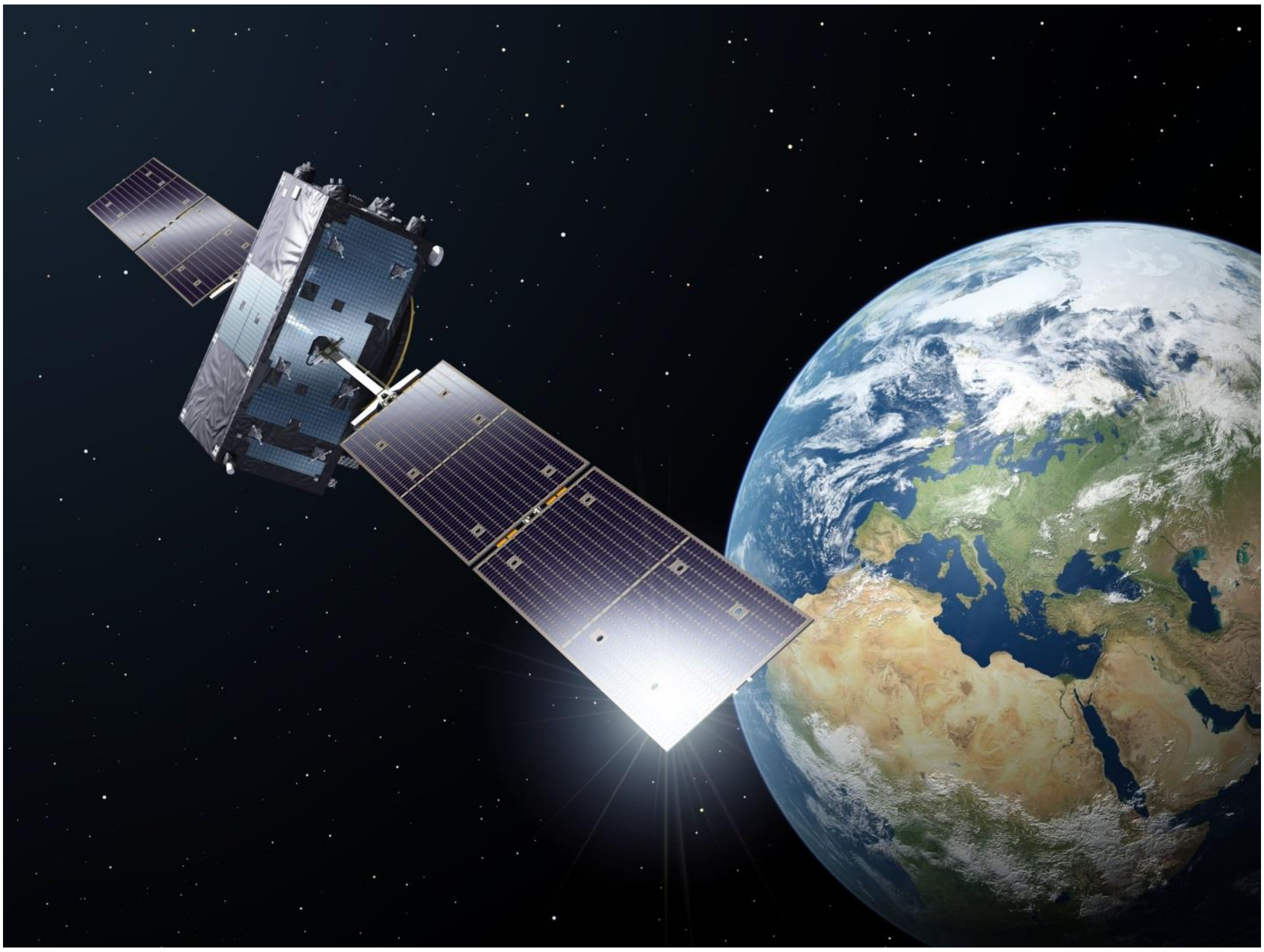
Lucht- en Ruimtevaart Nederland

Topsector HTSM

Roadmap Space 2015 - 2020



Issue 2.2

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PREFACE

This roadmap concerns R&D in the Netherlands for advanced space technologies and space applications and is an update of the roadmap Space from October 2012[1]*. Strong cooperation between industry, knowledge institutes and government in the field of space is normal practice and is vital for success. Institutional space programmes will remain important and the commercial market will become more significant due to its expected growth. Space is a critical enabler for innovations in many technical and societal fields of application and, as such, is a cross-sectorial activity in the 'Top sectors'*

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. Membership of ESA is a key element of European collaboration and crucial for the presence of ESA's largest site (ESTEC) in the Netherlands. Therefore in this document it is assumed that such participation and accompanying policy will continue independent of Top sector funding sources.

[1] This version describes the status of activities and initiatives end of 2014.

Topsector HTSM

Roadmap Space 2015 - 2020

SOCIETAL AND ECONOMIC RELEVANCE

>> Connection with the key societal themes

Modern society has become critically dependent on space, enhancing our quality of life. Satellite-based services are critical enablers of many key economic activities. Mobility is supported by a global network of navigation, communication and information systems. GPS receivers and internet access have an impact on our daily economic and social well-being. Observations from space are crucial to provide an urgent response to unprecedented environmental changes and are of key importance for monitoring climate change and (civil) safety.

Space increasingly provides essential information for socioeconomic areas. Applications of satellite data will make key contributions to innovative services in the Top sectors Water, Agro & Food, Logistics, and Energy and thus significantly improve the international market position of these sectors. Now that the provision of data from space is established, many more smart applications are being developed.

Scientific satellites are fundamentally changing our knowledge of the universe. The associated technologies developed have created a backbone for commercial success in the space arena and beyond.
An element not to be underestimated is the technology drive and spinoff from space-related activities. For instance, transfer of remote-sensing technology to medical applications, robotics for remote handling, contamination control.
Furthermore, it is a huge source of inspiration to young children and students to start a career in technical sciences.

>> Global market size addressed (2015-2020)

Sputnik, the first artificial satellite, was launched in 1957. Since then the global space economy has rapidly grown to a total yearly revenue and budget stream of $ 304 billion. Despite the worldwide economic and financial turmoil a growth rate of 6.7% was recorded during 2012.

The value of global space activities can be broken down into different segments as presented below:

Global Space Economy		
Segment	Revenue/*budgets* (2012, $ Billion)	Description
• Commercial infrastructure and support industry	109,9	Satellite manufacturing, launch industry, ground control stations, terminals, etc.
• Commercial products and services	116,0	• Satellite TV, satellite telecom, satellite radio, earth-observation data sales services and value adding, etc.
• US Government space budgets	47,9	DoD, NASA, NRO, NOAA, etc.
• Non-US Government space budgets	30,5	ESA, EU, Japan, BRIC countries, France, Germany, Italy, etc.
ESA	5,4	NL contribution 2.1%
EU	1.6	NL contribution 6.6 % (BNP level)
• Satellite manufacturing	14,6	
• Launch industry	6,5	
Total	**304,3**	
• Number of launches (2012)	**78**	114 more satellites into orbit in 2012 compared to 2010 adding up to a total of 1071

Sources: Space Foundation 2013, Satellite Industry Association (SIA)2013, ESA

Space companies in the Netherlands have a strong track record in this very demanding field of satellite and launcher manufacturing ("upstream") which is at the core of the space economy. This is a growing market, see table below.

Launch and satellites forecast			
	2002 - 2011	2012 - 2021	Growth rate
Total nr satellites launched	791 ($146 B)	1.073 ($198,3 B)	36%
Nr government launches	*525 ($94 B)*	*687 ($128,2 B)*	*31%*
Nr commercial launches	*266 ($ 52 B)*	*386 ($69,9 B)*	*45 %*

Source: Euroconsult

The main commercial satellite applications and services market ("downstream") consists of services from large telecommunication satellites for telecom traffic and direct-to-home TV, $116 billion in total for 2012 (ref SIA, 2013). The predicted growth in capacity is 40% for the next decade. The demand for standard telecom services is largely driven by emerging regions and novel broadband and mobile services in traditional space economy countries. The second largest services segment is based on satellite enabled location services and is estimated as $60 billion in 2012 (GNSS market report EU, 2013). According to EARSC, the global market volume for Earth Observation based geo-services and products is 1.6 B€ in 2012. Based on an annual growth of 10% per year between 2006 – 2012 this amounts to a global project global market volume of 3.2 B€ in 2020.

Data sales by remote sensing satellites is still a relatively small service that totalled $ 1,3 billion in 2012 (SIA, 2013). It is dominated by government (defence) users. Growth is predicted reaching $ 3,9 billion by 2021 with government demand accounting for 50% of this growth (Euroconsult). This data is the basis for a wide range of “downstream” applications.

>> COMPETITIVE POSITION OF DUTCH INDUSTRY: TOTAL R&D INVESTMENTS

The Dutch upstream space sector includes about 60 SMEs, knowledge institutes and universities, which together have an annual turnover of 140 million euros (unconsolidated).
The volume of R&D amounts to approximately one third of the annual turnover, of which 5-8% is self-funded. 80% of the workforce has a higher vocational or university education

Space is an export market par excellence in view of its cross-border nature. The strong position in the institutional market is enabling Dutch companies to acquire a growing share on the commercial market. The economic return on the Dutch contribution to ESA amounts to a factor of 5. The good score of the Dutch sector in winning contracts and the economic effects of ESTEC’s presence in the Netherlands (2700 employees) both contribute to this excellent figure.

The competitive position is focused on three areas: (1) High-Tech Space Instruments, (2) High-Tech Space Systems and Components, and (3) Downstream Space Applications and geo-Services. These areas are further described below.

APPLICATION AND TECHNOLOGY CHALLENGES

>> State-of-the-art for industry and science

Space is high-tech and high reliability. Multidisciplinary solutions are needed and development times are often long. Fixed delivery times often create high project and business risks. The harsh environment of space poses many technological challenges such as low mass, low-energy consumption, miniaturisation, robustness to harsh conditions and extreme reliability.

Only the most high-tech companies and organisations can remain competitive. An existing (market) position in the space sector can rapidly disappear when a more accurate, faster or cheaper solution is offered. The space sector is therefore characterised by a permanent effort in innovation and process improvement. Space hardware is always on the cutting edge of technological achievement.

- “High Tech Space Instrumentation" involves the development and use of space instruments for earth observation and astrophysics. The Netherlands has a strong heritage in designing, manufacturing, and use of (essential subsystems of) extremely robust and compact optomechanical instruments (see table below). SRON acts as a principal scientist in many programs. The combination of SRON, universities, TNO and the national space industry is a world famous powerhouse in this field. Furthermore, there is a growing synergy between the developments in ground–based (NOVA, ASTRON) and space-based instrumentation. The technological knowledge accumulated is intensively applied outside the space sector, such as in the semiconductor manufacturing industry.

- "High Tech Space Systems and Components" focuses on technologies and products which can be applied on various types of satellites or launchers and delivered to the global market. A strong competitive position exists in delivering recurring products, for example solar arrays, sun sensors, reaction wheels, and structures. Industrial parties in the Netherlands, in close cooperation with our knowledge institutes, have achieved important commercial successes on the global market.
- “Downstream Space Applications and geo-Services” involves the application of space based geo-information in applications with a strong Dutch heritage, e.g. in areas like water, agriculture, logistics and energy. Based on newly developed ‘smart satellite services’, innovations in these sectors will be applied on the home market; products and services are exported. This will stimulate the demand for new upstream industrial activities as well.

The Netherlands holds a strong international position in the three areas mentioned above. This has been achieved through cooperation between the government (via the Netherlands Space Office (NSO)), knowledge institutes (SRON, NLR, TNO, ASTRON, NOVA, universities) and companies, the so-called golden triangle, guided by an international space agenda formulated at ESA (and ESO) level. The Netherlands contribute to challenging EU programmes (Galileo, Copernicus, Horizon2020) and to the development of critical technologies in the framework of European non-dependence.

>> Future outlook in present and emerging markets

Societal and economic developments will lead to an increasing demand for space infrastructure and data applications to monitor natural and man-made global change (generally initiated by institutional bodies) and to meet a growing commercial call for products in areas such as communication, observation and navigation. These demands will jointly shape the global space market of the future.

The goal is to deliver lighter, better and cheaper products, high-tech instruments and enhanced services based on satellite data. This will require robust solutions, miniaturisation and standardisation, state-of-the-art technology and fusion with other knowledge domains. The Netherlands now faces a set of engineering challenges, and it can use the expertise and experience it has gained from its role in current programmes to contribute to the development of a new generation of launchers and satellites. This will require a further intensification of the existing strong collaboration between industry, knowledge institutes, universities, government and public/private (end)users of space assets to foster the development of new technologies.

To enhance international competitiveness and sustain the growth ambition in the commercial space market, the focus will be on developing products with a recurring character.

Private investments in space developments will lead to the growth of new commercial markets. This will require new ways of doing business and inventive collaborations and approaches. An example in the field of space tourism and transport is the company XCOR Space Expeditions (voorheen SXC). Also the emerging area of small and so called nanosatellites, having a much lower entry price, will allow for business models very different from what the space industry is used to nowadays. Taking into account the fact that the Netherlands actually has state-of-the-art knowledge and expertise in all areas of the value chain, it is of vital importance that national players join forces and establish a leading position worldwide.

What does this mean for the space sector in The Netherlands?
> High-Tech Space Instrumentation
The Netherlands holds a prominent position in space research – as represented by SRON, ASTRON, and NOVA – through its development of high-tech, world-class instruments. The ambition is to maintain this position and build on our track record. The next-generation instruments for

atmospheric research, currently under development (NSO/ESA TROPOMI, and successor: ESA/EUs Sentinel-5), benefits from innovative optics developed by TNO, providing more compact, efficient and accurate instruments. Driven by upcoming socio-scientific questions consortia of academia, institutes and industry are pushed to developing fully new innovative instrument concepts, notably the SPEX2Earth prototype. In particular innovative and relatively small instruments or instruments that can be implemented as a distributed space system offer excellent opportunities for tailored recurring business, e.g. in China. Dutch space institutions (golden triangle) together have the potential to create high potential technology/market combinations (scientific, societal, commercial). Therefore, long-lasting and structural collaborations between parties, facilitated by a clear focus of stimulating public investments, are needed to guarantee continuity of technology development, prototyping and flight developments.

A recent initiative in this area, by TNO and TU Delft, is the founding of the *Dutch Optics Center* (DOC).The mission of DOC is to strengthen the capabilities of companies in the domain of optics and high-precision opto-mechatronics and stimulate production of high-end systems in the Netherlands. DOC must ensure that in 2020 Dutch companies have a strong international competitive position and new OEMs emerge on the basis of next-generation technologies.
Other Dutch research organisations such as University of Twente, TUe, SRON and FOM institute AMOLF are being approached to participate in DOC. DOC enables and initiates the development of commercial projects with associated companies, stimulates start-ups and facilitates the production of small series of advanced instruments. DOC is also a center for collaborative opto-mechatronics research and a place where top researchers share state-of-the-art facilities and PhDs will be trained. To remain at the forefront of space science, future high-tech instruments for space science require detectors, subsystems and components that are not commercially available and must therefore be specially developed including the technology required. Such instruments are realised in large international consortia, consisting of institutes, academia and industry in missions within the Science program. The instrument is financed by the participating national agencies and scientific institutes. For multi-national (smaller) Earth Observation programs a similar governance structure might be applied. For the development of instruments within the Science programs of most notably ESA, but also of NASA and JAXA, the Netherlands play traditionally an outstanding role with SRON as PI institute leading international consortia to develop and realize the instrument (PI) or subsystem (co-PI). Presently SRON is co-PI for the development of the focal plane assembly of the X-IFU instrument of the selected ESA L-class mission ATHENA (ESA) and PI of the SAFARI instrument of the JAXA/ESA mission SPICA.

> High-Tech Space Systems and Components
Our current position in the institutional market is based on the high-quality Dutch contribution to ESA. At the same time, the Dutch space sector has achieved a significant position in the growing international, commercial space market. Space companies such as Airbus Netherlands[2] , Moog/Bradford, APP, together with a broad supply chain of companies including many SME's and supported by TNO and NLR already deliver 'world-class' products and form the backbone of the Dutch space sector. The ability to rapidly apply new technology in systems and components is essential if we are to comply with the increasing demand for space infrastructure and maintain our competitive advantage. The space sector would therefore benefit from synergy with other high-tech sectors and from generic technological developments in the field of materials, miniaturisation and integration.

> Downstream Space Applications and geo-Services

[2] Short for Airbus Defence and Space Netherlands

The worldwide availability of satellite data as 'raw material' for innovative environmental products and geo-services creates a fast growing market. The launch of the first Sentinel satellites with their open data policy and the consequent boost to value added geo-services is one of the key arguments for investing in technology in support of the NL downstream service sector today and to capitalise on the investment being made by the EU in Copernicus. Environmental information based on satellite data is a commercial asset of increasing economic and strategic potential. In 2014 the NL Taskforce ''Exploitation of satellite data'' concluded that the most promising international target markets for the NL downstream service industry are Agribusiness & Food Security, Energy, and Urban Development in Delta Areas. The Taskforce concluded that, with the right investment and support for a sustained strategy, the NL downstream service industry can target revenues of about € 105 M€ per annum by 2020. Using the multiplying factor of 15 to 20 for the impact of a domestic geo-information business on the wider economy (Boston Consult Group) and applying it to these results suggest an overall economic impact of about € 1.5 à 2 B (or ~0.7% of NL GDP) on the Dutch economy.
Earth observation data are growing in size and variety at an exceptionally fast rate (Big Earth Data), posing technological challenges and opportunities for their access and (commercial) application. Increasing diversity of space data, increasing combined use of diverse space mission's data, increasing integration of satellite born data with non-space ones naturally lead to an unprecedented opportunity to serve new types of applications impacting the way such data are collected, referenced and processed. This requires new data processing infrastructures bringing the (user) algorithms to the data and the cloud ('app service hosting') instead of downloading massive datasets, whereas the 'Internet of Things' will allow for combining the heterogeneous environmental information including space-based geodata ('satellite as a service').
Space-based geodata is a critical enabler for innovations in the target markets mentioned above. As such, they are at the basis of cross-sectorial activities to open these markets and to strengthen Netherlands regional economic priorities as well (Smart Specialization Strategy). This will enable to establish a unique Netherlands sensor-axis, combining space assets from ESA-ESTEC, data-processing and information extraction technology of NLR/ Geomatica Business Park (Flevoland) with non-space sensor assets from e.g. Sensor Universe (Drenthe/INCAS3).
Furthermore the roll-out of Galileo, the European constellation for satellite navigation and contributor to the Global Navigation Satellite System, will lead to a further growth in applications for positioning, navigation and timing. Dutch companies involved in the development of navigation equipment for the consumer market (e.g. TomTom), and companies that provide services based on satellite navigation to the professional market (e.g. Fugro) will benefit from and should capitalize on the availability of Galileo and its unique features, next to GNSS systems such as GPS . The planned realization of the Galileo Reference Centre in Noordwijk near ESTEC supports the development of receiver technology and GNSS-based applications and will be a Galileo centre of expertise in the Netherlands.

PRIORITIES AND PROGRAMMES

The future space priorities and programmes are based on the NSO roadmap process initiated at the end of 2010, and regularly update since. Roadmaps have been defined for the Netherlands space focal areas and have been reviewed in presentations organised jointly by SpaceNed and NSO. These roadmaps constitute the priority areas in the Netherlands and are supported by the entire Dutch space sector. The challenges facing the space sector combined with the technological expertise present in the Netherlands are described in these roadmaps. The roadmaps are grouped in the two aforementioned upstream focal areas: High Tech Space Instrumentation and High Tech Space Systems and Components. Roadmaps for downstream Space Applications and geo-Services are presently under development. The main objectives, themes and involved parties for each roadmap are outlined in the tables below[3].

Focus area: High-Tech Space Instrumentation	
Roadmaps	**Roadmap Coordinators and Participants**
1. Optical Instrumentation Optical elements for Earth atmospheric measurements and Space Science: Development of space based atmospheric and astrophysics optical instruments and related technologies (Integrated optics, Opto-mechatronics, cryogenic mechanisms, gratings, spectro-polarimetry; Detector technology, and ROICs; Spectrometers and interferometers)	Roadmap Coordinator(s): NSO, KNMI, Airbus Netherlands, TNO SRON, Cosine Participants: LioniX, Mecon, s[&]t , VSL, NOVA/ASTRON, Delft University of Technology (presently roadmap being revised)
2. Radio Frequency (RF) Technology 2a) MiniSAR : A small satellite platform demonstrating an end to end SAR radar instrument and operational system 2b) Radar Earth Observation antenna and instruments 2c) Other RF subsystem and component level topics are under definition	Roadmap Coordinator(s): SSBV (2a), TNO (2b&c) Participants: ISIS, NLR, Delft University of Technology, Eindhoven University of Technology, LioniX/SATRAX, ASTRON
3. On- board software & data systems A general purpose processor combined with a dedicated high performance co-processor and algorithms integrating an on board data platform with an intelligent instrument controller. An application is the MiniSAR satellite described in the RF roadmap	Roadmap Coordinator: SSBV Participants: NLR, Recore Systems
4. Ground segment data processing The intermediate technology for services required for opening the vast amounts of raw satellite based data for Astrophysics, Earth observation and "downstream" value adding applications. Themes include: data acquisition, storage, infrastructure, (re)processing and access and data transportation.	Roadmap Coordinator: KNMI Participants: TriOpSyS, NLR, Airbus Netherlands, University of Groningen, SRON, SSBV, S&T, TNO, Vortech
5. On Site Bio-Analysis Miniaturized bio analysis instruments for detection and analysis of organic molecules and organisms using a variety of technologies for space and terrestrial applications. Themes: astrobiology, life detection, planetary	Coordination: NSO & Core group: LioniX, Airbus Netherlands, Bioclear Participants, Culgi, s[&]t, Vitens, TNO, KWR Water Inst, Biotrack, Leiden University, Wageningen University, University of Twente, VU University Amsterdam, University of

[3] The tables have been drafted by the authors; the list of companies mentioned may be incomplete. A list of members of SpaceNed, the national branche organisation of space companies, can be found in Annex 1.

protection instruments, pathogen detection in manned space, water quality preservation, cell biology instrumentation, single molecule detection, micro-gravity reserch	Groningen/University of Groningen Medical Center, Utrecht University
6. Thermal control Instruments and payload elements Payload thermal control by sorption cooling or microcooling (Kryoz, Un. Twente, Airbus Netherlands) and stirling & pulse tube cooling (Thales Cryogenics) Themes: Micro cryogenic cooling systems for space instruments, sorption cooler for vibration free cooling, hydrogen and neon sorption coolers. Pulse tube and Stirling coolers for civil, military and space applications with related ground support equipment.	Coordination: Airbus Netherlands, Kryoz, Thales Cryogenics, University of Twente Participants: engineering and research institutes (To Be Specified)

Note: Partners active in ground based astronomy (supplying to ASTRON and NOVA) are not mentioned in the table above.

The actions in ”Optical instrumentation” are aimed at strengthening the Dutch position in astronomy and atmospheric measurements. The development of related instrumentation, in particular for astrophysical instrumentation, is characterised by long lead times, typically 10-20 years. Innovations therefore need an early start. Other applications may have considerable shorter instrumentation lead times. In all cases sound and focussed R&D programs are needed to comply with the requirements of future applications. Current ongoing projects are cryogenic detectors and read-out, cryogenic mechanisms, on-chip spectrometers, integrated optics, spectro-polarimetry (SPEX2Earth), and integrated electronics (aimed at more compact and lighter systems), smart processing, calibration and metrology.

Focus area: High-Tech Space Systems and Components	
Roadmaps	**Roadmap Coordinators and Participants**
7. Attitude and Orbit Control Systems This roadmap consists of three sub roadmaps. 7.1 AOCS systems. The AOCS design and testing for large space systems (ERA) and large science satellites (e.g. for ESA missions Herschel and Planck) and for very small satellites such as nano-satellites 7.2 AOCS components. Design, production and recurring supply of AOCS equipments: Reaction Control Wheels, (mini digital), Gyro’s and sun sensor systems for satellites 7.3 Sinplex. A small integrated Navigator for Planetary Exploration: a compact system for planetary exploration and other space missions.	Coordination AOCS systems: Airbus Netherlands, ISIS, NLR Coordination AOCS Components: MOOG Bradford with TNO, TU Delft, Lens R&D, Systematic design Coordination Sinplex: Cosine with TNO, Systematic design
8. Satellite Propulsion Design, production and recurring supply of propulsion subsystems and components for spacecraft:	Coordination: Moog/Bradford Participants: APP, Airborne Composites, CGG Technologies, APP, ATG Europe, NLR, TNO, Delft University of Technology

Components: pressure transducers, ultrasonic flow meters, passivation valves Subsystems: generic Xenon flow control unit, electric propulsion pressure regulation assembly, mono-propulsion system integration 8.1 sub roadmap Cool Gas generator Generation of gas for propulsion at room temperatures from solid state material Applications in cool gas propulsion systems. A potential specific application in Mars lander airbags	 Coordination: CGG Safety & Systems Participants: TNO, APP, MOOG Bradford, Laboratorium Medisan, ISIS
9. Structures Structural elements for launchers and spacecraft and structures systems for small satellites Themes: Metal and composite (CFRP) structure technologies and structural connection technologies Motor frames, inter-stages, cone caps for Ariane-space launcher family Spacecraft structures subsystems and parts Cubesat structures and dispensers Secondary small sat launch equipment structures.	Coordination: Airbus Netherlands Participants: Airborne Composites, Bayards, Breman, Chromalloy, DTC, Fokker Aerostructures, Futura, ISIS, JPC, NORMA, PM Aerotec, GTM, Delft University of Technology, NLR, TNO
10. Solar arrays Solar arrays for spacecraft. Major Dutch product for satellites for almost 40 years Themes: CFRP technologies for solar panels , deployment mechanisms and thermal knife based holddown system and electrical part (solar cells) Continuous product improvement and upgrades and preparing for upcoming novel flexible cell technologies. Applications: European (ESA, EU, commercial) and export spacecraft market. Related mechanisms products for deployment and for holddown and release	Coordination: Airbus Netherlands Participants: Airborne Composites, PM Aerotec, Neways, Brandt FMI, UMI, TU Delft, TNO, NLR, University of Twente, Radboud University Nijmegen, Solliance
11. Thermal control subsystems and components Recurring thermal control systems & components for application on space platforms and payloads Themes: heat transport technologies (micro pumps), heat storage and rejection (heat pipe radiators, radiator blanket, two phase pumped loops), materials (high-conductive CFRP),	Coordination: NLR, Airbus Netherlands Participants: Thales. Airborne Composites, ATG Europe, MOOG/Bradford Engineering, Kryos, University of Twente
12. EGSE & Simulation Electrical Ground Support Equipment and (Real Time) simulation and modelling for space systems testing and training. Segments: Front-ends & SCOE, Real-time simulation & modelling, Integrated EGSE, and CCS / Core EGSE NB: Largest base of installed EGSE in Europe.	Coordination: SSBV Participants: Airbus Netherlands(lead RT simulation and modelling) , NLR, NSPYRE, Terma (lead Central; Check Out Systems) , ISIS

12.1 subroadmap European Ground System Common Core A proposal for a single EGS CC system for future ESA applications avoiding current duplications leading to cost savings.	Coordination: Terma Participants: SSBV, Airbus Netherlands
13. Ignitors Ignitor systems for solid state and liquid rocket motors Themes: reliable pyro technology under high pressures and temperatures, cost and mass efficiency, material selection (REACH) Applications: Arianespace launcher family, possibly future space tourism systems	Coordination: APP, Participants: Moog/Bradford, Airborne Composites, TNO, CGG Technologies, PM Precision, Frencken, Norma
14. Distributed Satellite Systems Space system consisting of interacting small spacecraft (nano- and micro satellites) for a range of potential applications Themes: creating a systems level industrial base, technologies for efficient (series production) of nano-satellites, distributed processing, swarm deployment strategies, distributed payload forming virtual instruments Applications: emerging interest in nanosat constellations, QB50, long term perspective: realization of OLFAR system (Lofar on the Moon)	Coordination: ISIS Participants: NLR, SSBV, TU Delft, TNO, Airbus Netherlands, SRON, Groningen Univ., Twente Univ., Radboud Univ., MOOG Bradford, Cosine, `Lionix, CGG, APP, a.o.

Examples in this line are:

- "Solar Arrays" for energy supply of space systems that have the robustness of the current design and in the mid-term incorporate ultra-high efficiency thin film solar cell blankets to meet the requirements for a better power/weight ratio at lower costs.
- New lighter materials for launcher and satellite structures based on composites and additive manufacturing.
- Smart heat management of space systems such as thermal conductive structures, deployable radiators and advanced components/(sub-) systems for the positioning/control of satellites will be developed in this line as well.
- Advanced components for positioning and guiding satellites.

Focus area: Downstream applications and geo-Services[4].	
'Vertical' (sector-specific) actions in target markets	**Companies, End-users and Knowledge institutes**
1: Energy: Bathymetry, extreme waves, ice conditions, oil seepage and slicks, sediments and plumes, tides and ocean currents, metocean, windfields and	- Hermess B.V., Geoserve, Hansje Brinker - NL oil & gas & offshore & dredging & logistic provider industry (incl. Maritime Cluster Noord Holland), Ursa Minor, Fugro - ECN, MARIN +TO2 partners, INCAS3 a.o.

[4] This table has been drafted by the authors; the list of companies mentioned may be incomplete

waves, power output forecastinf, safety, ...	
2: Agribusiness & Food Security: Crop damage assessent, monitor crop disease and stress, crop yield forecasting, land use statistics, irrigation, ...	- Neo, eLeaf, EARS, SarVision, Cluster Sensorbased Agribusiness Flevoland, Geoserve - NL agribusiness: Agrifirm, Agrico, The Greenery, FrieslandCampina - WUR + TO2 partners, CAH/Dronten, UT/ITC, LTO, INCAS3
3: Urban development in Delta areas: Monitor land subsidence, dike safety, map and assess flooding, water quality, pollution, change detection urban areas, safety, ...	- Hansje Brinker, Hydrologic, Neo, Hermess, GeoServe, Nelen & Schouten, Future Water - Arcadis, Grontmij, Royal HaskoningDHV, - Deltares + TO2 partners, UT/ITC, INCAS3
4: Climate and air quality: provides distribution of sources (emissions) and sinks of greenhouse and air quality gasses, and aerosol types, derived from satellite measurements. Climate and air quality predictions.	KNMI, SRON, RIVM, TO2 partners, universities, S[&]T
5: Satellite Navigation: - Mission Critical Application (e.g. aviation) - Use of Galileo for safety & security (PRS) - Transport related applications (road, maritime, rail)	CGI, NLR, Fugro, S[&]T, 06-GPS, TomTom
'Horizontal' actions: Advanced processing and infrastructure:	**Participants**
Advanced Big Earth Data processing algorithms and infrastructures - Automated Information Retrieval (AIR) from BIG EO Data - App Service Hosting infrastructure, cloud computing	CGI, S&T, TriOpSys, SSBV, INCAS3, RUG, NLR, TNO, VORtech, NL e-Science Center, in cooperation with value adding industry

The roadmap process for downstream, initiated by NSO in 2013, will lead to a coherent set of sufficiently concrete action programs on a number of market segments. The topics of the roadmaps on these market segments are considered to be promising and/or mature enough in order to result in a strong growth of the use of space applications in the foreseeable future and a subsequent growth of the economic activities of the Dutch space sector. The market segments of the roadmaps find their application within the three worldwide target markets mentioned above, and may be considered the 'most readily available gains' based on available Dutch strengths and knowledge. In 2015 a synthesis of the roadmaps, which are developed in a more 'bottom-up' approach, and the selected target markets, which are selected from a more 'top-down' perspective, will be carried out in order to arrive at a comprehensive space application stimulation program in which the Dutch industry sector, government and knowledge sector cooperate.

PROPOSED IMPLEMENTATION

To execute this roadmap a loyal Dutch participation in the European Space Agency Programs is a prerequisite for competitiveness, because it ensures the qualification and in orbit validation of new technologies and products.

The proposed implementation of the Space roadmap will be realised by a combination of different regional, national and international partnerships.

Netherlands space ambitions and programs are firmly embedded in the international strategic research agendas of the space agencies (ESA, NASA, JAXA, KARI etc.), in many cases covered by MOU's. The TWA network and the technology ambassador role in trade missions plays an important role in these international contracts.

At European level the implementation will be realized through collective R&D within European programmes like the ESA technology programmes covering R&D from TRL level 1 to 7/8. This is only feasible with support of an adequate and focussed national R&D program (see below). For specific technology developments also relevant for Space Instrumentation the HTSM roadmap Advanced Instrumentation aims at R&D up to TRL level 4, while follow-up activities on TRL level 5 to 9 will benefit from synergies with these special developments, and are subject of the present HTSM roadmap *Space*.

Another example is Horizon 2020 which includes Space as a programmatic topic to execute the research and innovation elements of the European Space Policy of the EU.

The scientific activities will be realised in accordance with the NWO scientific ambitions and programmes. In the national context they are in agreement with the strategic plans of the astronomy (NCA on behalf of NOVA, SRON, ASTRON and NWO-EW) and earth and planetary research communities (SRON, KNMI, TNO, universities).

National R&D activities will be realised in collaboration with SRON and TNO/NLR and will include projects with SMEs and links with the NSO roadmaps.

National downstream space applications and services activities will be realised in collaboration with the Dutch Value Adding Industry, internationally operating sector specific NL industry along with the NL knowledge institutes (amongst others TO2 partners, ITC, TUDelft).

INVESTMENTS[5]

Roadmap	**2015**	**2016**	**2017**	**2018**	**2019**
Industry	6	6	6	7	7
TNO	4	4	4	4	4
NLR	1	1	1	1	1
NWO-SRON PPS/PPP*1)	2.5	3.7	3.5	3.5	3.5
Universities *2)	4.7	4.7	4.7	4.7	4.7
Government support space programs *3)	80	80	80	80	80
Departments and regions	4	4	4	4	4
Grand total	102.2	103.4	103.2	104.2	104.2
European agenda within roadmap	**2015**	**2016**	**2017**	**2018**	**2019**
Industry	2	2	2	3	3
TNO	0.5	0.5	0.5	0.5	0.5
NLR	0.2	0.5	0.5	0.5	0.5
NWO	0.1	0.1	0.1	0.1	0.1
Universities	4	4	4	4	4
Regions	0.5	0.5	0.5	0.5	0.5
EZ co-financing of European programs	0.5	0.5	0.5	0.5	0.5
European Commission *4)	8	8	10	12	12
Grand total	15.8	16.1	18.1	21.1	21.1

All figures in million euro cash flow per year (cash and in-kind value)

1) The total funding of NWO for SRON is 14 M€ annually
2) estimate, based on the amount of fte's involved in space research
3) estimate, based on anticipation contracts to be allocated by ESA and NWO
4) estimate, based on anticipation contracts to be allocated in Horizon2020 framework; EC programs Galileo and Copernicus are recurring and therefore not included in this table

[5] Investments listed concern **High-Tech Space Instrumentation** and **High-Tech Space Systems and Components.** Figures for **Downstream applications** will be included in a next issue of this document.

Annex I

List of SpaceNed members (status May 2015):

Aerospace Propulsion Products
Airborne Composites
Airbus Defence and Space Netherlands
ATG Europe
Moog Bradford
CGG Technologies
cosine
ESA BIC
DIMES
Fokker Aerostructures
ISIS
CGI
Neways Micro Electronics
Hyperion Technologies
JAQAR Concurrent Design Services
LioniX
NLR
SSBV
S[&]T
SystematIC Design
Terma
Thales Nederland
T-Minus Engineering
TNO
TU Delft
WEST END