelsat and SES and start-ups like LeoSat and OneWeb. The space-based IoT services company Hiber became a Dutch National Icon in innovation in 2019 starting initial services for early customers and ViaSat secured spectrum in the Netherlands for broadband services from low earth orbit. Free-space optical satcom solutions will provide secure broadband communication through space. Due to the crowded market place, the impact of Covid-19 and the limited spectrum available, a significant consolidation will take place in this market segment in the coming years.

In the Netherlands, such private initiatives start to take hold, basing their commercial activities on the decades of expertise, experience and technology developed largely for the institutional programmes. New telecommunication companies have established themselves in the Netherlands and various companies (established companies as well as start-ups and scale-ups) are beginning promising new remote sensing and telecommunications services.

In addition, the government is consolidating its views on the need for space data and services and providing valuable inputs for the short term and long-term needs with which the industry can work towards new solutions. The domain of defence and security is a particularly good example where initial pilot projects have started in the Netherlands and a national space strategy for defence and security is expected early 2021.

The next generation of European Launchers, Ariane 6 and VEGA-C will fly in 2021 and guarantee European access to space. Europe needs further technological evolution and reduction of cost to compete with Space-X and with launch services from Russia, India and China. A number of companies is expanding their position in the commercial rocket segment with new technology investments including the development of small lauchers (e.g RocketLab, PLD Space).

Europe cooperates with NASA to return to the Moon and go to Mars this decade. In the future, the space economy will further expand to new activities, such as the 'in-orbit economy' that includes in-orbit servicing and manufacturing, planet colonization, space tourism and asteroid mining.

Questions and milestones for this roadmap in 2025

Our challenge is to convert the strong positions of today into **solid growth for the Dutch space sector** in the growing market of space infrastructure and space applications. This requires that we further invest and improve our positions in ESA- and EU-programs and connect these positions with export opportunities and commercial applications.

It also requires that the sector provides space solutions for **the needs of government** as a smart buyer, for a broad range of ministries (MOD, J&V, I&W, BZK, BUZA) and EU/EDA in future space infrastructure and applications development. In particular, the development of a national and European Defence space strategy for **Defence** and the need for independent and safe navigation, observation and communication capabilities will pose new, explicit technology development questions. Clearly, the European space applications will directly contribute to the strategic autonomy the EU aims to achieve as geopolitical force amidst large economic and military powerhouses like China and the USA.

Through the ESA programme, the sector will develop a new generation of leading products for the space infrastructure. The NSO roadmaps provide detailed insights in these planned developments.

Competitive Optical Laser Satcom products (ground stations, terminals and subsystems) is an important development in this period with an expected uptake and strong growth of this commercial market in the second half of the decade.

The consolidation and expansion of our market position in the satellite segment with the strongest growth, i.e. that of the small satellites, require that we stay ahead in the development, launch, deployment and use of highly capable systems and applications e.g. in Earth observation for defence.

We will see increased application and added value of data from satellites through AI and big data processing. As an example, we will develop atmospheric monitoring services using satellites that allow the monitoring and control of individual emissions.

PRIORITIES AND IMPLEMENTATION

Implementation of this roadmap in public-private partnerships and ecosystems

The national space policy is implemented through investments in ESA and the national programme. In addition, the Space calls of the EU's Horizon programme and GSA provide grants for technology development. At government level the ministries of EZK, OC&W and I&W contribute financially; BuZa finances the G4AW programme that aims to develop operational space applications in support of agriculture in developing countries. The KIA "Veiligheid" defines the growing stakes of the ministries of Defence and J&V in space capabilities. The national programme stimulates cooperation by organizing networks of companies, institutes and universities, such as the so-called "Kennisnetwerken" and enables bilateral international cooperation.

In the roadmap process - coordinated by NSO in co-operation with SpaceNed - companies, universities and institutes outline the necessary development of key technologies. These roadmaps are updated every 2-3 years. The next update is planned in 2021 in preparation for the ESA Ministerial Conference in 2022. The roadmaps also describe the corresponding public and private budget sources and include national, ESA and EU programmes. Specific programmes and projects implement these roadmaps aiming at the development of products and services that serve the public and science community as well as commercial customers. The TO2 institutes (TNO, NLR) and NWO institute (SRON, Universities) have established space R&D programmes. The Top sector's instrument for public-private partnerships (PPP) facilitates the industrialisation of R&D results in new products. Space calls in the SBIR programme support the initiation of specific new space solutions; Instrument Cluster funding supports innovation in space instrumentation and applications based on their data.

Specific organisations, such as the Dutch Optics Centre (DOC) and the recently started Smart Advanced Manufacturing XL (SAM-XL) centre on the TU Delft campus and AVATAR organisation on applications of augmented and virtual reality (AR/VR) on the NL Space Campus Noordwijk, further stimulate public private co-operation. TNO, NLR and SRON make their production, test and qualification facilities available to companies in support of technology and product development.

The NL Space Campus Noordwijk is a major hub for the international space sector, closely connected to the knowledge centres ESA-ESTEC and the EU Galileo Reference Centre (GRC) which is part of the GSA. It is a meeting place where companies, organisations for research and education government meet and share space technology and develop applications. It also hosts the ESA-BIC as an incubator for innovations, start- and scale-ups and an inspiring environment for young professionals. With this perspective, the NL Space Campus develops R&D, educational and economic activities in the space domain.

The space sector is making a transition from its original institutional focus towards a merger of institutional and commercial initiatives, driven by demand for services from companies in the value chain with focus on the end-user. Satellite communication has been the first commercially successful application (also in the Netherlands with companies such as SES Newskies and ViaSat), now followed by satellite navigation and Earth observation.

A paradigm shift was initiated over the last decade in the US, with venture capitalists and internet billionaires (e.g. Richard Branson/Virgin Galactic, Elon Musk/Space-X and Jeff Bezos/Blue Origin)

joining forces with a different space and contracting policy by NASA, changing the global landscape of the use of space. This shift takes place also in Europe – albeit at a lower pace - with the advent of commercially funded constellations of small satellites such as Planet and Hiber. With the foundation of ArianeGroup, the governance of the development of the new European launchers has been transferred into the hands of private companies. In the European context, the implementation depends on the cooperation between many different countries, while private risk investments by venture capitalists are still at a relatively low level.

A number of new players have emerged in Europe in certain niche markets. Particularly the small satellite sub-domain has seen a surge in entrepreneurship and new companies (e.g. ISIS, Hiber, Hyperion), leading to significant growth in Dutch commercial space activities.

With this transition, the balance between institutional programmes (national, ESA and EU) and private initiatives gradually shifts. The challenge for the sector is to maintain a strong and internationally competitive basis for R&D and growth through effective cooperation and technology development through ESA and EU programmes and Public Private Partnership programmes between companies and knowledge institutes at low TRL level as well as national innovation instruments.

Linkage with other innovation instruments

Recent technology developments in space instruments (sensors) and miniaturization of technology, as well as the ever-increasing availability of high volume, high-quality, affordable satellite date has recently led to an increasing role of government as launching customer through public purchasing (such as the SBIR programme). The need for increased security and autonomy in intelligence has raised the awareness of the Dutch MOD (e.g. CLSK) for the possibility to develop its own space assets in co-operation with Dutch companies and institutes, for which pilot programmes (MilSpace, BRIK-II) are currently running. This is a first example of the government in the role of direct (smart-)buyer of space solutions.

The KIA “Veiligheid”, and more specifically the mission “Veiligheid in en vanuit de ruimte”, identifies R&D themes that are the focus of PPP initiatives. The latter KIA mission focusses on 5 main subprogrammes: robust positioning & time-synchronisation; national Space Situational Awareness, surveillance & tracking capability; ground-based situational awareness; Laser/optical communication for secure communication & enhanced data throughput capacity and (partially) national responsive and secure satellite availability. Although the main stakeholder of this mission are the departments of Defense and J&V other governmental departments can benefit. Within the annual Knowledge and Innovation Contracts (KIC’s) stakeholders can allocate budget to the implementation of the mission.

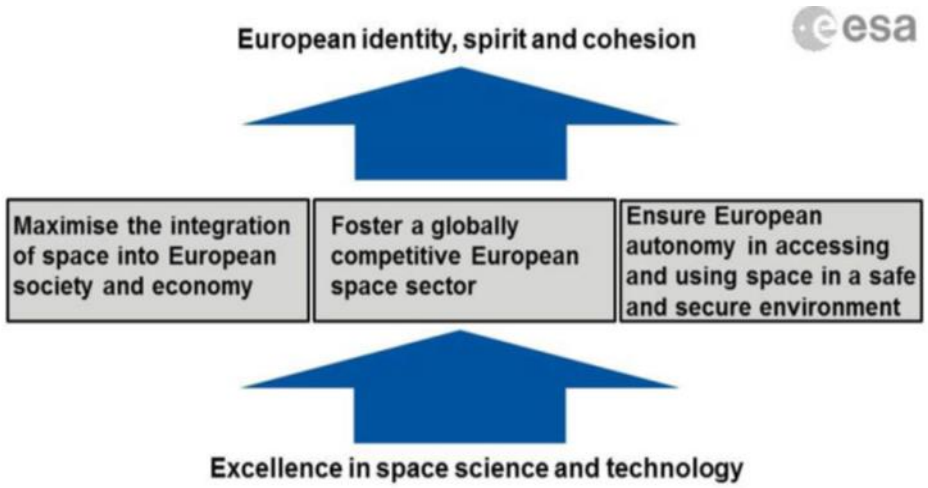
Collaboration in and leverage with international policies and programmes

International cooperation has been key in space activities from the start of the space age some 50 years ago, with the International Space Station and many science missions as examples. In Europe there is a strong co-ordination of space technology development through the European Space Agency (ESA), next to ESA’s Science oriented activities. ESA plays a key role in developing EU flagship space systems Galileo for satellite navigation and Copernicus for Earth observation. The European Commission has stimulated R&D in space through its Framework Programmes, now Horizon Europe, and continuing until 2027, possibly by setting up a Co-programmed partnership in co-operation with industry and R&D organizations.

EU's new Common Security and Defence Policy (CSDP) offers opportunities for space related R&D partnerships through its European Defence Fund (EDF). Through recent PADR and EDIDP pre-cursor calls Europe's defense industry and R&D organisations have been stimulated to cooperate in R&D theme's including some which are directly space-related, such as robust satellite navigation, Space Situational Awareness, laser communication a/o. Full EDF R&D funding will be available starting 2021. National MOD co-funding schemes are assumed and crucial to attract industrial interest as uncertainties in procurement policies and long ROI period in defence R&D projects deviate from traditional EU funding schemes.

In response to the growing worldwide competition in space from the US, China and India, the European Commission and ESA, by the end of 2016, formulated a joint space strategy with the objectives depicted in the figure below. In addition, the European Defence Agency (EDA) has announced a growing interest in space activities, where – as an example – ESA, EU and EDA compiled a list of Critical Technologies for Europe.

Also NATO Defence Ministers have now earmarked space as an operational domain and have formulated a space policy recognizing that space technology is crucial for our daily lives and security and may be used for both offensive and defensive purposes. As NATO alliance leaders endorse this new policy, space and space technology becomes strategic to the alliance and its members. Subsequently NATO will have to define what kind of relationships, if any, it should forge with the European Union, the European Space Agency, the United Nations and individual partner countries.



The Netherlands plays a significant role in research and technology development in the European environment. This is realized through involvement both in ESA's programmes and participation in EU Framework Programmes. This results in leveraging the knowledge and technology through projects executed in co-operation with European partners. Future EU EDF programmes will built on this to the benefit of the space sector. Both EU and several ESA programmes require national public funding as well as private co-investments.

PARTNERS AND PROCESSES

Partners in this roadmap from industry, science, departments, regions and cities

Membership of ESA is a key enabler for European collaboration and crucial for the presence of ESA's largest site (ESTEC) in the Netherlands. A robust Dutch participation in the European Space Agency Programs remains a prerequisite for competitiveness, ensuring the qualification and in-orbit validation of new technologies and products. ESA participation and national space R&D activities are the foundation of a "level-playing" field for opportunities in EU partnerships and programmes and the development of commercial applications.

National ambitions and programmes are firmly connected to international strategic research agendas of the space agencies (ESA, NASA, JAXA, KARI etc.), mostly covered by MOU's. The "Innovatie Attaché Netwerk" and technology ambassador roles in trade missions are important in international contacts.

Next to ESA, the European Union (EU) will be of increasing importance to the space industry. With the Copernicus Earth observation, the Galileo/EGNOS navigation and initiated GovSatCom and SSA programs, the EU operates four essential space-based services. The EU Horizon Europe programme will include space as a programmatic topic to execute the research and innovation elements of the European space policy and may include a Co-programmed partnership driven by industrial needs and support from European R&D organizations. EU's Common Security and Defence Policy (CSDP) offers opportunities for space related R&D partnerships through its European Defence Fund (EDF). EUMETSAT is a European operational satellite agency for monitoring weather, climate and the environment to which The Netherlands is contributing.

The 'regio deal' of the province of Zuid-Holland combines the establishment of a new International Meeting Facility (IMF) at ESA-ESTEC with a regional initiative (Province 8 M€, Municipality of Noordwijk 3 M€ in three years) to fund further development of the NL Space Campus in Noordwijk.

The incubation centre ESA BIC Noordwijk encourage further uptake of space based services, and supports business development and technology transfer activities from/to the space sector, accommodating promising space related start-ups.

Partnerships are initiated between EU regions with a strong capacity in space, such as between the space sectors and regional governments of Zuid-Holland and Bremen. At the national and European (EU/ESA) level additional technology development instruments could be made available to support bi-lateral technology development and innovation accelerating cooperation between regions.

Scientific activities are realized in accordance with the NWO's scientific ambitions and programmes. In the national context, they align with the strategic plans of the astronomy community (NCA on behalf of NOVA, SRON, ASTRON and NWO-EW) and earth and planetary research communities (SRON, KNMI, TNO, universities).

National space R&D builds on focused programs at SRON, TNO, NLR and universities and cooperation with space companies, most of them SME's and coordinated through the space technology roadmaps co-ordinated by NSO. The Dutch Value Adding Industry, along with the NL knowledge institutes and universities, will continue to develop end-user applications and services using satellite data driven by smart buy initiatives across the NL Government and end-user commercial companies.

Process followed in creating and maintaining this roadmap

A team of authors from all segments of the space sector in the Netherlands has created this roadmap. It is aligned with the space priorities as defined by NSO in the process of preparation of the ESA Ministerial Conference 2019. The roadmap is published on websites of Holland High Tech and SpaceNed, while stakeholders are informed about the roadmap and its objectives. The roadmap will be maintained through 3 to 4 yearly updates.

INVESTMENTS

Roadmap	2020	2021	2022	2023
Industry	21.0	23.0	23.0	23.0
TNO	10.0	11.0	14.0	14.0
NLR	2.6	3.0	3.1	3.1
NWO-SRON [1])	3.5	3.5	3.5	3.5
Universities	12.0	12.5	12.5	13.0
Departments and regions (excluding TKI)	7.0	7.0	7.0	10.0
ESA	93.0	93.0	93.0	120.0
Grand total	**149.1**	**153.0**	**156.1**	**186.6**

European programs within roadmap	2020	2021	2022	2023
Industry	2.0	3.0	3.0	3.0
TNO	2.0	2.0	2.0	2.0
NLR	0.6	0.7	0.8	0.8
NWO	0.1	0.1	0.1	0.1
Universities	1.0	1.0	1.0	1.0
EZK co-financing of European programs	1.0	2.0	3.0	3.0
MOD co-financing of EDF	p.m	p.m	p.m	p.m
European Commission co-financing	5.0	6.0	6.0	6.0
European Defence Fund	11.7	14.8	15.9	15.9
Grand total	**23.4**	**29.6**	**31.8**	**31.8**

[1]) The total funding of NWO for SRON is 14 M€ annually
All figures in million Euro per year

ANNEX I. Space sector in the Netherlands

NL Space maintains a directory of organisations active in the Dutch space sector: https://www.nlspace.nl/en/spacedirectory/

The following organisations are a member of SpaceNed (status of July 2020):

1	Aerospace Propulsion Products
2	Airborne
3	Airbus Defence and Space Nederland
4	ATG Europe
5	Bradford Engineering BV
6	Capable B.V.
7	Celestia STS
8	CGI
9	cosine BV
10	Dawn Aerospace
11	De Roovers Vacuum & Precision Technology BV
12	Dutch Aerospace Group
13	ESA BIC
14	European Test Services (ETS) B.V.
15	HDES – High-Density Energy Storage
16	Hyperion Technologies B.V.
17	ISIS Space
18	JAQAR Concurrent Design Services B.V.
19	Leidse Instrumentenmakers School
20	Lens R&D
21	LioniX International BV
22	MECON Engineering B.V.
23	METASensing
24	Koninklijk Nederlands Lucht- en Ruimtevaartcentrum - NLR
25	NOVA
26	Pentacon
27	Radboud Radio Lab
28	S&T
29	SRON
30	Stellar Space Industries
31	SystematIC
32	Technolution
33	Terma Nederland B.V.
34	Thales Cryogenics
35	TMC
36	T-Minus
37	TNO
38	TU Delft
39	TU Eindhoven
40	Verhaert Netherlands B.V.
41	WEST END