

Evaluation 2005-2010

SRON Netherlands Institute for Space Research

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1 Introduction

1.1 Scope and context of this review

This assessment concerns the research carried out at the SRON Netherlands Institute for Space Research since 2005. The evaluation was commissioned and organised by the Netherlands Organisation for Scientific Research (NWO).

The external evaluation follows the Standard Evaluation Protocol 2009-2015 (SEP). This is the protocol for research assessment in the Netherlands as agreed by NWO, the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Association of Universities in the Netherlands (VSNU).

The aims of the assessment procedure with regard to research and research management are:

- Improvement of research quality, including the scientific and societal relevance of research, research policy and research management, based on an external peer review;
- Accountability to the board of the research organisation, and to funding agencies, government and society at large.

To the evaluation criteria in the SEP, NWO added some supplementary questions addressed to the Evaluation Committee and the institute itself; some questions were to be raised in all evaluations of the NWO institutes in 2011, and four were specifically devised for SRON.

An Evaluation Committee was established and asked to produce a reasoned judgement of the institute and its research programmes in accordance with the SEP.

Prior to the external evaluation, SRON submitted a self-evaluation document covering the period 2005-2010. This report was approved by the Governing Board of NWO in October 2011. The self-evaluation report was drafted in accordance with the SEP guidelines and provided information both at the institute level and at the level of the research groups.

The self-evaluation report therefore offered a concise picture of the institute's and research groups' work, ambitions, output and resources.

Site visits form an important part of evaluations; both SRON's sites, in Utrecht and in Groningen, were visited. The committee held interviews with the management of the institute, the Science Advisory Committee, the SRON Board, division heads, scientific staff members, PhD students, postdocs, and technical and support staff. SRON offered a tour of the institute's cleanrooms and the laboratories at both locations.

1.2 The Evaluation Committee

The Evaluation Committee was appointed on 6 December 2011 by the Governing Board of NWO.

The members are:

Prof. dr. Anneila Sargent, chair	Caltech (USA)
Prof. dr. Reinhard Genzel	Max-Planck-Institut für Extraterrestrische Physik (D)
Dr. Chryssa Kouveliotou	NASA/Marshall Space Flight Center (USA)
Prof. dr. Ulrich Platt	Universität Heidelberg (D)
Prof. dr. Jonas Zmuidzinas	Caltech (USA)
Dr. Jerry Krill	Johns Hopkins University Applied Physics Laboratory (USA)

A short curriculum vitae of each of the members is included in Annex 1.

The Committee was supported by NWO staff (Marjolein Robijn and Raymond Schorno). Before the site visits all members of the Committee signed the NWO Code of Conduct, declaring that their assessment would be free of bias and without regard to personal interest, and that they had no personal, professional or managerial involvement with the institute or its research programmes. It was concluded that the Committee had no conflicts of interest.

1.3 Data supplied to the Committee

The Evaluation Committee received the SRON self-evaluation report, together with a bibliometric study of SRON over the period 2000-2010 and a report on the institute's relations with small and medium-sized enterprises. The Committee also received the site visit programme (included as Annex 2) and an explanatory letter referring to the secure SRON website and providing the codes for accessing that site. The secure website provided access to some additional documents, including the CVs of a subset of research staff and a list of guest researchers.

The self-evaluation report dealt with SRON's objectives, composition, quality and scientific relevance, scientific output, earning capacity, academic reputation, societal relevance, viability and short-term and long-term future strategy. In addition, the report contained information on the training of coming generations of researchers and a SWOT analysis of the institute, highlighting important developments that affect SRON. Supplementary SWOT analyses at the level of the two main programme lines, Astrophysics and Earth and Planetary Atmospheric Science, were included in the appendices. A total of eight appendices contained further information on the enabling and underpinning technologies, research output at institutional and programme level, signs of recognition of SRON research staff, and the composition of the SRON Board and Science Advisory Committee, as well as answers to the additional questions addressed to the institute by the NWO Governing Board.

The self-evaluation report contained tables – statistics presented both at institute level and at the level of the research groups – on SRON staff (tenured, non-tenured, PhD students, support staff, visiting fellows), on research output from SRON researchers (articles in refereed journals, articles in proceedings, books, theses, other scientific publications, popular/public presentations, media appearances), on the progress of PhD students (gender, year of enrolment, success rates per year), and on additional funding acquired (personal grants, contracts, project support and PI-related funding).

The documentation supplied to the Committee included all the information required by the SEP.

1.4 Procedures followed by the Committee

The Committee proceeded in accordance with the Standard Evaluation Protocol 2009-2015. The assessment was based on SRON's self-evaluation document and the other documentation provided by the institute, as well as on the presentations and interviews held during the site visits. The visits to both SRON sites, in Utrecht and in Groningen, took place from 6 to 8 December 2011. The programme of the visits is included in Annex 2.

The Committee met on the morning of 6 December to discuss and plan the interviews with SRON's Directorate, Science Advisory Committee, Governing Board, division heads, research staff, PhDs, postdocs, and technical and support staff. The Committee agreed on procedural matters and aspects of the assessment as described in the following paragraphs.

At a formal lunch in Utrecht, the Committee was informed of the aims of the evaluation by Professor B. de Kruijff, a member of the NWO Governing Board. In the afternoon, interviews were held at SRON with the SRON Directorate, the Science Advisory Committee and the Governing

Board. The Evaluation Committee was officially installed at a formal dinner with Professor J.J. Engelen, chair of the NWO Governing Board, and Professor B. de Kruijff.

The interviews with the SRON division heads, research staff, PhD candidates, postdocs and technical and support staff took place during the site visits to Utrecht on 7 and Groningen on 8 December 2011.

After completing the interviews, the Committee discussed the scores and comments with regard both to the institute and to the research programmes and divisions. The Committee reflected on the past performance of the institute over the period 2005-2010 and on its current and future strategy. Scores were determined as requested by the SEP for each of the four main SEP criteria; quality, productivity, societal relevance and vitality and feasibility.

At the end of the site visits, a meeting was held with the SRON Directorate and the chair and one member of the SRON Governing Board to report the Committee's main preliminary findings.

In March 2012 a draft version of the evaluation report was sent to the Director of SRON for factual correction and comments. The report was subsequently submitted to the Governing Board of NWO.

1.5 Aspects and assessment scale

The Standard Evaluation Protocol 2009-2015 requires the Evaluation Committee to assess four main aspects of the institute and its research. These are:

- Quality (sub-criteria: quality and scientific relevance of the research, leadership, academic reputation, organisation, resources, and PhD training);
- Productivity (productivity strategy and the actual productivity);
- Societal relevance (such as societal quality, societal impact, and valorisation);
- Vitality and feasibility (strategy such as strategic planning, SWOT analysis, robustness and stability).

These four main assessment criteria are rated according to a five point scale, as specified in the SEP. The verdict can be given in qualitative form, though a quantitative figure may be added. The scale is as follows:

5. Excellent

Research is world leading. Researchers are working at the forefront of their field internationally and their research has an important and substantial impact in the field.

4. Very good

Research is internationally competitive and makes a significant contribution to the field. Research is considered nationally leading.

3. Good

Work is competitive at the national level and makes a valuable contribution in the international field. Research is considered internationally visible.

2. Satisfactory

Work adds to our understanding and is solid, but not exciting. Research is nationally visible.

1. Unsatisfactory

Work is neither solid nor exciting, flawed in the scientific and/or technical approach, includes repetition of other work, etc.

2 Institutional framework of SRON

2.1 Mission

SRON's mission is to conceive and develop world-class innovative space instruments for Astrophysics and Earth and Planetary Atmospheric Science and to analyse the data provided by these instruments for advanced research. SRON is also the national institute that promotes, coordinates and supports Dutch activities in space research and advises the Dutch government on participation in international space research programmes, in particular those of ESA. It supports the knowledge economy by making its knowledge and expertise available to Dutch society.

SRON's research programme is based on the close interaction between the scientific challenges in specific areas, technological and scientific expertise, and the ability to develop, build and deliver instrumentation that meets the specifications for operations in space. It is this combination that gave rise to several Principal Investigator (PI) contributions in the past and that has given the institute a leading position in the international space research arena. It is SRON's firm ambition to continue in this leading position in future international space missions, and to keep on contributing significantly to scientific breakthroughs in Astrophysics and Earth and Planetary Atmospheric Science.

2.2 Research

SRON has two main programme lines, namely Astrophysics and Earth and Planetary Atmospheric Science. The focus is on key scientific questions that are formulated by the international science community in documents such as the ASTRONET roadmap, ESA's Cosmic Vision 2015-2025 programme, and ESA's The Living Planet programme. In principle, research is focused on topics that can be properly addressed only from space, with sensors that are optimised for the parts of the electromagnetic spectrum that are accessible only from space. In the case of atmospheric science, the main reason to use satellite instrumentation is the need for consistent global observations. Choices are further guided by the conviction that technological advances can push the frontiers of scientific discovery. This belief is at the heart of SRON's existence.

- The Astrophysics programme (High-Energy Astrophysics, HEA, and Low-Energy Astrophysics, LEA, Divisions) addresses several of the fundamental questions raised in ESA's Cosmic Vision programme: What are the fundamental physical laws of the universe? How did the universe originate and what is it made of? What are the conditions for planet formation and the emergence of life? To answer these questions SRON focuses on the use of spectroscopy at high (X-ray) and low (infrared and submillimetre) energies to study the physical and chemical properties of objects of interest.
- The Earth and Planetary Atmospheric Science programme (Earth and Planetary Science Division, EPS) addresses the physical, chemical and dynamical properties of the atmosphere of the Earth, the planets in the solar system and exo-planets. The main emphasis is on Earth atmospheric research with a strong interest in the themes of climate change, air pollution and ozone depletion, focusing in particular on the global carbon cycle, the global water cycle and aerosol. SRON employs spectroscopy and spectropolarimetry to address these topics. A few years ago its activities in Earth gravity field research (gradiometry) were discontinued in favour of the new field of planetary and exo-planetary atmospheric research, pursued in synergy with Earth atmospheric research.

Sensor research and technology (SR&T) is an integral part of SRON's programme. It enables and facilitates the development of novel instruments of world-class performance to meet scientific needs in the Astrophysics and Earth and Planetary Atmospheric Science programmes. The enabling technology programme (Sensor Research and Technology Division) concentrates on

those components that determine ultimate instrument performance, such as detectors, read-out electronics and optical components. In this context, the SR&T Division employs new detectors and/or existing detection principles and develops them further to fit the application. Since sensors are not operated in isolation, the research is done in close collaboration with the Engineering Division (ED), which provides crucial and innovative support concerning mechanics, electronics and product/quality assurance.

2.3 Organisational structure

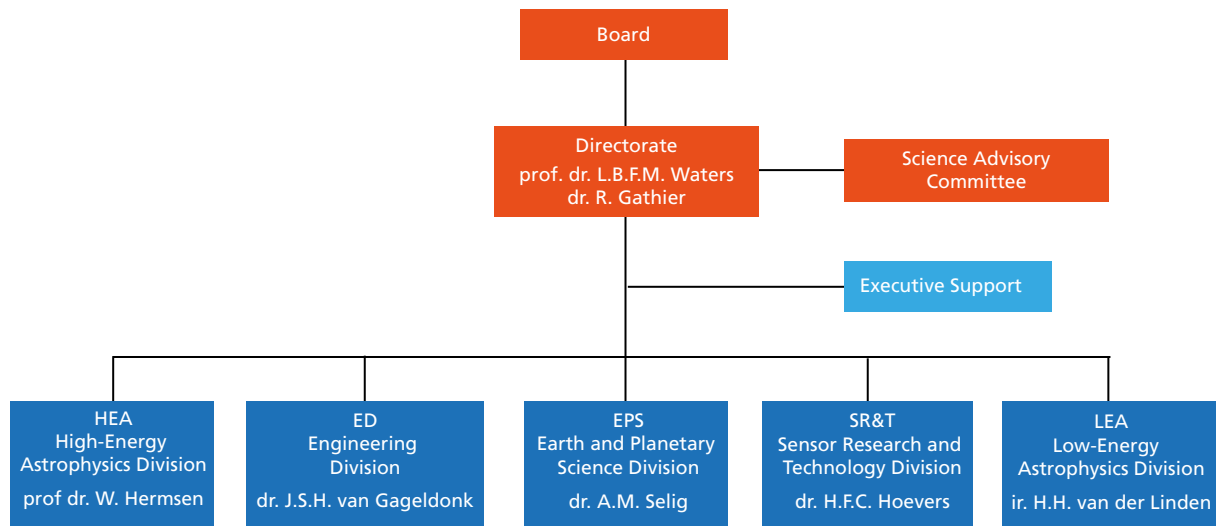


Figure 1 | SRON organisation chart

2.4 Financial matters

Table 1 shows an overview of SRON's funding. 'Direct funding' is the basic funding from NWO and the universities in Groningen and Utrecht (76% of SRON's income over the past 6 years). 'Contracts/grants' (16% on average) is funding acquired in competition. 'Other' (8% on average) is the special support that SRON received to speed up HIFI flight hardware production, funding not directly related to projects, etc.

Table 1 | SRON funding 2005-2010 in k€

	2005	2006	2007	2008	2009	2010
Funding						
Direct funding	13.591	13.742	14.228	14.656	15.152	14.506
Contracts/ grants	3.331	1.752	1.974	2.342	4.661	3.026
Other	3.122	3.123	2.979	2.061	1.544	1.512
Total funding	20.044	18.617	19.182	19.059	21.357	19.044

2.5 Staff

Table 2 | SRON staff 2005-2010 (in FTE-years)

	2005	2006	2007	2008	2009	2010
Tenured research staff	58.9	58.6	63.5	64.2	63.0	59.9
Non-tenured research staff	27.5	31.1	20.9	18.7	25.4	31.0
PhD students	10	9	9	8	13	17
Total research staff	96.4	98.7	93.4	90.9	101.4	107.9
Technicians and equivalent	46.0	44.4	46.8	53.3	58.7	54.7
Support staff	40.8	38.0	38.8	37.9	37.8	35.5
Total technicians & support	86.8	82.4	85.6	91.2	96.5	90.2
Total	183.2	181.1	179.0	182.1	197.9	198.1

3 Assessment of the institute

Institute level

Quality	5	Excellent
A2 Leadership	5	Excellent
A3 Academic reputation	5	Excellent
A4 Organisation	5	Excellent
A5 Resources	4-5	Very good / Excellent
A6 PhD training	5	Excellent
Productivity	5	Excellent
B1 Productivity strategy	5	Excellent
B2 Productivity	5	Excellent
Relevance	5	Excellent
C1 Societal relevance	5	Excellent
Vitality and Feasibility	5	Excellent
D1 Strategy	5	Excellent
D2 SWOT analysis	5	Excellent
D3 Robustness and stability	4-5	Very good / Excellent
Overall	5	Excellent

As already described in §2.1, SRON's over-arching mission is to conceive and develop world-class programmes and instruments for space research projects in Astrophysics and Earth and Planetary Atmospheric Science, and hence to advance understanding in these fields. An integral part of this mission is to support Dutch activities in space science in the broadest sense of the term, and to make the institute's knowledge and expertise available to Dutch society. To this end, SRON is organised into several interactive divisions. Three of these, Astrophysics, comprising High-Energy Astrophysics (HEA), Low-Energy Astrophysics, and Earth and Planetary Science (EPS), are focused on scientific research programmes. In order to undertake ground-breaking research, particularly in space, HEA, LEA, and EPS work closely together with a fourth division, Sensor Research and Technology (SR&T). The SRT programme concentrates on developing and improving components, such as detectors, that can lead to dramatic increases in performance levels when incorporated into new instruments. In turn, SRT relies on the Engineering Division (ED) for vital technical support. With sections devoted to mechanics, electronics, software engineering, and product and quality assurance, the ED is responsible for maintaining a high level of expertise in space engineering and technology across SRON and, as a result, has a presence in the SRON laboratories in both Utrecht and Groningen.

The Evaluation Committee finds the overall quality of SRON to be excellent. Over the last five years the institute has consistently fulfilled its mission. In particular, the Committee was impressed by how effectively the institute as a whole works towards the goal of contributing significantly to scientific research by seeking leading roles in the design and construction of instruments for international science facilities, especially in space missions. The ongoing interactions between the divisions mentioned above are of enormous importance and are commended by the Committee. Briefly, the well-planned alignment of SRON's scientific themes for each research area with its front-line technology development and instrumental programmes are the key to its successes. As described in more detail in the reviews of each division in §4, these scientific research themes include, and are often dominated by, questions that are recognized both nationally and internationally as grand challenges. Over the years, the innovative technologies that SRON provides to address these challenges, coupled with its considerable experience in space research, have enabled its scientists to win PI or co-PI status on a number of international science facilities, including XMM-Newton, Chandra, Herschel, and ENVISAT. Although a relatively small institute, SRON is making an impact far beyond the bounds of the Netherlands.

The scientific and societal impacts of the results obtained by the SRON instruments associated with numerous missions, including those mentioned above, are discussed in detail in the programme assessments that follow. In this respect, the Committee would like to draw particular attention to two outstanding SRON successes since the last review. The first is HIFI, the impressive heterodyne instrument for far infrared, that was developed through SRON and enabled Dutch PI status on the Herschel mission. Scientific results from HIFI have more than exceeded expectations, and astronomers – as well as the public and the media – across the world are reaping the benefits. The beneficial effects on Dutch astronomy as a whole are particularly noticeable, as the partnerships forged by SRON with the universities are paying off in terms of front-line science and publications.

The significant overall improvement in the focus, productivity, and outlook of the Earth and Planetary Science Division (EPS) is equally noteworthy. SRON's contribution to the SCIAMACHY instrument on ENVISAT has played a major role here. In addition, as national and world interest in EPS themes such as climate change and air pollution have intensified, SRON research has risen to the challenge. Finally, the 2009 introduction of a new EPS theme, exo-planet research, is already showing some success. By grounding the new effort on their proven expertise in modelling planetary atmospheres, the exo-planet group is carving out a unique niche in a highly competitive field.

Based on these achievements alone, SRON could be justly proud of its performance. In fact, as the individual programme assessments show, there have been many other noteworthy successes. In particular, the HEA Division has continued to derive new insights from XMM-Newton and Chandra data. At the same time, due to its internationally-recognized programme of development of the next generation high resolution X-ray spectrometer using transition edge sensors (TES), this group is playing a PI role and is leading the European effort in the Japanese Astro-H mission. Again, the management strategy of gaining leadership roles in large international projects by providing a first class instrument based on in-house technology development has been very effective. The Committee reiterates its conviction that SRON's ability to build novel and needed instruments is rooted in the synergy between its scientific themes and a remarkable technology development effort that would be impressive even in a much larger institution with considerably greater resources. As a result, SRON continues not only to enhance the national astronomy effort in the Netherlands, but also to have a significant impact on international space projects. Indeed SRON's impact may well be considered disproportionally large, coming from a relatively small country and given the institute's limited financial and human resources.

In terms of academic reputation and productivity, the Committee believes it is important to recognize that the scholarly research enabled by SRON's instrument development and construction programme extends well beyond the institute itself. In this respect, the Committee found it hard to judge the institute according to the standards defined in the protocol provided. SRON instruments have, quite simply, enabled both national and international astrophysics research over a broad range of topics. In particular, the astronomy research of the Dutch universities and, by implication, the academic reputation of Dutch astronomy as a whole, has benefited enormously from SRON's connections. Indeed, the SRON-university partnership has ensured optimum scientific output and many publications, despite the fact that, over the last few years, the limited size of the basic budget has unquestionably restricted the research and publication output of SRON itself. For example, the sacrifice of a number of SRON scientific staff positions was required to ensure that the technical staffing needs of HIFI could be met within the current budget constraints. Thus, in assessing the scholarly impact and productivity of SRON, the Committee has given considerable weight to SRON-enabled research throughout the Netherlands. There is little doubt that SRON's success in making itself a key player in international space projects has impacted favourably not just on the academic reputation of its own scientific staff, but also on that of the Dutch community at large.

The organisation of SRON seems to encourage a unified focus on success. The Committee was very pleased to see that the vision articulated by the Directorate seemed to be enthusiastically embraced by the leaders of the various groups. There was a very real sense of open communication

throughout the institute and the combination of enthusiasm, optimism, and determination shown by the scientists was overwhelming.

This open communication seems to be a hallmark of the leadership style of both the (relatively new) directors and is highly commendable. It was also impressive that each group appeared to be well aware both of its strengths and of its limitations in every area. There was a clear recognition of the need constantly to re-assess the research and societal impact of each field of endeavour. Plans for the future in both astrophysics and Earth and planetary science included not only new ventures but also a well-reasoned reassignment of resources and/or personnel from other areas of research to fields where their capabilities could have a more unique impact and make more effective use of constrained funding. For example, the LEA group's focus is shifting towards research areas also of interest to HEA, such as galaxy evolution. Similar changes of emphasis are proposed within HEA to make optimum use of existing resources. Encouragingly, given the implications for climate change, the EPS group is giving high priority to potential societal impact in planning its scientific programme. Given the timeliness and relevance of SRON research on climate change and carbon distributions, for example, the Committee concurs with the SRON management's goal of stepping up EPS activities.

Among SRON's societal contributions, the enthusiasm for educating graduate students and postdoctoral fellows and the effectiveness of the institute's training programme are particularly notable. The Committee had the opportunity to meet a representative sample of each of these groups and much enjoyed hearing their views and, especially, discussing the posters that illustrated their ongoing research. All appeared to be happily and productively engaged in their various fields of endeavour and all were remarkably complimentary about their professional experiences at SRON. The graduate students are, of course, based at different universities but seem to have found a special niche – really a professional base – at SRON. There was a strong sense that the training they were receiving – especially in technology and engineering – was unique. Members of both groups spoke enthusiastically about the accessibility of mentors at the institute and about the willingness of staff at every level, both scientific and technical, to provide information and advice or assistance.

However, both groups expressed concern about the planned closure of Utrecht University's astronomy department, which has had strong links with SRON. The strong SRON-university relationship was a key factor in these young people's satisfaction with their professional situation. SRON is a small institute and it is important that students, in particular, can also enjoy the academic advantages of a larger university campus. Given that changes in location are planned for the institute in the near future, this is an excellent opportunity for SRON to establish a new or stronger relationship with another university. The Committee was pleased to learn from the Directorate that appropriate negotiations to achieve this were already well under way.

The numerous collaborations and successful research projects involving graduate students, postdoctoral fellows, and university faculty clearly demonstrate that SRON's relations with the research community continue to be very productive. HIFI has of course raised these to a new level. There is no question that the scientific returns of the novel SRON instruments have contributed enormously to Dutch astronomy and to the community at large. Likewise, SRON training of next generation high-level technical staff for industry is beneficial to society. EPS Division's research on the Earth's atmosphere and climate change, with its emphasis on greenhouse gases and on global carbon distributions, will obviously make a significant contribution to SRON's societal impact in the immediate future. In the longer term, the technologies developed at SRON may also have an important impact.

Currently, based both on Committee perceptions and on the self-evaluation report, it appears that there is a good relationship between SRON and its suppliers, with the institute involving these suppliers in the entire process, from instrument concept through fabrication and testing. It may be that this relationship could provide greater value to SRON in terms of societal relevance than is now the case. The Committee suggests that the possibility of broader commercial ventures through

SRON's vendors, for example, might be addressed more strategically. The potential for broader economic use of the facilities of both SRON and the vendor community could also be explored. Activities like these could improve vendor relations as well as adding economic value.

In short, the Committee was very favourably impressed by the quality, productivity, relevance and vitality of SRON. The long-term strategic plan was not yet complete in all its aspects at the time of the review but the Directorate provided a frank and succinct account of long-term goals and strategy. Not surprisingly, the long-term plans are grounded in SRON's successful "expertise triangle" of science driver-enabling technology-novel instrument; most of them echo and develop the opportunities laid out in the SWOT analysis. Indeed, the Committee found the SWOT analysis to be excellent, reflecting an objective view of SRON's current position and future potential.

In assessing the institute, the Committee assigned the highest scores in almost all categories. Concerns about funding resulted in the assignment of slightly lower scores, 4-5, to items A5, "Resources", and D3, "Robustness and Stability." The Committee senses that the constrained basic funding for SRON may already be limiting success and may well constrain future aspirations. Until now, the combination of basic funding from NWO, participation as PI or co-PI in large international space missions, and supplementary funding from smaller missions and grants has been sufficient to enable SRON to maintain a premier position in space research. For the future, staff in EPS and in both HEA and LEA are developing proposals and instruments with a view to achieving PI-level status for SRON in upcoming major missions. In this respect the future looks bright; in addition to its leadership role in Astro-H, the Japanese Space Agency's (JAXA) X-ray mission, SRON could, potentially, secure PI roles on both ESA's Advanced Telescope for High Energy Astrophysics (ATHENA) and for the far infrared imaging instrument SAFARI on the Japanese SPICA mission. There is no reason to believe that SRON's success in competition will diminish.

Nevertheless, it is the opinion of the Committee that a stronger and more stable funding base is vital to SRON's continuing success. The likely transition to a different government funding model is particularly troubling. Perhaps the Committee's concern in this respect is due to an incomplete understanding of the advantages or expedencies of the proposed model, but the Committee certainly perceives the model as having the potential to diminish the successful enterprise that is currently SRON.

In addition, the manner in which space astronomy is carried out is changing. For example, it is expected that the technological complexities of future large missions will inevitably result in fewer such missions, separated by longer fallow periods. The effects of these changes must be carefully managed to ensure that SRON's tried-and-true success strategies are not impacted adversely. If SRON is to remain in the premier position it now occupies in space astronomy, with concomitant benefits to Dutch astronomy in particular, the research and development programmes on which the institute depends for its ongoing competitive success must continue throughout such between-mission periods. The Directorate is carefully reorganising and rebalancing both research goals and staff to help accommodate such a scenario but the Committee is convinced that an enhanced basic budget is also required, if only to maintain critical staff levels. In this regard, it is worth noting that the Committee already sees a resource challenge for SRON if, as seems possible, the institute secures PI roles in both ATHENA and SAFARI.

Initially the Committee had concerns regarding the effects of the institute's anticipated move to another site and the termination of SRON's long partnership with the University of Utrecht. These concerns were essentially put to rest by discussions with the SRON Directorate. Their planning process appears to have these issues well under control and the Committee supports their proposed strategies. In the view of the Committee, the limited level of assured funding over longer timescales remains the most pressing problem to be faced. Given the importance of SRON to Dutch astronomy as a whole, a robust future for the organisation is vital.

4 Assessment of the research programmes

Research Group or Programme level				
	HEA	LEA	EPS	SR&T
Quality	5	5	5	5
A1 Quality and scientific relevance	5	5	5	5
A2 Leadership	5	5	5	5
A3 Academic reputation	4-5	4-5	5	5
A4 Organisation	5	5	5	5
A5 Resources	5	5	5	5
Productivity	5	5	5	5
B1 Productivity strategy	5	5	5	5
B2 Productivity	5	5	5	5
Relevance	5	4-5	5	5
C1 Societal relevance	5	4-5	5	5
Vitality and Feasibility	5	5	5	5
D1 Strategy	5	5	5	5
D3 Robustness and stability	4-5	5	5	5
Overall	5	5	5	5

4.1 Astrophysics

4.1A High-Energy Astrophysics Division

High-Energy Astrophysics (HEA) is at the forefront of astrophysics, according to the most recent high-level reviews of science programmes in Europe and in the USA (ASTRONET, Cosmic Vision, Astro2010: “New Worlds, New Horizons”). All recommend that high spectral resolution (with imaging capabilities) should be among the top priorities for the next major X-ray mission; in the last decade several missions have proposed utilizing these capabilities (e.g. CON-X, XEUS, IXO, and now ATHENA, AXSIO).

In the last five years the SRON HEA Division, under the leadership of Professor Hermesen, has concentrated its efforts on the development of the next generation of high resolution X-ray spectrometers (TES microcalorimeters). In that technology, this group is today arguably the leading institute in Europe and one of the very few in the world. As a result, SRON has won PI roles in the Japanese Astro-H mission and in ATHENA, one of the proposed large ESA missions, and has participated in smaller internationally proposed missions built around TES technology (e.g. EDGE, ORIGIN, Xenia, and DIOS). The HEA Division also has a PI role in LOFT, one of the proposed (medium – M3) ESA missions. This aggressive placing in multiple missions assures international visibility and strategically enhances the division’s win opportunities.

In terms of publications, HEA is currently the most productive SRON division. Between 2005 and 2010, the group published 317 papers in refereed journals, on topics ranging from compact objects (neutron stars, black holes) to active galactic nuclei (AGN) and clusters of galaxies. It has continued harvesting science using XMM and CXO and is pushing the limits of these facilities. Major scientific results in the last five years are: (i) the detection, using XMM/EPIC, of a filament of the Warm Hot Intergalactic Medium (WHIM) in thermal emission between a pair of clusters (A222/ A223). Although the significance (5σ) is on the low side, this remains the best detection to date of an integrated filament emission; (ii) mapping of the feedback processes in galaxy evolution using

multi-wavelength campaigns; (iii) detection of hard spectral tails (above 100 keV) in the total and pulsed spectra of magnetars.

Over the next 5-10 years, the division plans to expand its scientific expertise while focusing on the star formation history of the universe (feedback/clusters of galaxies), and studies of black holes and their relation to feedback and galaxy formation. It will ramp down its research on galactic star formation and neutron stars. HEA currently has 5 senior astrophysicists, 3 postdocs and 10 PhD students. The division's strategic plan reflects the fact that its small manpower requires highly focused investments to place it in the premier league.

In summary, the Committee finds the quality of the research of the HEA Division excellent. However, the Committee believes that it will be important for the Directorate to monitor the balance between staff levels in scientific research and instrument development. There is a delicate boundary beyond which too much investment in technical development may weaken the scientific side of a division.

In general, the Committee had some issues with the criteria used in the bibliometric analysis. These are not the same as those widely recognized by the astrophysics community. Other commonly adopted criteria, such as the Hirsch index are also not invoked. We note that, although the division is very prolific in producing publications, its collective number of citations is relatively small (~3000 citations for the five senior astrophysicists since 2006); this finding is reflected in the 4-5 grade for academic reputation. Nevertheless, the Committee appreciates the differences in evaluation criteria, performance requirements, and labour distribution between theorists, observers and experimentalists, and understands the hysteresis between conceiving and building a mission and reaping scientific benefits after a successful launch. Taking into account all these factors, the productivity of the HEA Division is very good.

The HEA Division also has an excellent record in terms of societal relevance; the overall survey of industry stakeholders performed by SRON is very satisfactory. The average length of company involvement with SRON is ~ 8 years. The only major request that came out of the survey is for better communication of SRON's needs to industry. In addition, both the PhD students and the postdoctoral fellows were very satisfied with their environment. Both groups stated that they feel like members of a big family and that they are taken good care of. They also liked the combination of university and laboratory environment that Utrecht and SRON provided. There is some concern that, since salaries are not on a par with industry, it is difficult to attract and retain high quality employees.

To date the division's overall strategic planning and management have proven very successful, placing HEA in the very enviable situation of having a potential PI role in instruments for three missions. It seems likely that at least one, if not all, of these PI roles will be secured. However, the present infrastructure and funding level will make it difficult to fully support more than one mission at any given time. If selected for both ATHENA/XMM and SAFARI, the division would need at least an extra 15M Euros to develop the two missions, even assuming considerable common technology development. If it proves necessary to choose between them, the difference in timing between the final selection stages for ATHENA and SAFARI will be a problem. Although ATHENA might come first, the HEA team (and also SRON/LEA) has a longer-standing commitment to SAFARI, placing HEA in a quandary regarding its final decision. The Committee's concern about this situation is reflected in the 4-5 grade awarded for robustness and stability.

For at least the last decade, SRON has been recognized as an important global player in High-Energy Astrophysics. For a country of the size of the Netherlands to occupy such a prominent position in space science is exceptional. For the future, the aims are both to bring SRON technology to the non-space market to achieve valorisation, and to join forces with other laboratories and universities to develop more complex systems. For example, TES and KID are progressing, but

magnetic detector development is not yet possible. Remarkably, without SRON, the Dutch scientific community would not be in its current strong leadership position.

4.1B Low-Energy Astrophysics Division

The mission of the Low-Energy Astrophysics (LEA) Division is the development of novel sensors, detector systems, instruments and receivers for the infrared to submillimetre band, with an emphasis on spectroscopy, along with the scientific exploitation of these systems. This work is done in close collaboration with the rest of the Dutch and international science community. Beginning with the successful ISO-SWS development 15 years ago and continuing with Herschel-HIFI throughout the past decade, SRON-LEA has become one of the most renowned and successful space infrared-submillimetre instrumentation expertise centres worldwide. More recently, some LEA developments have been directed towards ground-based submillimetre work, especially for the ALMA project, and more such developments are expected for APEX.

Throughout the last decade, the work of the LEA Division focused mainly on the development and operation of the heterodyne spectrometer (HIFI) on the ESA Herschel mission, for which the institute also played the PI role (Thijs de Graauw and Frank Helmich). The highly visible leadership and successful completion of the HIFI project is an outstanding, world-class success. HIFI is one of the most complex and innovative instruments ever flown in space and was technically extremely challenging. The successful management of the worldwide consortium, consisting of 21 institutes, was an exemplary feat. Since its launch in 2009 (and despite the onboard anomaly that delayed routine operations for several months), HIFI has produced many scientific discoveries and exciting results in molecular astrophysics, and has more than fulfilled all the expectations and dreams that gave rise to its inception 20 years ago. Among these are the discoveries or detailed studies of H_2O and other hydrides (HF , H_2O^+ , OH^+ , H_3O^+ , CH^+) in a variety of galactic environments, the determination of the abundance ratio for deuterated to normal water in a comet, the discovery of water freeze-out in protostellar discs, the study of chemical fingerprints, shocks, photon dominated regions and outflows in star forming regions in our galaxy and external galaxies, and many more. LEA scientists have played an active, visible, and even leading role in this remarkable scientific harvest, with ~70 HIFI publications in the past year.

The LEA Division is also leading the European effort for the next generation cryogenic infrared space telescope, SPICA. SPICA is a mission of the Japanese space agency JAXA, with European participation led by ESA. LEA is the PI institute (Peter Roelfsema) for the SAFARI instrument proposed as an ESA participation in this cryogenic 'super-Herschel' telescope, which is intended to be launched about ten years from now. SAFARI is an extremely ambitious experiment aiming at improving the sensitivity of 40-200 μm spectroscopy by an order of magnitude or more. SRON's science strategy for SAFARI is geared toward one of the key future research areas enabled by SPICA – the possibility of observing for the first time the powerful mid-infrared fine structure emission lines in high-redshift galaxies, in order to probe their power sources and physical conditions.

To fulfil its ambitious role in SPICA/SAFARI, the LEA group is taking full advantage of system experience gained from HIFI (including AIV), the in-house development of sensitive TES bolometer arrays, and its extensive expertise in infrared and submillimetre spectroscopy. The Committee strongly endorses this strategic goal and commends SRON for winning the European leadership role. However, while applauding the strategy, the Committee notes that there are some substantial risks. The selections of SPICA on the Japanese side and of SAFARI on the ESA side are not yet secured, and the success of SRON's role in Safari also hinges on winning a large grant within the competitive funding line of NWO. Clearly a top priority for the SRON directors will be to keep a careful watch on developments in this important area and, if necessary, to adjust their strategy accordingly.

The LEA and SR&T Divisions (together with the University of Delft) are carrying out the development of very large MKID detector arrays for broad-band imaging in the submillimetre

band. The Committee was impressed by the high quality of the KID development (see our comments on the SR&T Division), which is among the best efforts worldwide in this promising technology. SRON is also working with the Max Planck Institute for Radio Astronomy to develop a large MKID camera for the APEX submillimetre telescope. This instrument will provide a major leap forward in the speed and quality of wide field submillimetre imagery over the next few years. Its development is an impressive demonstration of SRON's capabilities in implementing challenging and novel detector technologies, based on a thorough understanding both of the underlying physics and of the relevant astronomical systems and their scientific exploitation.

Together with NOVA, the LEA group has also successfully exploited the heritage of HIFI submillimetre mixers for the band 9 (600 – 700 GHz) ALMA receiver systems. The recently-delivered 72-module system fulfils, and may even exceed, the specifications. The development of the modules was carried out on budget and, most remarkably, all spares were also ready when the on-time delivery of the required set of modules took place. The Committee also took note of the ongoing development of ~650 GHz side-band separating SIS mixers, which will be of great interest for ALMA upgrade developments. Along with the number of PhD students and postdoctoral fellows benefitting from the HIFI results, this application of technology development to ground-based astronomy indicates the broader impact that SRON is having on the community.

Overall, the Committee considers LEA's research and development work to be not just of the highest level technically, but also of truly impressive scientific impact for the entire astronomical community. The Committee was deeply impressed by the depth, quality and wide range of the instrumental work carried out by the LEA Division, in close collaboration with the SR&T and ED Divisions. This achievement is especially remarkable given the relatively small size of the institution. Very few other institutions worldwide are working at a comparable level. The quality of the scientific and technical staff is excellent. The close and highly profitable relationship between the leadership of LEA and the Dutch scientific community is outstanding and has been the key to the good strategy and excellent scientific results achieved with the instruments developed at LEA. If SRON is planning to readjust its scientific thrust towards extragalactic research, given the scientific aims of SPICA, it will be highly advisable to do so in close consultation with the Dutch science community in that field, in order to maintain the highly successful symbiotic relationship of the past and present.

4.2 Earth and Planetary Science

The Earth and Planetary Science Division (EPS) focuses its research on the physical, chemical and dynamical properties of the atmosphere of the Earth, the planets in the solar system and, most recently, the atmospheres of exo-planets. As already noted in the review of the institute as a whole, the contributions of EPS over the last 5 years have been outstanding. The quality of the research is excellent and the enthusiasm of the group is palpable. The Committee was very impressed by the presentations. The strategic decision to discontinue activities in Earth gravity field research and emphasize programmes in planetary and exo-planetary atmospheres, exploiting the synergy with Earth atmospheric research, appears to have been a step in the right direction.

In addition to their appeal for the scientific community, the current major EPS topics

- Earth's atmosphere (especially greenhouse gas abundances and aerosol research)
- atmospheres of solar system planets
- exo-planet atmospheres

have enormous societal relevance at this time. The need for a better understanding of the Earth's atmosphere is obvious and, as more space missions probe the solar system, increased knowledge of planetary atmospheres will be vital. Arguably, the discovery of an exo-planet with an Earth-like atmosphere could have an even greater impact.

For Earth atmospheric research, EPS makes use of spectroscopy and spectropolarimetry to investigate climate change, air pollution and ozone depletion, in particular the global carbon cycle, the global water cycle and aerosols. SRON short-wave IR (SWIR) measurements of greenhouse gases have been notably successful. These SWIR techniques for greenhouse gases (in particular CO_2 and CH_4) have been developed over the years in close collaboration with the universities. As a result, following its policy of creating opportunities for innovative science through technology and instrument leadership, SRON has been able to successfully develop novel instruments for SWIR measurements, beginning with the highly successful SCIAMACHY (Scanning Imaging Absorption SpectroMeter for Atmospheric CartographY) instrument on ESA's ENVISAT mission. Furthermore, SRON's mission strategies enabled co-PI status for the EPS investigators on SCIAMACHY.

SRON/EPS research based on SCIAMACHY data can only be described as pioneering. This is particularly true of SWIR measurements of CO and CH_4 column averaged mixing ratios. The quantitative study of global CO - and CH_4 distributions is widely perceived as an extremely important contribution to climate research. These achievements laid the ground for successful proposals for future missions. Building on that heritage, SRON was able to win a significant role in the development of the TROPOMI instrument for the SENTINEL-5 Precursor mission (SENTINEL-5P), which is planned for launch in late 2014/early 2015. Again, SRON's use of newly-developed technology in a novel instrument, in this case immersed-grating technology, is remarkable. The SENTINEL-5P success will undoubtedly give SRON scientists a head start in making use of data from the SENTINEL-5 mission.

In parallel with excellent quality instrumentation programmes, and equally important for future success, the EPS Division is continuing to develop sophisticated inversion algorithms for the extraction of column-averaged greenhouse gas mixing ratios as well as of isotope ratios from SWIR spectra. The application of these algorithms to SCIAMACHY data has already led to new discoveries regarding the distribution of CH_4 sources and to new insights into the atmospheric water cycle from isotope ($\text{HDO}/\text{H}_2\text{O}$) data. SRON scientists are also applying these inversion algorithms to the evaluation of CO_2 mixing ratios from GOSAT (Greenhouse Gases Observing Satellite) spectra.

Another, and more recent, EPS venture is directed towards the design of hardware and algorithms for the determination of atmospheric aerosol parameters. Here, the novel approach relies on the systematic use not only of radiation intensity, but also of polarisation information. Studies using POLDER (Polarization and Directionality of the Earth's Reflectances) data are giving promising results. New instruments such as the spectropolarimeter for Planetary Exploration (SPEX) will allow full exploitation of the new approach.

A comparatively recent addition (2009) to the EPS research programme is the study of exo-planet surface and atmospheric properties from optical spectra. There is every reason to expect that, in this field, SRON's unique expertise in the area of atmospheric radiation transport will be very useful and may enable SRON research to take a leading position. To date, there are a few examples of excellent work suggesting that there may be a very productive future for SRON in this new, rapidly expanding, and highly competitive area of research. However, SRON's leadership must follow developments in this field carefully and make sure that EPS uses its unique expertise in the area of atmospheric radiation transport to its advantage.

As the EPS Division has excelled in performance over the last 5 years, it has also expanded considerably. Plans for SRON's future suggest that the activities of the division could increase even further over the next years, perhaps approaching equilibrium with those of HEA and LEA. This is not surprising in view of the enormous societal relevance of SRON's instrumental contributions in the initialization and verification of climate models, and in the verification of global emission reduction schemes. The measurements of aerosol optical densities and mixing ratios of the greenhouse gases CO_2 and CH_4 are central input parameters for climate modelling and verification of climate models. Since modelling is the prime source of information about the future climate, significantly improving the models has very high societal relevance. An important and fruitful field

of research for SRON could be global greenhouse gas emission verification in relation to follow-up Kyoto Protocol compliance. For example, if caps on schemes of carbon trading or emission are introduced on a global scale in the future, national claims for, say, emission reduction will need to be verified. In this context the instrumentation developed by SRON will be of considerable importance.

However, the importance of air quality research is not so obvious. Air quality is continuously improving in Western countries, and the expected reduction of fossil fuel use, along with other mitigating strategies such as electro-mobility, will carry the improvements still further. On the other hand, aerosol research is a highly competitive field and, given the size of the SRON group, it will probably not be feasible to compete with larger groups (e.g. Kulmala or Helsinki) across the entire breadth of the field. However, the Committee is of the opinion that the EPS group can make good use of its leading role in the employment of polarization information to derive highly accurate global aerosol fields and make use of these to improve knowledge on the impact of the direct and indirect aerosol effect on our climate.

At this time, the EPS Earth atmosphere programme has a record of excellent achievements and excellent prospects. With a possible role for SPEX in a Mars mission, there is a similarly optimistic outlook for the study of solar system planetary atmospheres. Finally, the Committee perceives the venture into research on exo-planet atmospheres as bold. To date it looks very promising but SRON leadership should continue to monitor the group's position in the field to ensure that in the long term this is the right direction for the institute.

4.3 Engineering Division

The Engineering Division appears to be productive and robust, with modern capital equipment and excellent staff expertise and stability. As yet, funding constraints appear to have had less impact here than in other parts of SRON. However, the Committee foresees that such constraints may in the future lead to fabrication cost increases, fabrication quality degradation, and/or increased repair rates due to delays in equipment updates and technology refreshes.

The division appears to be well managed with:

- ESA standards in place for quality and process control that are periodically audited by ESA,
- A strategic approach that anticipates:
 - Requisite new technology risk reduction activities for the scientific constituents
 - Assurance of technical capabilities
 - Partnerships with industry and with peers
 - Capacity with contingencies for surge conditions,
- A matrix structure for partnership with each PI team to assure that the instruments under development are what the scientists need and are managed to the proper schedule and cost profile,
- A good track record for delivery of space-qualified instruments within quality, cost and schedule expectations,
- A strategic approach to increasing the technology readiness levels (TRL) of promising new technologies of interest to the astrophysics and EPS communities that includes early prototyping,
- A reputation that makes the division sought after by industry and other agencies for help in times of surge activity or to assist in specialized technology developments in which it is expert.

The pipeline approach, with early-career staff being mentored by more experienced later-career staff, appears to be providing continuity of expertise, especially in the specialty areas.

A concern was expressed that the long intervals between major missions reduce opportunities for staff to experience the full end-to-end instrument development and fielding process. Exploration of broader instrument development opportunities within the international community is under

way to help mitigate such mission gaps for both the scientific and engineering divisions. However, we note here that although the ED could outsource instrument components for which it is not sole expert (e.g. circuits and mechanical fixtures) and thus take on a larger amount of work, such business ventures will be inherently limited by staff capabilities in the science divisions.

A principal area of focus appears to be the development of a strategy for the best mix of inter-facility collaboration and staffing to withstand surges, expand capability, and anticipate SRON's eventual switch to a new university partner. In our view, this is an excellent approach to managing the calculated risks of winning too much instrument work in order to assure an adequate baseline level.

A previous performance issue with HIFI was briefly discussed. The issue was corrected and identified as a combination of a hardware and a software problem. It is well recognized that development of highly advanced, space-qualified instruments is extremely challenging. As a result, engineering and fabrication organisations are continually reviewing their processes to minimize errors in design and fabrication while learning from those problems that inevitably occur. The division's processes are in conformance with ESA standards and subject to periodic inspection by ESA. It is recommended that the ED leadership should periodically visit international peer organisations to compare 'best practices', if it is not already doing so. Such visits can provide insights into such aspects as novel applications of equipment, extending equipment life, improving efficiency, and approaches to minimize rework. Also, some organisations design their processes to a combination of both space agency quality requirements and tailored ISO-9001 or AS-9100 requirements to better integrate design, fabrication, and test processes. This approach might be worth considering; compliance with international standards beyond those of ESA might strengthen SRON's competitive position in the international arena.

The department is clearly diligent in developing new approaches to increasing productivity and finding new uses for existing equipment. A concern was expressed during the administrative session about the ability to sustain modern facilities, as maintenance costs must be increasingly constrained. If this concern is not already being addressed, the ability to maintain state-of-the-art engineering and fabrication facilities should be considered as a key factor in providing the resources necessary to maintain SRON's world-class reputation.

4.4 Sensor Research and Technology

SRON is to be highly commended for its outstanding, world-class effort in sensor research and technology. This programme consists of strong, mutually supportive efforts in several superconducting detector technologies, including:

- Superconducting tunnel junction (SIS) receivers for heterodyne spectroscopy and interferometry
- Hot electron bolometers (HEB) for Terahertz spectroscopy
- Transition-edge sensors (TES) for X-ray microcalorimeters and far-infrared bolometers
- Kinetic inductance detector (KID) arrays for millimetre-wave, submillimetre-wave, and far-infrared imaging and spectroscopy

In addition, SRON has developed technology for optical-infrared spectroscopy (specifically, immersed gratings). These are used for studying molecular species and aerosols in the Earth's atmosphere and in the atmospheres of other planets around the sun and other stars. Such gratings allow very compact instruments to be constructed, a very important consideration for space. SRON's activities in this area are at the forefront worldwide. The Committee was impressed by the way in which SRON involves PhD students and postdoctoral research fellows in these developments and also collaborates with a number of external institutions, including universities, scientific institutes, and industry. The results of this research are published in leading scientific journals and

enable construction of state-of-the-art instruments for a variety of applications including, but not limited to, space projects.

At this time, facilities and staff expertise appear adequate to pursue long-term strategy with the caveat that, without either an increase in funding or a reduction of focus in some areas, no extra manpower is projected to be available to begin new projects. Our impression is that instrument work is well aligned to mission requirements, and that there is a strong focus on timely Technology Readiness Level (TRL) maturity. As a result, world-leadership in key technology areas is demonstrated by performance benchmarking with technologies from other organisations.

SRON's achievements in sensor research and technology over the evaluation period are extremely impressive. As highlighted in section 4.1.b, the crowning achievement must certainly be the successful development, delivery, launch, and science operations of the HIFI instrument for Herschel. SRON's experience in the superconducting SIS receivers developed for HIFI has also been very successfully applied to the construction of SIS receivers for ALMA. Very impressively, SRON performed this task on budget and ahead of schedule while meeting all performance requirements. The sensor research and technology group continues to work in this area by contributing to the development of a new generation of SIS receivers for ALMA. It is quite clear that SRON is at the forefront of the SIS field worldwide. However, with the launch of the HIFI and approach to completion of ALMA, it is also clear that this field is now mature and future opportunities may be limited. It is therefore an opportune time for SRON to evaluate its future in this area.

The HEB mixer work also traces its early roots to HIFI. SRON is at the forefront internationally in this field and has a clear lead in terms of sensitivity. SRT is now combining its HEBs with quantum cascade laser (QCL) local oscillators to enable heterodyne receivers operating above the 2 THz upper limit for HIFI. In partnership with the University of Arizona, SRON has proposed this technology to NASA for use in balloon-borne and airborne instruments. This is a commendable example of SRON seeking other channels for technology demonstration and funding support; SRON's LEA scientists should be encouraged to aim for a science role in these projects. As with SIS technology, the future of HEBs in space is not clear at the moment and a long-term strategic vision is needed.

SRON is also doing outstanding work in the development of X-ray TES microcalorimeters. This work is comparable in quality to that being done at the leading US institutions in this field, NASA's Goddard Space Flight Center and the National Institute for Standards and Technology (NIST) in Boulder, Colorado. As discussed in the HEA section, SRON's strong position in this technology puts it in an advantageous position to secure a PI role in a future X-ray mission. Furthermore, SRON is fully exploiting the very strong synergy between the X-ray TES microcalorimeters and the ultrasensitive far-infrared TES bolometers needed for the SAFARI instrument. SRON is fully aware of the opportunities for transferring this technology to the commercial sector and is actively seeking a path forward. The Committee strongly endorses this course of action.

The sensor research and technology group is already making excellent progress towards meeting the very stringent detector requirements for the SAFARI instrument. The laboratory measurements of detector optical sensitivity are rapidly closing in on the requirements. A proof-of-principle demonstration of the frequency-multiplexed readout technique has been achieved; the next major step is readout of a full, biased array with high pixel yield. It appears that very good progress is being made to retire the considerable technical risks with this new technology so that the detector array will not be a stumbling block to the implementation of the SAFARI instrument. Again, it is clear that the SRON team is at the leading edge internationally in this area.

SRON's achievements in the development of Kinetic Inductance Detectors (KIDs) are especially impressive. Working together with TU Delft, over the past several years the institute has published in prestigious journals a number of key papers on the fundamental physics of these devices. Their results have advanced the state of the art and informed other groups working in this field.

In collaboration with MPIfR Bonn, this technology is rapidly being brought to fruition with the construction of the A-MKID camera for the APEX telescope. When completed, A-MKID will be the largest submillimetre-wave camera in the world, eclipsing the current leader, the U.K. Scuba-2 instrument on the James Clerk Maxwell telescope – at a considerably compressed cost and on a much shorter schedule. The application of KID technology to enable on-chip submillimetre spectrometers is especially exciting and promises to open up very important new science applications. It is an excellent time to consider the future applications of these technologies in space.

Finally, SRON is actively exploring the prospects for commercial applications of TES, KID, and other technologies. At present, technology transfer activities are supported by government investment funds obtained through competition as opportunities arise. These funds are used to transfer technologies to industry. This stands in contrast to the approach used in many countries and research institutions, where licensing and royalty income is obtained as technologies are commercialized. It is recognized that such a technology transfer operation, with its attendant licensing, patenting, and inventor support, can be a significant expense. However, significant technology transfer revenue has been realized in a number of such organisations. The Committee suggests that NWO should consider the policy option of allowing institutes such as SRON to embark on a commercial technology transfer enterprise, perhaps in conjunction with other institutes and associated universities, as a means of providing additional resources for SRON. Even if such ventures fail to produce much revenue, they may well have important potential for valorisation in that they can be useful to the suppliers in enhancing their product lines.

5 Supplementary questions by NWO

5.1 General questions

Is the mission still appropriate? In the light of the mission of the institute, is a proper balance being struck between the institute's research, R&D and research facilities (their development and use)?

The Committee is convinced that the SRON mission is still appropriate and will remain appropriate for the foreseeable future. It provides, with considerable success, a conduit to cutting-edge astronomical research in space for the Dutch community, as well as for its own scientists. The successful development, delivery, launch, science operations, and scientific results of the HIFI instrument for Herschel are a testament to the remarkable capabilities of this relatively small organisation. The institute's world-class R&D work is also enabling innovative instrumentation for ground-based international facilities, such as ALMA in Chile.

Historically, SRON has maintained an excellent balance between research, R&D, and facilities. The HEA research programme is a very good example. However, the technical complexity of the HIFI instrument, coupled with an increasingly constrained base budget, required difficult decisions regarding staffing. In short, scientific research staff positions were sacrificed to ensure the technical success of HIFI. While this was undoubtedly the right decision at the time, much of the HIFI-enabled research is now taking place in the Dutch universities – albeit in collaboration with SRON. There are obvious advantages for the community in this scenario but, within SRON, some imbalance in the fraction of staff devoted to science has resulted. The Committee would like to emphasize that ongoing in-house research is a critical component of SRON's philosophy for success and considerable attention should be paid to ensuring appropriate staffing levels for research staff.

What is the national and international importance of the institute now and what will it be in the near future? Does the institute have the right policies in place to meet the new challenges?

As frequently mentioned in the assessments above, the institute has established and is maintaining a significant presence in space science, both nationally and internationally. Based on SRON's fundamental philosophy of how to achieve its mission goals, and taking into account the strategic planning that is already under way, there is every reason to expect this high standing to continue. From the Committee's perspective, the largest risks for the future derive from the funding profiles that result from government policies on research; from the fact that the kind of large missions in which SRON aspires to obtain a PI role are becoming even more complex, and hence less frequent; from the need to maintain active research and R&D teams between missions so as to offer the novel instruments that lead to PI roles; and from the reliance on supplementary funding from increasingly hard-pressed sources. The Committee observed that SRON itself acknowledges these difficulties but remains optimistic about fulfilling its mission.

Should NWO continue to support the institute? If so, for what reasons? Are there more effective ways for NWO to support the same type of research and/or facilities?

The Committee is strongly of the opinion that NWO should continue to support SRON and sees no real alternative. Our reasons may be found throughout this review. Briefly, SRON comprises a relatively small group of people working at the highest levels worldwide. They are very successful and have certainly helped to enhance the scientific stature of Dutch astronomy. Indeed, SRON is quite unique and deserves to receive sustained and appropriate financial support to continue doing what it does so well.

Is the institute doing enough to exploit its opportunities for cooperation with organisations outside the academic world?

Given the various institutional and legal constraints that may apply, the institute appears to be making appropriate efforts in this direction. The Committee suggested a number of additional options, described in the preceding sections and in its Recommendations, but which of these would be viable/effective was unclear.

5.2 Specific questions for SRON

What implications do SRON's strategic choices have for the focus or breadth of the institute's scientific profile? And how do the projects in which SRON hopes to play a Principal Investigator role fit within this?

SRON's strategic choices in scientific research and technology development are carefully tailored to complement each other and, as a result, are often mutually enhancing. There is a strong reliance on past experience (particularly successful experience) but the science focus is very much on the high priority, high visibility science questions identified by top level advisory committees in Europe and the United States. Since SRON's forte is to produce instruments that can address these questions in new and exciting ways, the institute's science is always focused on the cutting edge – an ideal scientific profile. The projects in which SRON hopes to play a PI role are just a natural fit with the in-house philosophy

Is SRON's current internal organisation adequate to support this strategy and appropriate to the institute's mission?

Currently, the internal organisation is adequate but, as the Directorate recognizes, it must be closely monitored, and probably modified, as the institute moves forward. To this end, it is proposed to change the scientific emphasis in HEA and LEA as described earlier, consolidating skills and focusing science to make optimum use of existing skills. Likewise, there is an expectation that activities in EPS will increase, especially given the worldwide focus on climate change. The proposed instruments and associated PI roles are well-matched to the reorganisations and the Committee concurs with the strategies being adopted by the Directorate.

How is SRON fulfilling its national role within the field of scientific space research in the Netherlands? What collaborative arrangements with other parties are important in this respect? Is SRON doing enough – apart from its participation in ESA programmes – to exploit its opportunities in Europe and elsewhere in the world?

As stated on multiple occasions in this review, the Committee was very impressed indeed with how much SRON and the space research projects it has enabled have impacted on space research, not just in the Netherlands but in the world at large. The successful scientific collaborations with Dutch universities have been cited time and again, as have SRON's relations with industry partners. The Committee applauds all of these and urges the institute to make every effort to ensure that they continue. In terms of exploiting opportunities beyond ESA, we need only point to the burgeoning activities with JAXA, as well as the ongoing NASA collaborations.

What is SRON doing to assure the support of, and coordination with, the research community, including the users of its research facilities?

Again, multiple examples are presented in the preceding sections that indicate excellent relations with the research community and users of its research facilities. Recent HIFI experience is particularly notable. Aside from numerous scientific collaborations and papers, graduate students and postdoctoral fellows appear to move easily between the universities and SRON. The loss of the long-standing and strong relationship with Utrecht University's astronomy department is of course regrettable but the Directorate appears, as part of its relocation strategy, to be seeking a similar link to another university. The Committee heartily endorses the establishment of such a relationship.

In this regard, the only area where the Committee could see room for possible improvement was in the Science Advisory Committee structure and management. This committee provides an obvious, front-line link to the community and users and, at present, both the SAC and SRON appear to be comfortable with the number and style of meetings, as well as overall interactions. The Committee believes, however, that a more focused SAC, meeting more frequently and charged with providing advice on a broad range of topics, including long-term strategy, funding opportunities, and relations with university users, could be very helpful to the Directorate at a time when difficult decisions are probably going to be necessary.

6 Conclusions and recommendations

6.1 Conclusions

The Committee is satisfied that SRON is carrying out every aspect of its mission in an excellent manner. The institute's leadership is to be commended for the steps that have been and continue to be taken to make optimum use of available resources and ensure that the high status of SRON in the national and international research community is maintained. The relationship with Dutch universities seems mutually beneficial, as does the training of graduate students and postdoctoral fellows, both in scientific and technical research. SRON research is also increasing our understanding of issues that are of considerable interest to society, such as climate change and air pollution. Ongoing partnerships with industry are well managed and further links are being sought. The Committee was very pleased to learn from the Directorate that, following the closure of the Utrecht University astronomy department, the institute expects to establish ties to another university very shortly. The Committee's main concern was that adequate funding should be available to enable the institute to continue to carry out its mission. The recommendations that follow emphasize this need.

6.2 Recommendations

1. SRON currently occupies a premier position in international space astronomy and brings considerable benefit to the Dutch astronomical research community. To ensure that the institute continues to fulfil all aspects of its mission successfully, the Committee strongly recommends that additional and stable basic funding be awarded. The institute has until now maintained its high standards of achievement by competing for and winning PI roles in large missions, while supplementing its resources through participation in smaller missions and competitively available grants. Changes in government funding policies for space science and the ever-lengthening intervals between large missions suggest that increased basic funding will be required to accommodate the new funding profiles. In particular, it is critical that SRON has the resources to continue its science-motivated technology research and development programmes – on which its competitive success depends – without interruption.
2. SRON's effective strategy of linking research goals and technology development to achieve its mission goals demands a fine balance in the allocation of resources to staffing, scientific research, technical research and development, infrastructure, and mission building. Even with increased funding, hard choices will have to be made. The Committee concurs with the ongoing and proposed refocusing of research priorities in the science divisions. In addition, the Committee recommends that:
 - a. The balance between scientific research and technical development staff should be continuously and carefully monitored. There must be a sufficient number of in-house research scientists to provide background and day-to-day advice for technical development teams but, just as importantly, SRON must invest enough in technology development to continue delivering the highest quality instruments. With the implementation of HIFI, SRON reached a new high in this end-to-end production capability and it is imperative that the standard be maintained.
 - b. Serious consideration should be given to the support needs that will arise if SRON achieves PI status for both ATHENA/XMS and SAFARI. If outside partnerships are required, they should be established early and to SRON's advantage.
 - c. The maintenance of state-of-the-art engineering and fabrication facilities should be considered a key factor in assuring the maintenance of SRON's world-class reputation.
3. Given the overwhelmingly positive impact of SRON-university collaborations on HIFI, SRON should strive to nurture synergy with the academic community in a similar way in future missions. In particular, Science Advisory Committee (SAC) duties and accountabilities

should be reviewed and strengthened. It appears to the Evaluation Committee that infrequent meetings and teleconferencing prevent the SAC from being involved sufficiently to provide more than superficial advice. SRON might consider working with the academic community to implement a different review and advice structure that would require more immediate interaction between the academic community and the institute, with concomitant opportunities for advice as it is needed.

4. Although perhaps not competitive with larger groups working on air quality research, the EPS group should consider exploiting its leading role in the application of polarization information to derive very accurate global aerosol fields and improve understanding of the impact of the direct and indirect aerosol effects on our climate. SRON management might also consider the merits of becoming involved in the future in the verification of national claims of reductions in greenhouse gas emissions (Kyoto Protocol compliance).
5. SRON should develop a strategic vision for its detector effort beyond SPICA/SAFARI. This vision should consider the long-term future for heterodyne detectors (SIS, HEB) as well as direct detectors (TES, KID, and chip spectrometers). The potential applications of the latter technologies for space appear to be particularly exciting.
6. If not already usual practice, the ED leadership should periodically visit international peer organisations to compare 'best practices'. Such visits can provide insights into such aspects as novel applications of equipment, extending equipment life, improving efficiency, and ways to minimize duplication of effort.
7. The institute should continue to seek opportunities to cooperate with organisations outside the academic world. The Committee suggested a number of options including those below but, given the various institutional and legal constraints that may apply, it was not clear which of these would be effective or, indeed, viable. Even if such ventures fail to produce much revenue, they may well be important for valorisation, enabling suppliers to enhance their product lines.
 - a. NWO might seriously consider the policy option of allowing institutes such as SRON to establish a commercial technology transfer enterprise, perhaps in conjunction with other institutes and associated universities, as a means of obtaining additional institutional funding.
 - b. The possibility of broader commercial ventures through SRON's vendors should be addressed more strategically and the potential for broader economic use of SRON/ vendor facilities could also be explored. Expanded activities like these could improve vendor relationships as well as adding economic value.
 - c. This is an appropriate moment for the SR&T detector group to explore models for technology transfer.

Annex 1 Curricula Vitae of Evaluation Committee Members

Chair

Prof. Dr Anneila Sargent. Anneila Sargent is the Benjamin M. Rosen Professor of Astronomy and Vice President for Student Affairs (since 2007) at the California Institute of Technology (Caltech). A native of Scotland, she received her BSc with honours in Physics from the University of Edinburgh, and her PhD in Astronomy from Caltech. Her research has concentrated on understanding how stars form in our own and other galaxies and how other planetary systems are created and evolve. She was Director of Caltech's Owens Valley Radio Observatory from 1996 to 2007, and founding Director of the Combined Array for Research in Millimeter-wave Astronomy (CARMA) from 2003 to 2007. Dr Sargent is a past President of the American Astronomical Society and a fellow of the American Academy of Arts and Sciences. In 2008 she received an honorary doctorate from the University of Edinburgh. She lectures widely and has chaired a variety of national and international committees including NASA's Space Science Advisory Committee, the US National Research Council (NRC) Board of Physics and Astronomy, and the Board of the international Atacama Large Millimeter Array (ALMA).

Members

Prof. Dr Reinhard Genzel. Director of the Max Planck Institute for Extraterrestrial Physics, Garching, Germany, Head of the infrared and sub-millimetre research group and Scientific Member of the Max Planck Society. In addition, Genzel holds the position of Professor in the Physics and Astronomy Departments of the University of California, Berkeley, USA, and is an Honorary Professor at the Ludwig-Maximilian University in Munich, Germany. Genzel received his PhD in Physics and Astronomy from the University of Bonn in 1978, after which he was a Postdoctoral Fellow at the Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts. Since 1980 he has been affiliated to the University of California. Genzel has received many prizes and awards, including the prestigious Balzan and Shaw Prizes and an honorary doctorate from the University of Leiden in 2010, for his ground breaking research in studies of star formation and interstellar matter in galaxies across cosmic time, and in particular in proving the existence for a massive black hole at the centre of our own galaxy, and his developments of a range of innovative infrared instrumentation. He is a member of multiple science advisory committees and experienced reviewer.

Dr Chryssa Kouveliotou. Astrophysicist at NASA's Marshall Space Flight Center. Before joining NASA in 2004, she was the Director of the Universities Space Research Association (USRA) Astronomy Program in Huntsville. A native of Greece, she received her PhD in Astrophysics from the Technical University of Munich in 1981. She is one of the 249 most-cited space science researchers worldwide for her research on Gamma-Ray Bursts (GRBs) and magnetars. She has won many prizes and awards, including the 2003 Rossi Prize (for confirming the existence of magnetars), the 2002 Descartes Prize (for her contributions to the study of cosmic GRBs), and the 2012 Heineman Prize (for her extensive accomplishments concerning GRBs and magnetars). She is a member of multiple international advisory committees, boards, and review panels. She has served as the Chair of the Division of Astrophysics of the APS, on the Council of the American Astronomical Society (AAS) and as the Chair of the High-Energy Astrophysics Division (HEAD) of the AAS; she is the US Liaison of the Astrophysics Commission 19 of IUPAP. She is a Fellow both of the American Physical Society (APS) and of the American Association for the Advancement of Science (AAAS).

Prof. Dr Ulrich Platt. Director of the Institute for Environmental Physics of the University of Heidelberg since 1990, leading the research group on Atmosphere and Remote Sensing, founding father of the DOAS-technique. His group addresses both tropospheric and stratospheric research topics and has active projects using among others both satellite and balloon platforms. General research interests are environmental physics (climate/global changes), experimental physics, atmosphere and radiation. Platt is a member of the Max Planck Society and of several other scientific advisory committees such as for GOME(-2), OMI and SCIAMACHY. Visiting Professor of the Gwangju Institute of Science and Technology in Korea, he has served on the scientific steering committees of IGAC and SOLAS. Platt was born in 1949 in Eberbach. He received his PhD in 1977 from the University of Heidelberg and has since worked as a scientist at the Jülich Research Centre, the University of California and the University of Cologne. He has been dean of the Faculty of Physics and Astronomy at Heidelberg and a member of the Heidelberg Academy of Sciences.

Prof. Dr Jonas Zmuidzinas. Jonas Zmuidzinas is the Merle Kingsley Professor of Physics at the California Institute of Technology (Caltech), and in 2011 was named Chief Technologist for the NASA Jet Propulsion Laboratory (JPL). He is also a Senior Research Scientist at JPL and in 2007-2011 he served as Director of JPL's Microdevices Laboratory. A California native, Zmuidzinas attended Caltech as an undergraduate and received his PhD in Physics from the University of California, Berkeley in 1987. He spent two years as a postdoctoral fellow at the University of Illinois before joining the Caltech faculty in 1990. He specializes in submillimetre astronomy and instrumentation, with a particular focus on the development of superconducting detectors including invention of the microwave kinetic inductance detector. He initiated the effort at Caltech to develop the 25-metre Cornell-Caltech Atacama Telescope (CCAT) and served as CCAT Project Scientist during 2003-2011. He has served on a number of NASA, NSF, DOE, and international review panels and was Chair of the AUI/NRAO Visiting Committee in 2010.

Dr Jerry Krill. Assistant Director for Science and Technology and Chief Technology Officer at Johns Hopkins University Applied Physics Laboratory, a 5000-staff research centre. Previously he served as the JHUAPL Assistant Director for Programs and Chief Quality Officer. In that position Dr Krill was responsible for all programmes and implemented a comprehensive ISO-based quality management system including AS-9100 compliance for the JHUAPL space sector. He co-led the readiness review of NASA's New Horizons mission to Pluto and a milestone design review of the Radiation Belt Storm Probes mission. Previous positions at JHUAPL include executive for air defence programmes and head of the Power Projection Systems Department. He joined JHU in 1973 and holds a doctorate in electrical engineering from the University of Maryland. He was instrumental in developing the US Navy Cooperative Engagement Capability that networks air defence systems. He holds 18 patents and was selected as Innovator of the Year by the Baltimore Daily Record for his optical communications innovation. A member of the US Naval Studies Board, he has served on NSB and Defense Science Board panels. Other memberships include the IEEE, American Institute of Aeronautics and Astronautics, National Defense Industrial Association, National Space Society, and the International Council of Systems Engineering.

Annex 2. Programme of the Site Visits

Tuesday 6 December 2011 – Utrecht

10.30 – 12.30	Closed Committee session	
12.30 – 13.30	Lunch and briefing by NWO Governing Board member	Ben de Kruijff (NWO GB)
13.30 – 14.00	Transport from Hotel Karel V to SRON	
14.00 – 15.00	Interview with SRON Directorate	Rens Waters, Roel Gathier
15.00 – 15.15	Tea break	
15.15 – 15.45	Interview with Science Advisory Committee	Xander Tielens (chair), Steve Kahn (videolink), Thomas Röckmann
15.45 – 16.15	Interview with SRON Board Members	Ewine van Dishoeck, John Marks, Ralph Wijers
16.15 – 17.15	Closed Committee session	
17.15 – 17.45	Transport from SRON to Hotel Karel V	
19.00	Welcome dinner with NWO Governing Board representatives	Jos Engelen, Ben de Kruijff (NWO GB)

Wednesday 7 December 2011 – Utrecht

08.00 – 08.45	Transport from Hotel Karel V to SRON Utrecht	
08.45 – 09.30	Presentation and interviews with division heads AP	Wim Hermsen, Henk van der Linden
09.30 – 10.30	Presentation and interviews with scientists AP	<i>HEA</i> : Elisa Costantini, Jan-Willem den Herder, Peter Jonker, Jelle Kaastra; <i>LEA</i> : Andrey Baryshev, Frank Helmich, Peter Roelfsema, Floris van der Tak
10.30 – 10.45	Coffee Break	
10.45 – 11.30	Tour of cleanroom ¹	Marcel Bruijn, Tonny Coppens, Jan-Joost Lankwarden, Rien van der Linden, Jan van Schaijk possibly: Rens Waters, Roel Gathier
11.30 – 12.30	Closed Committee session	
12.30 – 13.00	Lunch	
13.00 – 13.35	Presentation and interview with division head EPS	Avri Selig
13.35 – 14.15	Presentations and interviews with scientists EPS	Ilse Aben, Otto Hasekamp, Ruud Hoogeveen, Sander Houweling, Martijn Smit, Daphne Stam
14.15 – 15.00	Presentation and interview with head ED	Hans van Gageldonk, Henk van der Linden
15.00 – 15.45	Tour of laboratories ¹	Johannes Dercksen, Hans van Gageldonk, Pourya Khosropanah, Peter-Paul Kooijman possibly: Rens Waters, Roel Gathier
15.45 – 16.15	Closed Committee session	

Thursday 8 December 2011 – Groningen

09.00 – 09.45	Presentation and interviews with division head SR&T	Henk Hoever
09.45 – 10.30	Presentation and interviews with scientists SR&T	Jochem Baselmans, Marcel Bruijn, Gao Jian-Rong, Pourya Khosropanah
10.30 – 11.00	Coffee break and closed Committee session	
11.00 – 11.30	Interviews with selection of 6 PhD students	Theodora Karalidi, Dinand Schepers, Marianne Heida, Ciro Pinto, Yunhee Choi, Pieter de Visser
11.30 – 12.00	Interviews with selection of 8 postdocs	Paul Tol, Daniel Guirado Rodriguez, Frans Alkemade, Jelle de Plaa, Andrey Khudchenko, Maja Kazmierczak, Pascale Diener, Darren Hayton
12.00 – 12.30	Poster session with PhDs and postdocs	Rens Waters, Roel Gathier
12.30 – 13.30	Lunch with Directorate	Rens Waters, Roel Gathier
13.30 – 14.00	Interviews with support & technical staff	Hans Bloemen, Gerard Cornet, Annemieke Oehlen, Frank van Rijn, Frans Stravers, Yvonne Vermeulen
14.00 – 14.45	Tour of laboratories ¹	Rens Waters, Roel Gathier
14.45 – 17.00	Closed Committee session	
17.00 – 17.45	Closure with Directorate & Board of the institute	Directorate: Rens Waters, Roel Gathier; Board: Paul Korting (chair), Ralph Wijers

¹ In view of time constraints, the tour of the cleanroom was performed in parallel with that of the laboratories, the committee being split into two groups .