



Lucht- en Ruimtevaart Nederland

TOP SECTOR HTSM ROADMAP SPACE 2012-2020





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PREFACE

This roadmap concerns R&D in the Netherlands for advanced space technologies. 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, 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 will continue independent of top sector funding sources.



TOP SECTOR HTSM

ROADMAP SPACE 2012-2020

SOCIETAL AND ECONOMIC RELEVANCE

>> Connection with the key societal themes

Modern society has become critically dependant 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 fast 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.

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 thereby significantly improving the international market position of these sectors. Now that the provision of data from space is guaranteed, 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. Space drives engineers to the highest standards of quality and product assurance, important for many other technical fields. Space activities inspire today's youth to choose careers in science and technical fields, as is illustrated by the continuous growth in the number of students at the Faculty Aerospace Engineering of Delft University of Technology.

>> Global market size addressed (2012-2020)

Sputnik-1, the first artificial satellite, was launched in 1957. Since then the global space economy has rapidly grown to a total annual revenue and budget stream of \$ 276.5 billion. Despite the recent economic and financial turmoil a growth rate of 7.7% was recorded during 2010.

The value of global space activities in 2010 can be broken down into different segments as presented below:



GLOBAL SPACE ECONOMY 2010		
Segment	Revenue/ budgets (\$ billion)	Description
• Commercial infrastructure and support industry	87.39	Satellite manufacturing, launch industry, ground control stations, terminals, etc.
o Satellite manufacturing	3.41	
o Launch industry	2.45	
• Commercial products and services	102.00	Satellite TV, satellite telecom, satellite radio, earth-observation data sales services and value adding, etc.
• Commercial space transportation systems	0.01	(Sub)Orbital flights, space tourism
• US Government space budgets	64.63	DoD, NASA, NRO, NOAA, etc.
• Non-US Government space budgets	22.49	ESA, EU, Japan, BRIC countries, France, Germany, Italy, etc.
	<i>ESA</i>	<i>4.60</i>
	<i>EU</i>	<i>1.63</i>
	Total	276.52
• Number of launches	74	118 new satellites into orbit adding up to a total of 957 satellites

Source: Space Foundation 2011

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:

Launch and satellites forecast			
	2001 - 2010	2011 - 2020	Value Growth rate
Number of satellites	756 (\$131 B)	1145 (\$ 196 B)	50%
Of which: Government satellites	511 (\$ 80 B)	777 ((\$137 B)	70%

The commercial satellite applications and services market (“downstream”) mainly consists of services from large telecommunication satellites for telecom traffic and direct-to-home TV, which accounts for 95% of the \$ 102 billion in total for 2010. The predicted growth in capacity is 40% for the next decade.

Earth-observation-based services, location-based services and value adding is a new, and still relatively small market but is predicted to grow by 80% per annum over the next decade with government demand accounting for 65% of this growth.



>> **Competitive position of Dutch industry: total R&D investments**

The Dutch space sector includes about 60 SMEs, knowledge institutes and university departments, which together have an annual turnover of 140 million euros (unconsolidated, 2009 figures). The volume of R&D amounts to approximately one third of the annual turnover, of which 5-8% is self-funded. Eighty per cent 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 of the commercial market. The economic return on the Dutch contribution to ESA is a factor of 3.4. The good score of the Dutch sector in winning contracts and the economic effects of ESTEC's presence in the Netherlands (2600 employees) both contribute to this excellent result.

The competitive position is focused in three areas: (1) High-Tech Space Instruments, (2) High-Tech Space Systems and Components, and (3) Downstream Space Applications and 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 risk. Multidisciplinary solutions are needed and development times are long. The need to launch payloads from the Earth's surface by existing rockets and 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 investigator institute in many programmes. The combination of SRON, universities, TNO and the Dutch space industry is a world-famous powerhouse in this field. Also KNMI is intensively using advanced space instruments for operational and scientific purposes.
- The technological knowledge accumulated is intensively applied outside the space sector, for example in the semiconductor manufacturing industry. There is a growing synergy between developments in space-based and ground-based instrumentation; both rely on state-of-the art



solutions and solutions that are not yet available anywhere in the world. Based on a proven track record, science and industry in the Netherlands are well positioned to tackle these challenges. Examples are developments for SPICA/SAFARI and the E-ELT, both part of the National Roadmap for Large Research Facilities.

- "High-Tech Space Systems and Components" focuses on technologies and products that can be used in 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. Dutch industrial parties, in close cooperation with knowledge institutes, have achieved important commercial successes on the global market.
- "Downstream Space Applications and Services" involves the use of space based information in applications with a strong Dutch heritage like water, agriculture, logistics and energy. Based on newly developed 'smart satellite services', innovations in these sectors will be applied within the home market; products and services will be exported. This will stimulate the demand for new upstream industrial activities as well.

The Netherlands holds a strong international position in these three areas. 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. It should be noted that the Netherlands contributes 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. These engineering challenges can be mastered through the expertise and experience industry 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, technical universities and government to foster the development of new technologies.

To enhance competitiveness and sustain the growth ambition in the commercial space market, the focus will be on developing products with a recurring character, e.g. solar arrays for the commercial telecommunication market.



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 Dutch company Space Expedition Curacao (SXC).

What does this mean for the Dutch space sector?

→ *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 (TROPOMI, ESA's Sentinel-5 successors and SPEX2EARTH) benefit from innovative optics, providing more compact, efficient and accurate instruments. There are good global commercial opportunities in the field of earth-observation instruments outside Europe.

To remain at the forefront of space science, future high-tech instruments for space research require detectors and components that are not commercially available and must therefore be specially developed. Such instruments will be realised in large international consortia of institutes, academia and industry participation in missions in the European programmes.

The Netherlands will also exploit its strong position in naval radar by applying this technology in potential new space missions and applications.

→ *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 Dutch Space, Bradford Engineering and 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 Services*

The worldwide availability of satellite data as 'raw material' for innovative environmental products and services is a growing market. Environmental information based on satellite data is a commercial asset of increasing economic and strategic potential. For example, in the field of water there are export opportunities in the context of the "Water & Climate Covenant", a consortium of more than 30 Dutch knowledge institutes and companies in the areas of water, space and geomatics. The ambition is to further strengthen the international market position by combining the application of knowledge with data from space-based and ground-based sensor networks to develop new smart services.



PRIORITIES AND PROGRAMMES

The future space priorities and programmes are based on the NSO roadmap process initiated at the end of 2010 in preparation for ESA's ministers conference in 2012, and are supported by the entire space sector in the Netherlands. The challenges facing the space sector combined with the technological expertise present in the Netherlands have resulted in the topics/programmes itemised below. The partners for each topic/programme are stated and their commitments are detailed in the Letters of Intent accompanying this Innovation Contract.

FOCUS AREA: HIGH-TECH SPACE INSTRUMENTATION	
Programs (bold) and activities	Partners
1. Optical Instrumentation Optical elements; Integrated optics; Optomechanics; Detector technology and ROICs	TNO, cosine, Dutch Space, LioniX, Mecon, s[&t] , VSL, KNMI, NOVA/ASTRON, SRON, Delft University of Technology
2. Radio Frequency (RF) Technology Small satellite radar & platform; Active electronically scanned array radar; Antennae	Thales Nederland, ISIS, SSBV, NLR, Ursa Minor, Delft University of Technology, Eindhoven University of Technology, LioniX, TNO, ASTRON
3. On- board software/data systems General purpose (co-) processor; Integrated on-board controller; algorithms	SSBV, NLR, Neways, SRON
4. Ground segment data processing Data processing, data archiving, data archiving toolboxes	KNMI, NLR, Dutch Space, University of Groningen, SRON, SSBV, s[&t], TNO, Vortech
5. In situ bioanalysis Life detection; Planetary protection instruments; Pathogen detection in manned space; Water quality preservation; Cell biology instrumentation; Single molecule detection	LioniX, Dutch Space, Bioclear, Culgi, CapiliX, Aqua Explorer, s[&t], Vitens, TNO, Leiden University, Wageningen University, University of Twente, VU University Amsterdam, University of Groningen/University of Groningen Medical Center
6. Thermal management& cooling systems Payload thermal control (sorption cooler, stirling & pulse tube cooler	NLR Dutch Space, Cryoz, Thales Cryogenics, University of Twente

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 is characterised by long lead times, typically 10-20 years. Innovations therefore need an early start. Current on-going projects are on-chip spectrometers, integrated optics and integrated electronics (aimed at more compact and lighter systems), smart processing, calibration and metrology.



FOCUS AREA: HIGH-TECH SPACE SYSTEMS AND COMPONENTS	
Programmes (bold) and activities	Partners
7. Attitude and Orbit Control systems Reaction Control Wheels, (mini digital) sun sensor systems	Bradford, TNO, ISIS
8. Satellite Propulsion Latch valve, flow valve, pressure components, cold gas generators	Bradford, APP, Airborne Composites, CGG Technologies, Dutch Space, NLR, TNO, Delft University of Technology
9. Structures Carbon fibre and metal technology for launchers, radiators, (mini) satellite structures and substrates for solar arrays	Dutch Space, Airborne Composites, Bayards, Breman, Chromalloy, DTC, Fokker Aerostructures, Futura, ISIS, JPC, NORMA, Tecnovia, GTM, Delft University of Technology, NLR, TNO
10. Solar arrays Short term: CFRP technology, insulation foil, panel hinges, Double linkage yoke, NELS Hold-Down and Release System, wiring, thermal knife heater Medium term: Thin film GaAs, interconnection, transparent foil, solar panel frames, unfolding system)	Dutch Space, Airborne Composites, Tecnovia, Neways, Brandt FMI, UMI, Delft University of Technology, TNO, NLR, University of Twente, Radboud University Nijmegen, Solliance
11. Thermal management & cooling systems (small systems & components); deployable radiators; high-conductive CFRP	NLR, Airborne Composites, AOES, Bradford, Dutch Space, NLR, University of Twente,
12. EGSE/Simulation Front-ends & SCOE, Real-time simulation & modelling; Integrated EGSE, CCS / Core EGSE	SSBV, Dutch Space, NLR, Nspyre, Terma, ISIS
13. Igniters Igniters for: Vinci, Vega Evolution, NGL, space tourism and thruster ambition	APP, Bradford, Airborne Composites, NLR, TNO
14. Satellite cluster technology Assessment of clusters /constellations of satellites	ISIS, NLR, SSBV, TU Delft, TNO, University of Twente
15. Miniaturised accelerometers High-resolution MEMS accelerometers, capacitive and optical read-out	University of Twente, Axiom IC, Bruco, Shell, Fugro, Delft University of Technology, TNO

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.
- 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.

Elements of “Downstream Space Applications and Services” are detailed in the table below. A roadmap process will be initiated by NSO during 2012 leading to cross-sectorial business groups. A starting point is the National Satellite Databank currently under construction. This will be used to initiate the development and introduction of ‘smart’ services for innovations in agro/food, water, energy and logistics on the home market.



National Satellite Database: provides GMES-compatible satellite data for satellite application development, knowledge creation and support to market development	geo-ICT companies, satellite value adding companies, service companies, knowledge institutes, universities, institutional service providers, government geo-ICT organisations, ..
- Agro & food: Precision agriculture, yield mapping & prediction, moisture assessment, food security	- e-Leaf, SARVision, EARS, Geomatics Business Park, Wageningen University, Alterra, ITC/University of Twente, Geoserve, Delft University of Technology , TNO, ..
- Water: flood prediction & management, delta life, maritime services, automatic identification for shipping, oil slick monitoring, dredging support, eco engineering, water quality, dike monitoring	- Arcadis, BMT ARGOSS, Fugro, Deltares, INFRAM, Wageningen University, TNO, van Oord, Boskalis, Hydrologic, NEO, Grontmij, Water & Climate Covenant partners, Delft University of Technology , Havenbedrijf, Waterschappen, ..
- Logistics: navigation, routing, transport safety, AIS, tracking & tracing	- BMT ARGOSS, Arcadis, Logica, NLR, TNO, Ursa Minor, Havenbedrijf, ..
- Energy: monitoring climate change/treaties, supporting on-/off-shore drilling activities, land subsidence, environmental conditions for deep-sea mining, ice monitoring, monitoring pipeline safety, wind energy yield prediction	- BMT ARGOSS, Wageningen University, ITC/University of Twente, Fugro, Shell, NAM, Gasunie, NL Contractors, Delft University of Technology , ECN, TNO..

PROPOSED IMPLEMENTATION

To execute this roadmap a loyal Dutch participation in the European Space Agency Programs is a prerequisite not only for the societal benefits for the Netherlands but also 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 programmes 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 play an important role in these international contracts. Activities are developed in large international consortia consisting of research institutes and industry.

At a European level the implementation will be realised through collective R&D within European programmes like the ESA technology programmes covering R&D from TRL level 1 to 7/8. Another example is the FP-7 programme and its successor Horizon 2020, which both include Space as a programmatic topic to execute the research and innovation elements of the EU's European Space Policy.



The scientific activities will be realised in accordance with the NWO/SRON scientific ambitions and programmes. In the national context they are in agreement with the strategic plans of the astronomy (NOVA) and earth and planetary research communities.

National R&D activities will be realised in collaboration with 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 parties such as the Geomatics Business Park (a fast-growing, leading European business and science park that has evolved into a 'hot spot' for earth observation based geo-information), the Water & Climate Covenant leading to business groups formed together with partners in the top sectors Water, Agro, Logistics and Energy.

COLLABORATION ACTIVITIES QUALIFYING FOR TKI

High-Tech Space Instruments, High-Tech Space Systems and Components and Downstream Space Applications and Services could potentially qualify for a TKI, as in most cases a structural long-term cooperation exists between multiple companies and knowledge institutes.

For example such potential TKI's could be built around:

- 1) **TKI Advanced Instrumentation**, connecting space instrumentation with other cutting edge instrumentation within the HTSM top sector, like biomedical instruments, security screening instruments and novel techniques for encrypted information, materials analysis etc.
- 2) **TKI Aerospace**, connecting both the space and aeronautics R&D based on the specific nature of the industries like long-development cycles, high safety and certification standards etc.

At this moment the rules and conditions for TKI's are not yet clear enough to further detail the TKI's. Therefore, in the current budget tables it is assumed that some 50% of the activities will be TKI-suitable. During 2012 and 2013 a transition towards TKI will be initiated.

ENGAGED PARTNERS FROM INDUSTRY AND SCIENCE

More than 60 industrial and scientific partners are currently active in the field of space and space-based applications and services. This number is set to grow, as evidenced by the budget tables in the next section. The annexed Letters of Intent underline the commitment in the sector.



INVESTMENTS

>> Public-private partnership R&D (budget tables 2012, 2013, 2014-2016)

Year 2012

↓ Execution \ Financing →	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Foreign Contracts
Universities TKI	0.175	0.05	1.937	0.3	0.575	0.875	0.65
Universities non-TKI	0.175	0.05	1.937	0.3	0.575	0.875	0.65
TNO / NLR TKI	0.3	2.85		0.65		1	0.35
TNO / NLR non-TKI	0.3	2.85		0.65		1	0.35
Companies	2.325			1.3		0.875	2
Companies non-TKI	2.325			1.3		0.875	2
International R&D	0.1					1.5	0.95
Total Million € per year	5.7	5.8	3.874	4.5	1.15	7	6.95

Year 2013

↓ Execution \ Financing →	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Foreign Contracts
Universities TKI	0.25	0.05	2.037	0.3	0.825	1	0.75
Universities non-TKI	0.25	0.05	2.037	0.3	0.825	1	0.75
TNO / NLR TKI	0.3	2.85		0.65		1.25	0.4
TNO / NLR non-TKI	0.3	2.85		0.65		1.25	0.4
Companies	2.775			1.3		1	2
Companies non-TKI	2.775			1.3		1	2
International R&D	0.1					1.5	1.4
Total Million € per year	6.75	5.8	4.074	4.5	1.65	8	7.7

Year 2014-2016 (over 3 years)

↓ Execution \ Financing →	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Foreign Contracts
Universities TKI	1.15	0.15	6	0.9	2.6	3.25	2.25
Universities non-TKI	1.15	0.15	6	0.9	2.6	3.25	2.25
TNO / NLR TKI	0.9	8.55		1.95		5	1.5
TNO / NLR non-TKI	0.9	8.55		1.95		5	1.5
Companies	8.75			3.9		3.25	7
Companies non-TKI	8.75			3.9		3.25	7
International R&D	0.5					5	5
Total Million €	22.1	17.4	12	13.5	5.2	28	26.5

>> Other innovation instruments

Opportunities for valorisation can be supported by funding schemes like SBIR with a space paragraph.



APPENDICES

1. Background document - Roadmap HTSM Space Downstream; Short description of the potentials in the Netherlands
2. Background document - Roadmap HTSM Space Upstream; Short description of NSO Roadmaps 2.0

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