ESTEC White Paper

Spinning in and spinning off: Ways to strengthen the ties between ESTEC and the Dutch knowledge infrastructure

The High Tech Systems and Materials top team

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by

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Summary and conclusions

In the *Proposal for an Innovation Contract for the Top Sector High Tech Systems and Materials* (HTSM) (December 2011, see www.htsm.nl), the HTSM top team concludes that ESTEC, the European Space Agency (ESA) technology and research site in the Netherlands, is an important contributor to this top sector's innovation ecosystem. ESTEC is by far ESA's largest site. As space-related markets and applications continue to grow, the top team sees additional opportunities arising. To be able to seize those opportunities, an even stronger collaboration between ESTEC and the Dutch knowledge community is required (for example, to fully capitalize on the crossover technology areas and application domains in the HTSM sector). This white paper identifies and makes recommendations for some of those opportunities and is, we hope, the start of a continuous process of cooperation.

This white paper and the Netherlands' activities in space must be viewed in their international context. Space involves global strategic interests and offers societal and economic benefits. The dominant drivers enabling the space sector to thrive therefore stem from political choices: public interests, the desire for technological independence, and the associated public procurement. European cooperation is essential vis à vis the USA, Russia, and China. For this reason, the EU has developed its own space policy in which ESA, as its research and development organization, plays a major role. For a small country like the Netherlands, ESA and the EU are the main mechanisms for taking part in space activities in an effective and efficient way. In the last 10 years, the Netherlands has contributed on average 89 M€ per year to ESA's budget. In 2011, ESTEC created revenue in the Netherlands of 354 M€: 4.26 times the Dutch contribution in that year to ESA of 84 M€.

The space sector has an intrinsic value, offering unique economic and societal benefits for the Netherlands; the location of ESTEC in the Netherlands reinforces those benefits manifold. Dutch companies and research institutes have direct and easy access to ESTEC's unique knowledge and facilities, with direct and indirect benefits for their technical capabilities. Given the present budgetary outlook, Dutch participation in ESA is expected to decrease significantly due to the announced cuts, in particular those by the Ministry of Economic Affairs, Agriculture and Innovation (EL&I). A sharp decrease in the Dutch contribution to ESA's optional programs will not only have a direct impact on industry, but may also prompt other member states to plead for an increase in ESA sites in their own countries. This may lead to decreasing investments in the ESTEC site, with undesirable consequences for the knowledge infrastructure in the Netherlands.

This white paper argues that the Netherlands should not risk decreasing investments in ESTEC by decreasing its contribution to ESA's optional programs. However, continued financial contribution should be tied to measures to increase ESTEC's value for the Dutch infrastructure. Although ESTEC's net economic and societal contribution is already significant, the Netherlands and ESA can mutually benefit if we take action in the following five areas:

1. Stimulate the use of economic and societal applications from space data and infrastructures.
2. Enhance technology transfer and valorization.
3. Strengthen ties between academia, research institutes and ESTEC.
4. Share and maintain research facilities.
5. Improve the visibility of the space sector and ESTEC within the Dutch knowledge infrastructure.

This call for action translates into the following recommendations linked to an organization to take the initiative:

1. Stimulate the space applications market by raising awareness of and demonstrating commercial applications to the other top sectors as potential users. The four top sectors agrofood, energy, water, and logistics are viewed as the most promising (see also the background document Downstream on our website: www.htsm.nl/Roadmaps/Space). Under the supervision of the Netherlands Space Office, other key actors to be involved here are ESA Business Incubation Centre, TNO, NLR, and the top teams of these four top sectors.
2. Strengthen links between ESTEC and (regional) industry, research and development clusters (ground-based, space-based, geomatics). Here regional actors should take the lead. The top team welcomes the initiative taken by the Holland–Rijnland region (Leiden, Noordwijk and Delft) to strengthen the space cluster linking ESTEC, the Space Business Park, the Leiden Bio Science Park, and the universities in Leiden and Delft. The province of Flevoland can take the lead in further developing the Geomatics Business Park and the new opportunities it offers for fledgling and established businesses.

3. Improve matchmaking and crossovers between ESTEC and ESA programs on one hand and Dutch industry on the other hand by re-establishing the Dutch Technology Transfer Program as an efficient method for technology transfer linked to the ESA incubator. Within the Netherlands in the past decade, 40 feasibility studies for technology transfer have been carried out (ESA/government/TNO funding approx. 0.2 M€ per year with at least equal industry matching), resulting in 12 commercial successes and more than 10 potential commercial successes. The top team will link this recommendation to its efforts to set up a Small and Medium-sized Enterprise (SME) program within the Top consortium Knowledge and Innovation HTSM.
4. Organization of Space-MATCH by the Netherlands Space Office in 2012 within the framework of the innovation contract for the top sector HTSM.
5. The HTSM top team should make a continued effort to stimulate crossovers between the space roadmap and other HTSM roadmaps as a task of the Top consortium Knowledge and Innovation for this top sector. The potential for crossovers should also be reflected in the programmatic choices for Dutch participation in optional ESA programs. Therefore the Cabinet should take into account—besides the existing strengths of Dutch industry and knowledge institutes—possible crossovers with other roadmaps in the top sector HTSM and other relevant top sectors. The Netherlands Space Office has to take these considerations into account in its advisory role, by consulting the HTSM top team and the different roadmap teams at an early stage.
6. Stimulate technology transfer from other HTSM roadmaps and top sectors toward ESTEC by making better use of ESTEC's Networking and Partnering Initiative. The NPI can become a more (pro)active instrument for the spin-in of advanced technologies developed in universities and research institutes for non-space applications. The structured dialogue mentioned in the following recommendation can serve as the platform for this exercise.
7. The Cabinet is advised to initiate a structured dialogue between ESTEC and relevant research institutes in the Netherlands, i.e. the three technical universities and the beta-technical faculties of the general universities, NLR, TNO, SRON, STW, FOM, ASTRON, and the NWO domains Physical Sciences and Earth and Life Sciences, with the objective to intensify the cooperation within the space community and stimulate the crossover of know-how between space and non-space. Proposed elements for this dialogue are strengthening the ESTEC Networking and Partnering Initiative, shared professorships, the exchange of PhDs and post-docs, education, training, and the pooling of specialists. This structured dialogue can build on the existing informal contacts and should be facilitated by an independent chairperson with a profile and background in both academia and industry.
8. Explore cooperation between ESTEC and Dutch universities and companies through teaming up in EU programs, including joint technology initiatives and key enabling technologies.
9. Within the framework of the structured dialogue, develop an infrastructure-sharing mechanism and investigate the pooling of competences and facilities between ESTEC and Dutch research institutions, such as ESTEC's collaboration with Delft University of Technology (TU Delft) on the Robotics Lab.
10. The Netherlands Space Office, the space roadmap team for the top sector HTSM, and ESTEC should work together to develop a communication plan to improve ESTEC's visibility. Better visibility of ESTEC and the space industry will significantly facilitate the previous recommendations.

1. The role of ESTEC in the Netherlands

1.1 The space industry in a global context

Space is a global strategic interest
Space research and development, from satellites to launchers to ground stations, is traditionally perceived by nations as a national strategic interest. It is viewed as a symbol of national technological prowess and has military significance. In the course of time, these military space technologies have evolved into civil technologies, without which our modern daily life is almost unthinkable. Probably the best-known example of this is the American Global Positioning System. Space is of increasing socioeconomic relevance: from science (greater understanding of the universe and Earth's systems) to technology (both HTSM and other sectors) to applications (communication, navigation, Earth observation).

Public funding and institutional interests remain dominant
Space involves global strategic interests and offers societal and economic benefits. The dominant drivers enabling the space sector to thrive therefore stem from political choices: public interests, the desire for technological independence, and the associated public procurement. These public space programs enable private and public research companies to participate and subsequently to enter the growing commercial market. Following the already strong commercial satellite communications market (for example global broadcasting of sports events), other markets are also growing. Thus competition is becoming a stronger driver, pushing innovation. Even so, public funding and regulation remain the dominant drivers. As a result, space research and industry have unique characteristics, whereby companies have no other option than to compete on the institutional market in order to enter the commercial market.

Dutch Space is the largest space company in the Netherlands with some 240 employees, of which 74% have a higher and academic qualification. Of its 2010 revenue of 57.5 M€, some 56.5% comes from the institutional (public) market, 34.5% from the commercial market, and 9% from the defense and non-space markets. More than 40% of its revenue is generated through collaborative contributions from Dutch (SME) companies and institutes. The contracts it performs for the public market (ESA, European Union, Netherlands Space Office) allow Dutch Space to make high-quality competitive products for the commercial market. Dutch Space revenue has been steadily growing in recent years after its acquisition by EADS Astrium. The source of this positive development lies in the combination of program decisions from the 2008 ESA Ministerial Conference in The Hague, the competition for Galileo contracts (a European Commission-funded program), and significant involvement in a commercially procured NASA program.

ESA is Europe's answer to remain independent and keep a stake in the global space market
Thanks to ESA, Europe is one of the world's key space players, competing on the commercial markets for telecommunications and launchers and forming a key partner for the USA, Russia and other countries in scientific and human spaceflight missions. ESA guides the development of Europe's space capability and carries out pioneering research in all areas of space activity. For over 50 years, ESA and its predecessors have been shaping and sharing space. They manage the research and development programs required to keep Europe at the forefront of space exploration and applications. ESA has ensured that investment in space delivers benefits to the citizens of Europe and the world: from jobs and economic growth to public services, efficient communications, and security.

ESA in facts and figures
- Over 50 years of experience
- 20 member states and growing
- 5 sites in Europe
- 4,000 M€ annual budget (2010/11/12) (see figure 1)
- Over 80 satellites designed, tested and operated in flight
- 6 types of launcher developed, 3 launch systems in operation today
- More than 200 launches

ESA's annual budget comes from member states' subscriptions to mandatory and optional programs, the European Union (e.g. the Galileo navigation program) and other cooperating states (see figure 1).

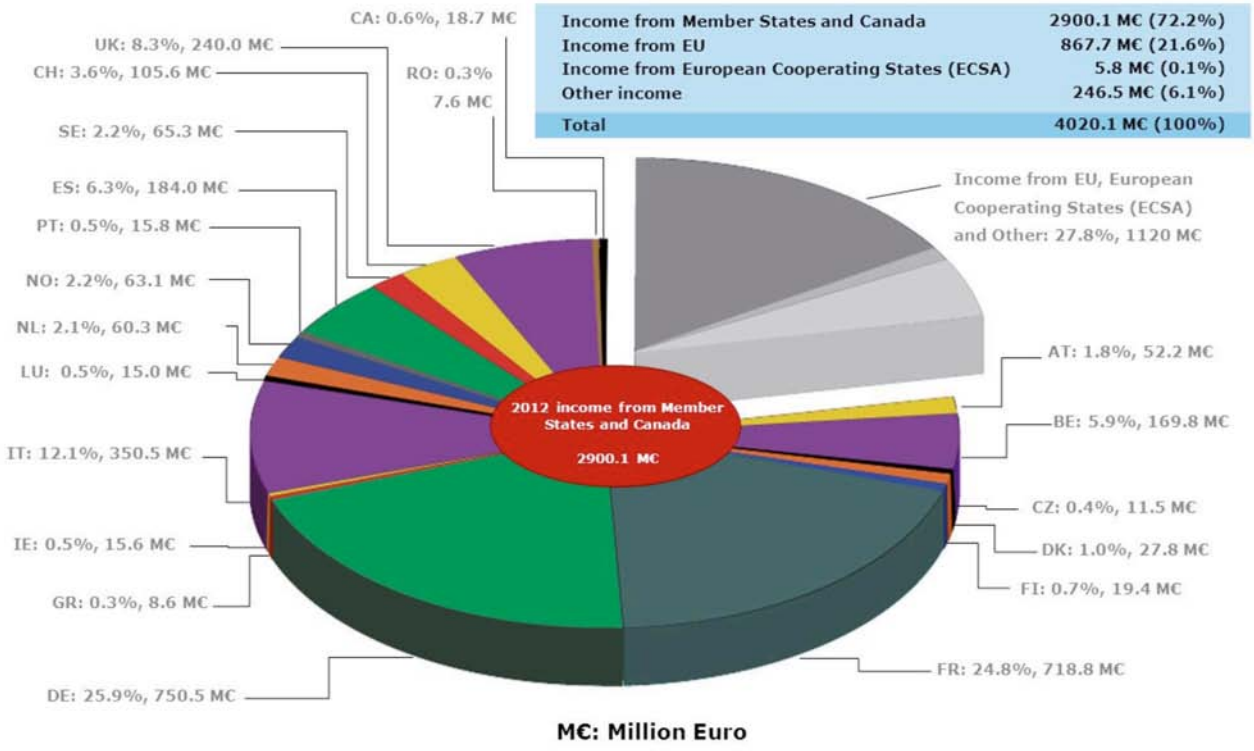


Figure 1: ESA 2012 income from member states and Canada (total mandatory and optional)

1.2 The Netherlands from a European perspective

The Netherlands is a founding member of ESA

For a small country like the Netherlands, ESA and the EU are the main mechanisms for taking part in space activities in an effective and efficient way. The Netherlands is a founding member of ESA, which was established in 1975 by merging two existing organizations: European Launch Development Organization and European Space Research Organization. ESA is an inter-governmental organization. Programmes carried out under the General Budget and the Science Programme are 'mandatory'; they include the agency's basic activities (studies on future projects, technology research, shared technical investments, information systems and training programmes). All member states contribute to these programmes on a scale based on their Gross Domestic Product (GDP). Over the period 2009–2011, the Dutch contribution to the mandatory programs was 4.67%. Table 1 shows the contribution to ESA in the period 2009–2011 for its mandatory programs.

Table 1: Contribution to ESA mandatory programs 2009–2011

	2009	2010	2011
	M€		
Overall contribution to ESA for mandatory programs	698.1	687.4	739.0
Of which the Netherlands' share: 4.67%	32.6	32.1	34.5

ESA works on the basis of the industrial return on national contributions, with a guaranteed industrial return rate of 96% (i.e., for each euro contributed, 96 cents is returned in industry contracts through a system of competitive tendering whereby invitations to tender are sent out to industry). Therefore, despite the return rule, Dutch industry must still be

very competitive compared to its European counterparts. The fact that the Netherlands consistently has a return of more than 100% (for each euro invested in ESA, more than one euro is won back by Dutch industry) shows this is indeed the case.

High-tech space instrumentation: Dutch public-private partnership leading to international excellence
Within the scope of the ESA Ministerial Council in 2008 in The Hague, the Netherlands allocated 78 M€ to develop, build and exploit TROPOMI (TROPospheric Ozone Measuring Instrument) as an in-kind contribution to the European Global Monitoring for Environment and Security (GMES) program. TROPOMI (to be launched on an ESA satellite in 2014) will provide us with tools to better understand our environment and will help us take effective steps toward keeping our planet healthy. TROPOMI builds on the success of two previous Dutch sensors, SCIAMACHY (aboard the ESA satellite ENVISAT) and OMI (aboard the NASA satellite Aura), and guarantees the data continuation key to scientific studies. The development of TROPOMI links Dutch scientific, societal, and industrial objectives and capabilities. The immersed grating concept created by SRON and TNO, as well as improvements in spectrometer calibration, have led to a huge technology advance in Earth observation possibilities. A broad international scientific user community is being led by KNMI and SRON. KNMI brings practical data analysis and use to the table, with pollution images viewable online and even as a layer in Google Earth. Dutch Space leads the instrument's development and creation and the Netherlands Space Office plays the role of project initiator. Three Dutch ministries (Economic Affairs, Agriculture and Innovation; Education, Culture and Science; and Infrastructure and Environment) have come together to finance the project.

Participation catered to national interests
ESA also runs optional programs, in which member states can voluntarily participate. Countries participate in these programs on the basis of industrial, societal and scientific interests and capabilities (see the TROPOMI example above). These optional programs generally have a four-year focus. Table 2 shows the contribution to optional programs for the period 2009–2011. This is a relative contribution of 2.55%, which is significantly lower than the Netherlands' relative GDP size.

Table 2: Contribution to ESA optional programs 2009–2011

	2009	2010	2011
	M€		
Contribution from the NL to optional programs	69.0	64.2	49.7

Direct economic and scientific spin-off
These ESA programs have significant benefits for the Netherlands. Today, the Netherlands has an internationally competitive sector with 140 M€ annual revenue by Dutch companies, as well as indirect spin-off from space technology development. There are strong public-private partnerships between universities, R&D institutes and industry. Dutch companies and research institutes such as TNO, KNMI, and SRON are particularly competitive in the fields of high-tech space instrumentation and high-tech space systems and components. These are also the two focus areas in the space industry roadmap prepared for the HTSM top sector innovation contract.

Fifty-six companies and research institutes contributed to the HTSM space roadmap, of which 19 companies and 5 research institutes further underlined their commitment by submitting a letter of intent: Airborne, AOES, APP, Bayards, Bradford, Cosine, Dutch Space, GTM AS, ISIS, Kryoz, Lionix, SSBV, S&T, Target Holding, Tecnovia, Terma, Thales, TriOpsys, VORtech, the Radboud Nijmegen faculties Physical Sciences, Mathematics, and Informatics, the University of Groningen faculties Mathematics and Physical Sciences, the ThermoPlastic composites Research Center, TU Delft, and the University of Twente. These organizations cover more than 80% of the private sector financial commitment for this roadmap.

And indirect spin-off, too

As well as a direct return on program participation, ESA's mandatory and optional programs produce a very important indirect spin-off. The space environment places extreme demands on materials, instruments and mechanical engineering. There are many examples of companies and research institutes transferring technological expertise to new markets outside the space industry. An example is the development of on-chip analysis devices for robotic exploration missions, from which applications such as "microlabs" for medical purposes or food quality can be derived. Space systems engineering expertise is being used by the design team for the ITER (International Thermonuclear Experimental Reactor) being built in Cadarache, France. Another example is the application of world-class technology and expertise derived from the development of unique optical space instruments such as TROPOMI (see box above) by ASML's R&D division for their next-generation wafer stepper.

High-tech space instrumentation expertise benefits the Dutch semiconductor industry

The current strong position of Dutch semiconductor companies (especially ASML) is supported by the optomechanical expertise acquired in the Netherlands in recent decades through the design and realization of space instruments. This has led to global excellence in the development of reliable, high-precision optomechanical instrumentation for extremely harsh conditions (e.g. vacuum, cleanliness, mechanical loads). This exceptional technology base has given the Dutch semiconductor industry a considerable boost from the 1990s onward. In the near future, semiconductor lithography will see the introduction of EUV (extreme ultraviolet) wavelengths. Space technology will be able to support the development of dedicated EUV optics with high reflectivity and long lifetimes and to address technical challenges in future systems. In order to achieve higher productivity, the accuracy of future lithography machines will have to come down to the picometer level. The space sector has already proven it is able to realize such metrology demands, and it will provide the expertise to minimize the all-important thermal effects. Furthermore, today's expertise in vacuum cleanliness – a key technology that ASML and TNO have developed to a world-class level – can also be spun in for space instrumentation development, where there are similar technological challenges with regard to contamination.

1.3 ESTEC's position in Europe and the Netherlands

ESTEC in Noordwijk is the technical heart of ESA

ESA has sites in several European countries, but the European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands, is the largest. ESTEC is ESA's technical heart, the incubator for the European space effort where most ESA projects are born and where they are guided through the various phases of development.
More than 60% of ESA's budget is spent by ESTEC. ESTEC distinguishes itself from other international organizations located in the Netherlands through its nature as a "hands-on" operational high-tech R&D organization and through its accessibility to the Dutch high-tech sector, thus adding to innovation in the Dutch ecosystem. ESTEC also adds value to the regional economy.

Principal tasks

ESTEC's principal tasks are as follows:

- Studies, preparation, and management of most ESA space programs: science, applications, human spaceflight, and future exploration
- Technical support for ESA project teams, including preparation and coordination of ESA space technology R&D program and operation of specific laboratories
- Product assurance and safety responsibility for all ESA space programs
- Management of the ESTEC Test Center and coordination with other test centers in Europe

ESTEC is one of the top five Dutch research organizations

Today, about 2,700 full-time equivalent staff work at ESTEC, among them 600 Dutch employees. Some 1,580 scientists and engineers work on-site, which puts the center in the top five research organizations in the Netherlands alongside TNO, Deltares, FOM, and ECN. All scientific papers with ESTEC involvement are added to the Dutch publication index.

Proximity gives Dutch parties good access to unique knowledge within ESTEC
Knowledge is best transferred during face-to-face contact. Although ESTEC is equally open to all of its member states, people from Dutch academia, research institutes and industry are physically close to ESTEC and automatically profit from this easy access to ESTEC's people. These informal contacts have already benefited Dutch industries and scientists. As an example, ESTEC's cooperation with the Faculty of Aerospace Engineering at TU Delft has resulted in a number of traineeships and master theses done on-site at ESTEC. ESTEC also hosts master classes at TU Delft. The proximity of ESTEC to TU Delft can help attract foreign students to its Faculty of Aerospace Engineering, which is the largest faculty in Western Europe with around 500 students starting each year.

On-site synergies
The concentration of expertise and facilities within ESTEC has intrinsic value for ESA: space is an engineering discipline where all components have to function together in extreme environments. This favors collective efforts by engineers and scientists, if possible at the same location. ESTEC's combined expertise attracts new projects and investment, such as the European Union's development of the European satellite navigation system Galileo. These location synergies will be lost if ESTEC is torn apart into different sites or a multiple-location strategy is pursued.

Significant regional economic benefits
In 2011, ESTEC created revenue in the Netherlands of 354 M€: 4.26 times the Dutch contribution to ESA of 84 M€. This ESTEC-generated revenue is on top of the industrial return mentioned under 1.2 above, through which the Dutch contribution to ESA was already won back in industrial contracts. Adding the industrial return increases the multiplier to 5.3. ESTEC is an important customer for hotels in the Noordwijk area (16,500 nights in 2011), in particular during the off-peak season. ESTEC is in the top 10 of KLM-Air France customers in the Netherlands, with an annual expenditure of 8–12 M€. Seventy thousand visitors from all over the world came to ESTEC last year, among them the Irish president, the heads of the Russian and Chinese space agencies, the NASA Jet Propulsion Laboratory director and a number of world-renowned scientists and engineers.

1.4 Looking ahead: the risks and rewards of the budgetary outlook

Decisions on 2013–2015 ESA programs to be made in November
In November 2012, ESA's member states will decide on the financing of new mandatory and optional programs within the ESA budget for 2013–2015. The Netherlands' mandatory contribution can thereby be viewed as a given. The coming months will be crucial to determine not only the amount of Dutch participation in optional programs, but also the choice of optional programs. The Netherlands Space Office (NSO) is tasked by its steering group[1] with the implementation of national space policy, which includes an advisory role on programmatic choices. The NSO provides its advice based on an extensive technology roadmap exercise that was started in 2010 in broad consultation with all stakeholders (see also the background document Upstream on our website: www.htsm.nl/Roadmaps/Space). These roadmaps have also formed the basis for the space roadmap within the HTSM innovation contract.

The budgetary outlook in the Netherlands is grim
Given the present budgetary outlook, the prospect for Dutch participation is grim: it is expected to decrease significantly due to the announced budget cuts, in particular those of the Ministry of Economic Affairs, Agriculture and Innovation. The budget for space science at the Ministry of Education, Culture and Science will remain fairly stable, but it is certainly not going to grow. It is as of yet unclear to what degree other member states will follow this trend. We know, however, that countries such as Germany and France have maintained their budgets for science and technology, and are therefore not likely to cut the budget for this field.

The risks of a decreased contribution to ESA
A sharp decrease in the Dutch contribution to ESA's optional programs will have a direct impact on research institutes and industry. The Netherlands will lose its prominent position in space-based (scientific) research into the Earth and the universe. Fewer tenders will be open for Dutch industry (resulting from the industrial return principle described under 1.2). Critical resources and capabilities that have been built up over many years will disappear (people leaving those

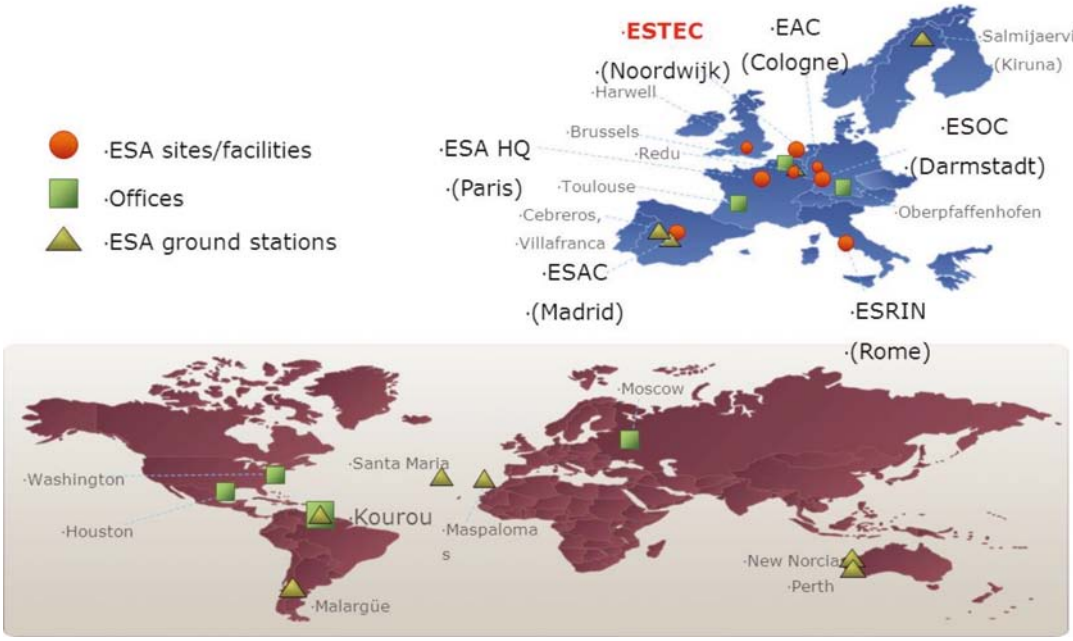
[1] Steering group members are the Ministry of Economic Affairs, Agriculture and Innovation; the Ministry of Education, Culture and Science; the Ministry of Infrastructure and Environment; the Netherlands Organization for Scientific Research (NWO).

companies, facilities not kept up-to-date and so forth). There will be fewer opportunities to validate new technologies within the ESA framework and hence more obstacles to proving capabilities in the commercial/non-ESA market. Last but not least, there will be fewer opportunities for technology transfer from and to ESA projects.

Pressure to move away parts of ESTEC

A decreased Dutch contribution to ESA will also prompt other member states to plead for an increase in ESA sites in their own countries (see figure 2 below). This process of increasing investments in other ESA sites has already begun and may accelerate if the Netherlands continues to invest seriously below its GDP ratio. This will lead not only to decreasing economic and scientific benefits for the Netherlands—by a factor of 5.3!—but also to fewer synergies, to which the present concentration of activities within ESTEC gives rise.

Figure 2: ESTEC in relation to other ESA sites



More interlinkages between ESTEC and the Netherlands for mutual benefits

The space industry, and the special position of ESTEC in particular, have unique economic and societal benefits for the Netherlands. Dutch companies and research institutes have special access to ESTEC's unique knowledge and facilities, with direct and indirect benefits for their technical capabilities. Space is, after all, a global industry, naturally operating at the forefront of technology.

Yet the space industry and ESTEC are not very visible. Although their net economic and societal contribution is already significant, we as a country can gain additional benefits if we take action in the following five areas:

1. Stimulate the use of economic and societal applications from space data and infrastructures.
2. Enhance technology transfer and valorization.
3. Strengthen ties between academia, research institutes, and ESTEC.
4. Share and maintain research facilities.
5. Improve the visibility of the space sector and ESTEC within the Dutch knowledge infrastructure.

Given the public discussion on the budgetary outlook for optional ESA programs, this white paper explores what actions can be taken in these five areas.

2. Spinning in and off: stronger linkages between ESTEC and the Netherlands

2.1 Economic and societal applications from space data

Satellite data form the core of the downstream space market

Satellite data connect the upstream (space infrastructure) technology with the downstream (space applications) market. There is already strong collaboration between science, research and development (R&D) organizations, industry, and user communities on the development and maintenance of the technology and related applications. This is necessary, as the user requirements need to be translated into technical and scientific requirements and, conversely, the user communities need to be made aware of new science and technology developments. A shift is now occurring, from a primarily public (authorities) market toward commercial markets.

They also enhance the competitiveness of other top sectors and produce societal gains

The downstream services, i.e. applications based on satellite data, can be viewed as an enabler for many other top sectors. Spatial information plays an important role in many activities, such as georeferencing, mapping, change detection, surface deformations, and the state and quality of land, water and atmosphere. Satellite data are an important source of spatial information and, as the quality and number of satellites increase, the number of users of these data is growing rapidly. As a consequence, the related commercial services sector is growing rapidly, also in the Netherlands.

Applications	Organizations
National satellite data portal: provides GMES-compatible satellite data for satellite application development, knowledge creation, and support for market development	Geo-ICT companies, satellite value-adding companies, service companies, knowledge institutes, universities, institutional service providers, government geo-ICT organizations
Agrofood: precision agriculture, yield mapping and prediction, moisture assessment, food security	eLEAF, SARVision, EARS, Geomatics Business Park, Wageningen University, Alterra, ITC/University of Twente, Geoserve, Delft University of Technology, TNO
Water: flood prediction and 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 and climate covenant partners, Delft University of Technology, port authorities, water boards
Logistics: navigation, routing, transport safety, Automatic Identification System, tracking and tracing	BMT ARGOSS, Arcadis, Logica, NLR, TNO, Ursa Minor, port authorities
Energy: monitoring climate change/treaties, supporting on- and offshore 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, Dutch contractors, Delft University of Technology , ECN, TNO

ESTEC helps entrepreneurs and researchers

ESTEC is one of the key technology centers for these activities and manages the relevant ESA programs (Earth Observation Envelope Program, Integrated Applications Promotion, Telecommunications, Technology Development). ESTEC's proximity offers unique access for Dutch entrepreneurs, as geographical barriers to engaging with ESTEC personnel are simply lower. ESTEC activities are carried out in the surrounding region. For example, initial experiments on the PARIS campaign, a project using GNSS reflectometry (navigation time signal) technology to measure macro-scale movements, were performed in Rotterdam. Experiments to calibrate a radar payload for the RADAR project were carried out in Flevoland.

Present efforts to facilitate economic and societal applications

The "linking pins" between ESTEC and its programs on one hand and satellite applications users on the other are the ESA Business Incubation Centre (BIC) in Noordwijk and the Geomatics Business Park in Flevoland. These centers host the

start-up companies that develop new applications and the value-adding companies that translate data into products and services for specific markets. ESA BIC Noordwijk was created in partnership with national and local entities. It supports 10 start-ups per year; since its inception, 70 start-ups have received support (compared to 140 total ESA BIC start-ups in Europe). ESA BIC is housed in the Space Business Park in Noordwijk, which has 15 hectares for space-related businesses. These start-ups make use of ESTEC's nearby expertise, support and facilities to apply space technology to new solutions.

National satellite data portal

Within the next few years, the European Global Monitoring for Environment and Security (GMES) program will provide continuous, free Earth observation data. That makes operational applications that rely on frequent inputs possible, such as precision agriculture, water management, land movement, algae monitoring, and more. The Netherlands Space Office and the Ministry of Economic Affairs, Agriculture and Innovation have taken the initiative to prepare Dutch industry, institutes, and government prior to the launch of GMES by making data available through the national satellite data portal. This enables industry and institutes to already begin developing new applications and allows (government) users to prepare for new information services that become available in their policy domains. The satellite data portal was opened on March 21, 2012 and already some 70 business users have registered, ranging from small IT value-adders to large engineering firms and from varying domains such as water, horticulture, nature protection and infrastructure management (http://www.spaceoffice.nl/nl/Satellietdataportaal).

An example of new business

eLEAF's mission is to be the global reference for reliable data on water and vegetation on any land surface to support sustainable water use, increase food production, and protect environmental systems. eLEAF is building a global, accessible information infrastructure on vegetation, water, and climate to help feed the world sustainably. eLEAF's product offering targets the entire agribusiness value chain, ranging from farmers to food processors as well as non-profit organizations, public institutions and governments.

Two recommendations

The top team has two recommendations to stimulate the application of satellite data for commercial and societal purposes:

1. Stimulate the space applications market by raising awareness of and demonstrating commercial applications to the other top sectors as potential users. The four top sectors agrofood, energy, water, and logistics are viewed as the most promising (see also the background document Downstream on our website: www.htsm.nl/Roadmaps/Space). Under the supervision of the Netherlands Space Office, other key actors to be involved here are ESA BIC, TNO, NLR, and the top teams of these four top sectors.
2. Strengthen links between ESTEC and (regional) industry, research, and development clusters (ground-based, space-based, geomatics). Here regional actors should take the lead. The top team welcomes the initiative taken by the Holland–Rijnland region (Leiden, Noordwijk and Delft) to strengthen the space cluster linking ESTEC, the Space Business Park, the Leiden Bio Science Park and the universities in Leiden and Delft.
   The province of Flevoland can take the lead in further developing the Geomatics Business Park and the new opportunities it offers for fledgling and established businesses.

2.2 Technology transfer and valorization

The ESTEC Technology Transfer Program Office
ESTEC already actively supports technology transfer to non-space applications (spin-off). Technologies resulting from the various European space programs that are being developed by European industry are made available through the Technology Transfer Program Office located at ESTEC (http://www.esa.int/esaMI/Technology/).

The Dutch Technology Transfer Program
The Dutch Technology Transfer Program, which ran up to 2009, was an excellent technology transfer mechanism for exploring the feasibility of space technology for non-space applications, one particularly well suited to start-ups and SMEs. The program provided 50% support to feasibility studies (thus requiring a minimum of 50% private funding) up to a maximum of €30,000. The program supported 40 feasibility studies in its 2001–2009 operating period. Of these, 12 have resulted in a commercial success and 10 in a potential commercial success. One example is the development of a composite hydrogen cartridge, with technology "donors" ESA and Bradford Engineering and technology "recipient" Formula Zero (see box below).

Composite hydrogen cartridge for Formula Zero
Transportation without negative effects on the environment is something we all want. Fuel cells and the hydrogen economy bring us the promise of a clean energy future. Interestingly, the technology is already available today; the next step is to gain mass support by capturing the interest of the general public. Formula Zero is a new generation of auto racing that exploits motorsport's popularity to champion clean fuel by using fuel cell-powered go-karts.

In setting up Formula Zero, however, the problem of how to store hydrogen safely was raised. The answer came from a collaboration between Formula Zero, TNO Space, and Bradford Instruments, a spin-out company from the Dutch firm Bradford Engineering BV. The result: the H2 Cartridge co-developed by Formula Zero and Bradford Instruments and designed to make a safe "click and go" cylinder exchange possible for small to medium fuel cells. In developing the H2 Cartridge, Bradford Instruments used Bradford Engineering's knowledge of gas handling systems, developed for space applications. In return there are opportunities to spin hydrogen handling systems back into the space industry, based on the experiences with the high-pressure hydrogen storage cartridge for Formula Zero's fuel cell race kart.
(source: http://esamultimedia.esa.int/docs/industry/TTPO/ESAtoday/ESA-Today_on-TTP_April07.pdf)

Matchmaking activities
An important aspect of technology transfer and new entrepreneurship is matchmaking between people and organizations. This is accomplished through Space-MATCH, an annual event to present space technology to non-space industry. A further valorization mechanism is the TNO Small Business Innovation Research program, matching TNO space technology with innovative entrepreneurs in order to bring new products and services to market.

Networking and Partnering Initiative
While technologies for space have significant spin-offs for non-space applications, some very advanced technologies developed by universities and research institutes for industrial or domestic applications often have potential spin-in for use in space. For this reason, ESTEC runs the Networking and Partnering Initiative (NPI). The NPI invites universities and research organizations to submit innovative proposals that extend their research activities into any technical field relevant to space and make a vital contribution to Europe's space program. The NPI provides an important opportunity for the space sector to take advantage of potential spin-ins from new technologies in non-space sectors such as consumer electronics, material sciences, and the emerging nano- and microtechnology domains.

By intensifying its interaction with university departments and research institutes, ESA intends to strengthen those organizations' links with space institutions and industry, encouraging them to embark upon space-related technology and make a vital contribution to meeting the long-term needs of Europe's space program. Accepted proposals are offered support in a number of ways:

- Co-funding – The NPI can co-fund research up to 50% or €30,000 per year for a doctoral degree or post-doctoral investigations.
- Access to ESTEC laboratories – NPI participants are able to use ESTEC facilities for a minimum of 6 and a maximum of 12 months.
- Technical support – NPI participants gain access to ESA experts with whom they can discuss proposal concepts and verify their potential for space applications.
- Networking – NPI participants are able to search for industrial partners for further cooperation and build "innovation networks" through ESA links.

Untapped opportunities in technological spin-in and spin-off

On the basis of a short survey by TNO Space, the top team has identified technology areas and application domains within the HTSM sector, other top sectors and non-space that are promising with regard to technology transfer from and to space (see also appendix 1). The most promising spin-off areas are semicon equipment, solar energy, health care, automotive, aeronautics, and high-tech materials. This should also promote technology transfer from those areas back into space. Regarding other top sectors, the top team views three as promising: energy (space technology is being applied in the development of nuclear fusion), water (lab-on-chip nanotechnology, developed in the framework of Mars planetary exploration and the search for extra-terrestrial life, is being applied to measure the quality of terrestrial water), and agrofood (the same lab-on-chip nanotechnology is also being applied to pathogen detection for food security).

The crossover between semiconductor equipment and space

- The crossover between semiconductor equipment and space lies primarily in the area of optomechanics: the expertise to combine the optical and mechanical design in an optimal way to realize a highly accurate imaging system that performs well under extremely harsh conditions.
- In the near future, lithography will see the introduction of extreme ultraviolet wavelengths. Space technology will be able to support the development of dedicated EUV optics with high reflectivity and long lifetimes and to address problems with regard to thermal loading and energy usage in future systems. In order to achieve higher productivity, the position accuracy of future production machines will have to come down to the picometer level. Space technology has already proven it is able to realize extreme metrology demands and it will provide the expertise to minimize the all-important thermal effects.

Four recommendations

The top team has four recommendations to increase the crossover between space and top sector roadmaps:

3. Improve matchmaking and crossovers between ESTEC and ESA programs on the one hand and Dutch industry on the other by re-establishing the Dutch Technology Transfer Program as an efficient method for technology transfer linked to the ESA incubator. Within the Netherlands in the past decade, 40 feasibility studies for technology transfer have been carried out (ESA/government/TNO funding approx. 0.2 M€ per year with at least equal industry matching), resulting in 12 commercial successes and more than 10 potential commercial successes. The top team will link this recommendation to its efforts to set up a Small and Medium-sized Enterprise (SME) program within the Top consortium Knowledge and Innovation HTSM.
4. Organization of Space-MATCH by the Netherlands Space Office in 2012 within the framework of the innovation contract for the top sector HTSM.
5. The HTSM top team should make a continued effort to stimulate crossovers between the space roadmap and other HTSM roadmaps as a task of the Top consortium Knowledge and Innovation for this top sector. The potential for crossovers should also be reflected in the programmatic choices for Dutch participation in optional ESA programs. Therefore the Cabinet should take into account—besides the existing strengths of Dutch industry and knowledge institutes—possible crossovers with other roadmaps in the top sector HTSM and other relevant top sectors. The Netherlands Space Office has to take these considerations into account in its advisory role, by consulting the HTSM top team and the different roadmap teams at an early stage.
6. Stimulate technology transfer from other HTSM roadmaps and top sectors toward ESTEC by making better use of ESTEC's Networking and Partnering Initiative. The NPI can become a more (pro)active instrument for the spin-in of advanced technologies developed in universities and research institutes for non-space applications. The structured dialogue mentioned in recommendation 7 can serve as the platform for this exercise.

2.3 Stronger ties between academia, research institutes and ESTEC

Linking people together
Innovation comes from people. Therefore the top team feels that, in order to capitalize on the opportunities for technology transfer and economic and societal applications described in sections 2.1 and 2.2, stronger ties need to be developed between the people in Dutch academia, research institutes and ESTEC. The building blocks that form the foundation for strengthening these ties have already been established. Collaboration is already strong in some areas (such as the co-development of the Robotics Lab by ESTEC and TU Delft described under 1.3). These often ad hoc informal contacts can be turned into a structured dialogue to foster cooperation. There are programmatic ties between the mission advisory groups and scientific advisory groups for ESA programs and activities directed from ESTEC. Opportunities also exist for joint research projects under the European Research and Development programs.

Figure 3: SRON develops instruments for use in space

Projects and facilities offer another mechanism for contact with Dutch academia and knowledge institutes. Proximity to ESTEC allows easy access to both expertise and facilities such as the Life Support laboratory. Last but not least, ESTEC has an active outreach program, opening its doors to visits from young researchers to ESTEC facilities, participating in projects (master theses), providing guest lecturers from its staff, and participating in joint ESA-university funding of PhDs and postdocs. On a different level, the HTSM top team feels that the national government should keep up its efforts to ensure that a sufficient number of Dutch nationals work at ESA and ESTEC, not only in the scientific domain, but also in management positions. These jobs not only offer exciting career opportunities, but also aid the balancing of national interests.

ESTEC's greatest asset is its people; its 1,580 scientists and engineers have backgrounds in physics, mathematics, electrical engineering, mechanical engineering, software and systems engineering, life sciences, and quality and product assurance. ESA's Young Graduate Trainees program offers recently graduated men and women a one-year (with the opportunity for a one-year extension) training contract designed to provide valuable work experience and to prepare them for future employment in the space industry and space research. The Advanced Concepts Team brings together young scientists and engineers with different backgrounds to find breakthrough solutions.

Two recommendations

7. The Cabinet is advised to initiate a structured dialogue between ESTEC and relevant research institutes in the Netherlands, i.e. the three technical universities and the beta-technical faculties of the general universities, NLR, TNO, SRON, STW, FOM, ASTRON, and the NWO domains Physical Sciences and Earth and Life Sciences, with the objective to intensify the cooperation within the space community and stimulate the crossover of know-how between space and non-space. Proposed elements for this dialogue are strengthening the ESTEC Networking and Partnering Initiative, shared professorships, the exchange of PhDs and post-docs, education, training, and the pooling of specialists. This structured dialogue can build on the existing informal contacts and should be facilitated by an independent chairperson with a profile and background in both academia and industry.
8. Explore cooperation between ESTEC and Dutch universities and companies through teaming up in EU programs, including joint technology initiatives and key enabling technologies.

2.4 Sharing and maintaining research facilities

Academic facilities within ESTEC and in Dutch research institutes, such as those of the Netherlands Organization for Scientific Research (NWO), are often already open to "outside" use. This sharing of facilities is not only an efficient use of financial resources, but also a way to bring people from different organizations together. As such, it underpins human capital development and the flow of people and ideas. Furthermore, Dutch experts are well positioned to engage in the maintenance and upgrading of these extremely sophisticated facilities, which is often outsourced. Although forms of facility sharing already exist, they can be developed further within the framework of the structured dialogue in recommendation 7.

Figure 4: The Hydra Shaker tests satellites, but also large objects such as trains

ESTEC can provide technical and scientific expertise support to universities, research institutes and national agencies. In some cases, client organizations are able to perform their own tests using ESTEC facilities with the assistance of ESA personnel. ESTEC's facilities include engineering labs and the Concurrent Design Facility (CDF), as well as 17 laboratories specializing in electrical engineering, mechanical engineering, software and systems engineering, and quality and product assurance (such as the Propulsion Lab and the Radio Navigation Lab). In addition there are the ESTEC Test Centre, the Large European Acoustic Facility, the Hydra six-axis hydraulic shaker test facility, and the Large Space Simulator.

One recommendation

9. Within the framework of the structured dialogue, develop an infrastructure-sharing mechanism and investigate the pooling of competences and facilities between ESTEC and Dutch research institutions, such as the collaboration with Delft University of Technology on the Robotics Lab.

2.5 Improving ESTEC's visibility in the Dutch knowledge infrastructure

We conclude that the space sector should communicate its activities, including those of ESTEC, more often and more clearly; should demonstrate the social and economic relevance of its work; and should explain the role space plays in high-tech research and development. This should lead to better visibility of ESTEC, which can then serve as a basis for the success of the preceding recommendations.

One recommendation

10. The Netherlands Space Office, the space roadmap team for the top sector HTSM and ESTEC should work together to develop a communication plan to improve ESTEC's visibility. Better ESTEC and space industry visibility will significantly facilitate the previous recommendations.

Appendix 1: Technology crossovers from space to other roadmaps in the top sector HTSM and other top sectors

The objective was to identify technology transfer (crossover) opportunities from space to the other technology areas and application domains within the HTSM sector, from space to the other top sectors, and from non-space to ESTEC. These are described below. Under contract to ESTEC, industry and R&D organizations have built up technical expertise that can be transferred to other HTSM roadmaps. A first assessment has identified six application domains and technology areas within HTSM for technology transfer from and to space.

1. Semicon equipment
2. Solar energy
3. Health care
4. Automotive
5. Aeronautics
6. High-tech materials

1. Semiconductor equipment

The current strong semiconductor position of Dutch companies (especially ASML) is in part due to the expertise gained in the Netherlands starting in the late 1960s regarding the design and realization of astrophysical instruments. This led to global excellence in the development of high-precision optomechanical instrumentation for extreme conditions (e.g., vacuum, cleanliness levels, and high mechanical, thermal, and UV loading). This exceptional technology base has given the Dutch semiconductor industry a considerable boost from the 1990s onward.

The crossover between semiconductor equipment and space lies primarily in the area of optomechanics: the expertise to combine the optical and mechanical design in an optimal way to realize a highly accurate imaging system that performs well under extremely harsh conditions.

In the near future, lithography will see the introduction of extreme ultraviolet wavelengths. Space will be able to support the development of dedicated EUV optics with high reflectivity and long lifetimes and to address problems with regard to thermal loading and energy usage in future systems. In order to achieve higher productivity, the position accuracy of future production machines will have to come down to the picometer level. Space has already proven it is able to realize extreme metrology demands, and it will provide the expertise to minimize the all-important thermal effects.

2. Solar energy

The crossover between solar energy and space logically lies in the area of photovoltaics. Most satellites use solar panels for their energy supply, with a strong focus on efficiency, reliability, robustness, and durability in the harsh environment of space. Therefore these “space panels” are often too expensive for the earthly market, where the focus is primarily on efficiency and low cost. Thus the crossover area between solar energy and space does not lie in the development of the solar cells themselves, but primarily in the optimization of the production process and manufacturing equipment.

Some of the most promising crossover areas are listed below:

- in-line inspection and quality control (e.g., contamination control)
- production optimization (e.g., integration of process steps; atmospheric vs. vacuum)
- green processing (e.g., reduced use of solvents, cleaning materials, and gases)
- materials optimization and innovation (e.g., flexible encapsulants, diffusion barriers, antireflection layers, and substrate materials (low cost, high-temperature resistant))

3. Health care

The crossover between health care and space lies primarily in the area of medical imaging. The majority of astrophysical observations are made using the electromagnetic spectrum – the same spectrum used for medical imaging. In astrophysics, the ambition to look back in time to the creation of the universe has resulted in the creation of increasingly sensitive detectors. Current detectors, such as those developed by SRON, are even able to detect a single photon. These developments from space can be used to improve the detection capabilities of future medical imaging equipment, providing better image quality and enabling reduced radiation levels.

Interesting transfers may also be established in the area of home and community care, based, for example, on developments in human spaceflight and space exploration. An illustrative example from the past is the development

of a portable device to continuously and non-invasively monitor astronauts' blood pressure. This development, originally financed by NASA, CNES and ESA and performed by TNO in the 1990s, led to the production of a commercially very successful instrument for ambulatory blood pressure measurement, the Portapres.
A more recent example is the development of an optofluidic lab-on-a-chip by Lionix for the ESA ExoMars mission. This demanding space application is a perfect starting point for the development of a range of robust and lightweight diagnostic instruments in the medical, pharmaceutical, food quality, environmental, and safety and security fields.

4. Automotive

One of the crossover areas between automotive and space lies in the area of smart mobility, making use of the future Galileo network of European navigation satellites. The Galileo network will provide more accurate and more reliable signals than the current GPS system.
Other transfers may take place in the area of light constructions: for example, using high-tech composite materials such as carbon fiber reinforced plastics and fiber metal laminates.

5. Aeronautics

Several crossover areas between aeronautics and space have been identified:

- aerostructures: composites, coatings, fiber metal laminates, and structural health monitoring
- engine subsystems and components: high-temperature materials
- future concepts: self-healing and multifunctional materials

6. High-tech materials

The crossover between high-tech materials and space lies primarily in the area of hybrids and composites. The space sector initiated the first industrial applications of carbon fiber reinforced plastics in order to manufacture lightweight but strong constructions. The potential of these materials is huge, especially if we succeed in further increasing the strength-to-weight ratio in combination with cost reductions.
This is typically an area of strong collaboration with many common research issues:

- improved toughness
- impact
- fatigue and corrosion behavior
- improved resins and injection techniques
- 3D composites to increase design freedom
- minimum shrinkage
- automated fiber placement
- nanocomposites
- improved properties at high temperatures
- joining, inspection, and repair methods

7. Technology transfer to and from other top sectors

Direct technology transfer to and from other top sectors can be significantly increased. The following examples are currently ongoing:

- Energy: space technology is being applied to the development of nuclear fusion.
- Water: lab-on-chip nanotechnology, developed in the framework of Mars planetary exploration and the search for extraterrestrial life, is being applied to measure the quality of terrestrial water.
- Agrofood: the same lab-on-chip nanotechnology is also being applied to pathogen detection for food security.
- Security: the world-class radar technology developed in the defense framework is being adapted to meet requirements for use in space.
- Horticulture: existing horticultural knowledge of closed ecosystems and recycling is being adapted for use in the International Space Station and for the development of other future habitats in space.

Appendix 2: Acknowledgements

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Name	Organization
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Geert Mennenga	Dutch Space
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Bas van der Peet	NLR
Eddy Pijpers	NLR
Frans Martens	NWO
Eric Vredebregt	Province of South-Holland
Roel Gathier	SRON
Henk Hoevers	SRON
Rinze Benedictus	Delft University of Technology
Eberhard Gill	Delft University of Technology
Bas Dunnebier	TNO
Ad Maas	TNO

Appendix 3: Top team High Tech Systems and Materials

Chair

A.H. (Amandus) Lundqvist
Chair Surf Foundation, past chair Board Technical University Eindhoven, past CEO IBM Netherlands

Members

Science
D.H.A. (Dave) Blank
Professor University Twente, scientific director MESA+

Government
J.K. (Jasper) Wesseling
Deputy-director general, Ministry of EL&I

SME
M.H. (Marc) Hendrikse
CEO NTS Group

Secretariat

Government
E. (Eelco) van der Eijk
Ministry of EL&I

Industry
A.J. (Fred) van Roosmalen
FME, editor-in-chief innovation contract

Industry
G. (Geert) Huizinga
FME

Science
E.E.W. (Eppo) Bruins
STW

Science
A.J.A. (Arnold) Stokking
TNO

More information can be obtained from:

Office top team High Tech Systems and Materials

Boerhaavelaan 40
Postbus 190
2700 AD Zoetermeer
The Netherlands
www.htsm.nl
www.hollandhightech.nl

Projectmanagement
DB Huisstijlmedia

Design
Bruikman Reclame, Den Haag

The Hague, May 2012