

Evaluation 2005-2010

ASTRON Netherlands Institute for Radio Astronomy

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1 Introduction

1.1 Scope and context of this review

This assessment concerns the research carried out at the Netherlands Institute for ASTRON Radio Astronomy 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 ASTRON.

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

Prior to the external evaluation, ASTRON submitted a self-evaluation document covering the period 2005 – 2010. This report was approved by the Governing Board of NWO in August 2011. The self-evaluation report and Appendix 1 and 2 were drafted in accordance with the SEP guidelines and provided information both at the institute level and at the level of the research groups. The other Appendices (3-8) and References served as background information.

The main self-evaluation report with Appendices 1 and 2 and the other information offered a concise picture of the institute's and research groups' work, ambitions, output and resources.

Site visits form an important part of evaluations and include interviews with the management of the institute, the programme coordinators, other levels of staff, and site visits to laboratories and facilities. ASTRON offered a tour of the institute's laboratories and facilities, trips to LOFAR and WSRT, and interviews with stakeholders, business partners, and LOFAR/WSRT users.

1.2 The Evaluation Committee

The Evaluation Committee was appointed on 11 May 2011 by the Governing Board of NWO. The members are:

Dr Catherine Cesarsky, chair	High Commissioner for Atomic Energy (FR)
Prof. Michael Bode	Liverpool John Moores University (UK)
Prof. Roger Blandford	Stanford University (USA)
Prof. C. Megan Urry	Yale University (USA)
Prof. Andrew Lawrence	University of Edinburgh (UK)
Dr Antoine Roederer	TU Delft (NL)

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

The Committee was supported by NWO staff (Margreet Bouma, Committee secretary, and Patricia Vogel, observer).

Before the site visit, 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 documentation supplied to the Committee included all the information required by the SEP, the additional questions raised by NWO, and instructions for accessing the secluded ASTRON evaluation website.

The Evaluation Committee received the self-evaluation report from ASTRON, together with the site visit programme and an explanatory letter providing the codes for accessing the secure ASTRON website set up specifically for this evaluation. The secure website contained documents about the present and previous evaluation (8 Appendices, 11 References and other relevant documents and websites).

The main self-evaluation report dealt with ASTRON's objectives and research area, their composition, the research environment and embedding, quality and scientific relevance, output, earning capacity, academic reputation, societal relevance and economic valorisation, training of 'the next generation', a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats), viability and a strategy for the next decade. Information was added about the changes that have taken place since the last evaluation in 2005 and about the next generation of researchers. The departments in ASTRON are the Astronomy Group, the Radio Observatory and the R&D Laboratory.

Of the eight Appendices, the first two were to be read together with the main self-evaluation document. Appendix 1 contained tables – statistics presented both at institute level and at the level of the departments – on ASTRON staff (tenured, non-tenured, PhD students, support staff, visiting fellows); on research output from researchers on the ASTRON payroll (refereed and non-refereed articles, books, book chapters, refereed conference papers, professional publications, publications aimed at the general public, and other research output such as software, media appearances etc.); and on the progress of PhD students (gender, year of enrolment, success rates per year). Appendix 2 contained the institute's response to supplementary questions posed by the NWO Governing Board.

Among the eleven References, there were overviews (LOFAR, APERTIF, EMBRACE AAVP) and a Bibliometric study on ASTRON 1999 – 2010 (CWTS; Leiden University; working document August 2011, final report to be published).

During the site visit, the Committee received handouts with regard to 'societal relevance': Other societal applications [LOFAR, SKA] (2 pp.), and SKA: a major driver for innovation in ICT and sensor technology (1 p.). And also handouts with regard to planning and financial information: LOFAR 2009-2017 (1 p.); Projects and competences: a forward look with a APERTIF roll-out action plan dated 7 October 2011; and a report by the LOFAR Commissioning Coordination Group dated 2 February 2011. The Biennial Report 2009 – 2010 of the Joint Institute for VLBI in Europe (JIVE) was also given to the Committee.

1.4 Procedures followed by the Committee

The Committee proceeded in accordance with the Standard Evaluation Protocol 2009 – 2015. The assessment was based on ASTRON's self-evaluation document and the other documentation provided by the institute, as well as on the 'Tour of science, technology and laboratories', interviews with and (poster) presentations by management, directors, group heads, staff members, postdocs and PhDs, and trips to LOFAR and WSRT. The site visit was made on 19 and 20 October 2011. The programme for the visit is included in Annex 2.

The Committee met on the afternoon preceding the site visit to discuss and plan the inter-views, the tour, the trips, and the meetings with (and choice of) PhDs and postdocs. The Committee agreed on procedural matters and aspects of the assessment.

At a formal dinner in Fluitenberg, the Committee met with Professor J.J. Engelen, chair of the NWO Governing Board.

After completing the full site visit programme with its interviews, tour, trips and poster session, the Committee discussed the scores and comments with regard both to the institute and to the research programmes and major departments. The Committee determined the institute's scores for the four main SEP criteria and decided on the main preliminary findings to be reported in the final meeting with the ASTRON General and Managing Directors and the chair of the ASTRON Governing Board.

At the end of the site visit, a meeting was held with the ASTRON directorate and the chair of the ASTRON Governing Board to report the Committee's main preliminary findings and scores.

In December a draft version of this report was sent to the ASTRON General Director 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 inter-national 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 ASTRON

2.1 Mission

ASTRON is the Netherlands Institute for Radio Astronomy. The original organisation, Stichting Radiostraling van Zon en Melkweg (literally, the Foundation for Radio Radiation from the Sun and Milky Way) was founded on 23 April 1949. At that time, ASTRON's primary goal was to exploit the great advances that were then being made in radar and microwave technologies. ASTRON's current mission statement remains remarkably close to that original goal:

"Making discoveries in radio astronomy happen, through the operation of world-class facilities, fundamental research and the development of novel and innovative technologies".

The institute's aim is to be a global leader and innovator in the field, developing and adopting new and novel technologies for advanced radio astronomy instrumentation, providing astronomers with access to outstanding radio telescope facilities, and broadly contributing to astronomical research in general.

ASTRON's mission is focused on the area of radio astronomy, and its single over-arching objective is to make, and enable others to make, discoveries in this field. This is accomplished via three main research programmes: (i) the pursuit of fundamental astronomical research, (ii) the operation of radio telescope facilities for the national and international community, and (iii) the development of novel techniques and innovative technologies for the next generation of radio astronomy instrumentation and software. In addition to these three main activities, ASTRON places weight on the valorisation of its research. Projects are organised in such a way that companies can collaborate and benefit to the full from the institute's high-tech developments. Programmes to inspire young people are stimulated and initiated, encouraging them to study science and technology at school and establishments of higher education. Together with private partners, ASTRON brings technologies developed for radio astronomy to industry.

ASTRON's major objectives in the coming decade are to make LOFAR (Low Frequency Array) a success, to ensure that the Netherlands plays a pivotal role in all aspects of the international Square Kilometre Array (SKA) project, and to maintain and further develop a strong fundamental and applied research programme, including the training of a new generation of radio astronomers and engineers. A long-term goal is to establish a Centre of Excellence for SKA Science Support and Operations in the Netherlands. ASTRON is committed to achieving these objectives via a wide range of different activities that benefit the national knowledge-based economy and society at large.

2.2 Research

The research area and main focus of ASTRON's mission is radio astronomy. Perhaps uniquely, ASTRON brings together under one roof all the essential elements required to fulfil its mission in this field: fundamental research in astronomy, the operation of world-class observing facilities, and an advanced technology development programme. Research – fundamental and applied, astronomical and technical – plays a key role in each of these elements. They are organised as three distinct departments.

- The Astronomy Group is primarily charged with conducting fundamental astronomical research, utilizing the telescope facilities at ASTRON and other observatories overseas. While the group's main expertise lies in the field of radio astronomy, there is also significant multi-wavelength experience in the sub-mm, NIR-optical and X-ray domains. The group has recently expanded, and an important element of its activities is the support it provides to the other two departments.

- The Radio Observatory's main responsibility is the operation and maintenance of the WSRT (Westerbork Synthesis Radio Telescope) and LOFAR. In addition, it participates in the European Very Long Baseline Interferometry (VLBI) Network. LOFAR is currently being commissioned by the Radio Observatory, working together with the large national, and indeed international, research community associated with the various LOFAR Key Science Projects (KSPs). The Observatory also provides comprehensive support for astronomers using any of ASTRON's telescope facilities. This support ranges from advice on the mechanics of proposal submission to help with data analysis. Although their work is mainly operational in character, Observatory staff members also contribute to the fundamental research output, primarily via the support scientists and senior engineering staff.
- The *Research & Development Laboratory* executes a technical and applied research programme that focuses both on the development of innovative new instruments for new and existing telescopes and on the study of emerging technologies, with a view to their application in future observing facilities. The department has expertise in all areas necessary for the end-to-end development of facilities: system design, digital and embedded signal processing, mechanical design and production, antennas, photonics, computing and advanced algorithm development. As recently demonstrated via the design and development of LOFAR, the R&D Laboratory has significant experience in the area of system design, integration and verification. It also plays a supporting role in providing technical assistance for the Radio Observatory and indeed for the Joint Institute for VLBI (JIVE). The Laboratory is heavily engaged in collaborations with external national and international partners, including universities, other research institutes, commercial companies and government agencies. It plays a crucial role in the valorization of ASTRON's research.

2.3 Organisational structure

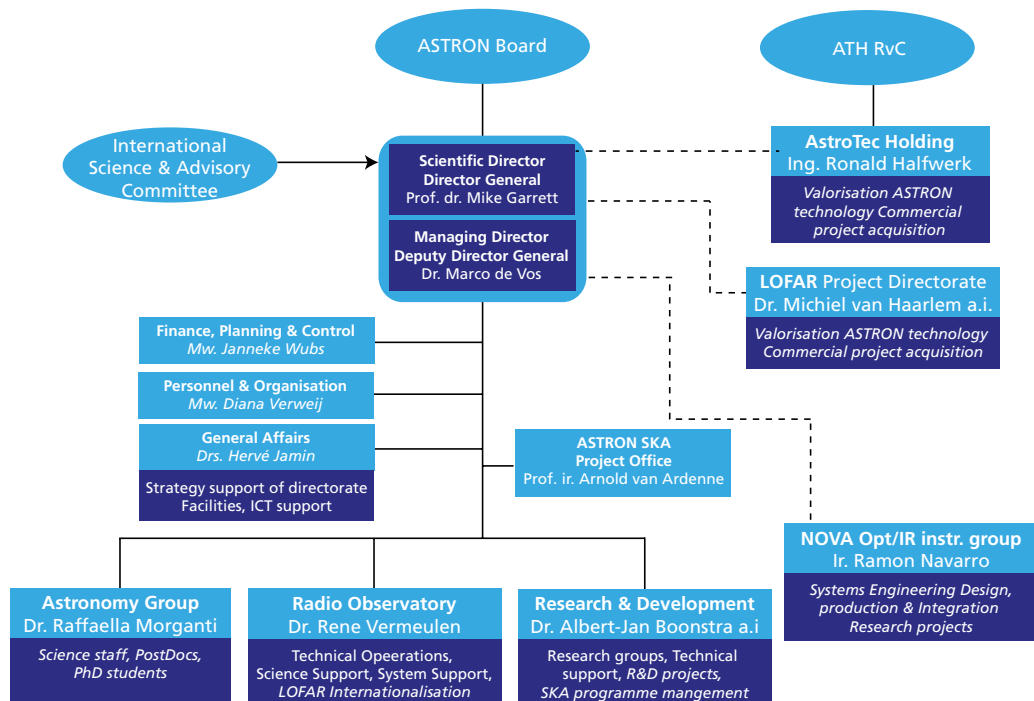


Figure 1 | ASTRON Institute structure

In 2008 a new governance model for ASTRON was introduced. In particular, the composition of the ASTRON Board was changed to exclude direct stakeholders in the institute's activities (e.g. university astronomers).

The directorate of ASTRON is composed of Professor Michael Garrett (General and Scientific Director) and Dr Marco de Vos (Managing Director). The General Director is ultimately responsible for all institute matters and has the specific task of developing the institute's overall strategy and future direction. The Managing Director is responsible for implementing this strategic programme, taking account of the various financial and resource constraints.

The management team is made up of the directorate, plus the heads of General Affairs, the Astronomy Group and the Research & Development Laboratory, and the Director of the Radio Observatory.

Under the newly established governance model, a Science Advisory Committee (SAC) was instituted, partly to compensate for the exclusion of stakeholders from Board membership. The SAC provides the General Director with advice on the general scientific direction and strategic policy of the institute.

ASTRON also hosts the Joint Institute for VLBI in Europe (JIVE), the NOVA Optical/IR Group and ASTROTEC Holding BV (ATH: a commercial company).

2.4 Financial matters

ASTRON is funded by a structural grant from NWO (base budget), by additional grants acquired in open competition, and by (semi-)commercial contracts. For some time, the long-term strategy of ASTRON has been to assume that about half the total budget can be obtained through these additional grants and contracts. This is the only way to realize the ambitions of the institute and to create sufficient critical mass to execute the programme. The base budget is necessary for regular institute operations, but more importantly as a source of co-financing ('matching') of external grants. Many funding programmes in the Netherlands and from the European Council require at least 50% matching funds. ASTRON's base budget has been temporarily raised by a grant of 2M€/yr (2008 – 2017) from the Ministry of Education, Culture and Science to provide partial compensation for the increased operating costs associated with the LOFAR telescope.

Table 1 | ASTRON funding 2005 – 2010 in k€

	2005	2006	2007	2008	2009	2010
Funding						
Direct funding from NWO	7.084	7.212	5.864	9.663	10.747	10.858
Research grants	1.169	160	741	672	1.791	963
Contract research	10.127	4.082	8.587	10.484	5.600	5.796
Other	1.342	2.289	3.656	1.158	2.055	1.231
Total funding	19.721	13.743	18.847	21.977	20.192	18.848

2.5 Staff

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

	2005	2006	2007	2008	2009	2010
Tenured staff	54	66	55	50	45	45
Non-tenured staff	34	28	28	26	31	31
PhD students	6	12	6	5	6	6
Total research staff	94	106	89	81	82	82
Support staff	90	75	74	66	62	63
Total	184	181	163	147	144	145

3 Assessment of the institute

Table 3 | Scores at institute level

Quality	5	Excellent
A2 Leadership	5	Excellent
A3 Academic reputation	5	Excellent
A4 Organization	5	Excellent
A5 Resources	5	Excellent
A6 PhD training	5	Excellent
Productivity	5	Excellent
Relevance	5	Excellent
Vitality & feasibility	5	Excellent
D1 Strategy	5	Excellent
D1 Robustness and stability	5	Excellent
Overall score of ASTRON	5	Excellent

3.1 Overall assessment of the institute

The overall assessment of the institute is Excellent (5). ASTRON has implemented all of the recommendations of the previous report and has continued to develop its international standing in the interim, as outlined in the following paragraphs.

The institute has published many high impact scientific results since the last review. These include: very deep observations of HI in galaxy clusters at interesting redshifts of $z \sim 0.2$ - observations that are important precursors to SKA science; important steps towards unravelling the magnetic structure of the interstellar medium through the novel utilization of polarization measurements, including pioneering use of Rotation Measure Synthesis; important advances in furthering our understanding of pulsars, including exploration of the radio pulsar/X-ray binary link and their sub-pulse modulation properties; radio follow-up of the most distant ($z = 8.2$) Gamma Ray Burst; the use of HI as a probe of gas accretion by galaxies, plus outflows and feedback. Their pioneering work to connect WSRT to the EVN via fibres has also enabled detailed studies of the origin and evolution of jets in e.g. Cyg X-1 and Cyg X-3, plus many other programmes requiring the combination of extremely high spatial resolution and sensitivity.

ASTRON has maintained WSRT as an internationally competitive radio observatory through a continuous programme of upgrades. The APERTIF development now promises to provide a significant future enhancement to the international competitiveness of the observatory, particularly in terms of large area surveys, through the next review period. Indeed APERTIF will increase the efficiency of the array for conducting surveys by a factor of approximately 30. In response to the first call for proposals, the international community submitted proposals for 18 major programmes, requiring a total of around 20 years' worth of time.

The period since the last review has been dominated by LOFAR. Despite some delays to the project, the first images from LOFAR are very impressive and have convincingly demonstrated the ability to clean up unwanted radio frequency interference. Examples of very recent, as yet unpublished, results include cosmic ray acceleration at a galaxy cluster interface; multi-beam observations of pulsars, and detection of ultra high energy cosmic rays. Current plans are to begin more routine science operations open to the wider scientific community early in 2012 (Phase I), including a start on the very important Epoch of Recombination programme.

LOFAR has raised high expectations in the international astronomical community and its level of international visibility is unusual for a facility of this size. In short, this project is a major triumph in the offing for the institute and will be central to the development of ASTRON in the coming decade.

Together with technological developments such as APERTIF and EMBRACE, LOFAR puts ASTRON in an exceptionally strong position to play a major role in the SKA. The institute's significant involvement in both SKA pathfinders is also to be applauded. Although ASTRON was unsuccessful in its bid to host the SKA Project Office, in hindsight this might have been a distraction and the failure should not prevent the institute from achieving its future and more appropriate goal of playing a leading part in implementing the project itself.

ASTRON's academic reputation is in line with the excellence of the facilities and instruments it provides. This is evident from the visibility of its staff members in high level committees, from the awards they receive, and from the number of invitations to deliver papers at scientific gatherings.

3.2 Organisation, management and staffing

Following the recommendations of the previous report, ASTRON now has an efficient and effective senior management structure, with the Science Advisory Committee playing an important role. Overall, the ASTRON directorate appears to have a very clear view of the future direction of the institute.

The creation of the Astronomy Group is a very positive development. It will help to ensure that instruments are at the cutting edge of discovery. All the astronomers appear to be well integrated into the activities of ASTRON. The Group has reached approximate critical mass and the Committee would not wish to see this diminish. The Committee was also pleased to note that its concern that ASTRON astronomers were finding it difficult to pursue the development of the SKA science programmes is being addressed through a new senior appointment.

The transfer of staff from Westerbork to Dwingeloo seems to have been successful. A lot of effort has also gone into addressing gender imbalances. As yet, this does not seem to have had any significant effect but the continuing efforts of the management in this area are to be applauded.

PhD students and postdoctoral researchers appear to be satisfied with their experience of working at the institute. However, they do tend to suffer more than other groups from the relative isolation of the site. The establishment of a crèche facility would be advantageous. More could also be done in terms of engendering a group spirit among the graduate students, in particular because they spend the majority of their time away from ASTRON at universities across the Netherlands. Specific, regular – if not necessarily frequent – events, such as poster sessions or journal clubs, for these students might help. The provision of enhanced mentoring, particularly in terms of career advice, is also recommended. Overall, the graduate student cohort is relatively small and efforts should be made to increase its size.

Relations with NOVA, the major Dutch university groups, and in particular JIVE, appear to be very positive and mutually beneficial.

We share the concerns of ASTRON management about the impact of future funding levels on the institute's ability to maintain and enhance its current international profile and its outstanding national and regional impact in areas of societal relevance. This concern over core funding is particularly important to note as we move into the era of full operation of LOFAR and the first full phase of the SKA.

Overall, ASTRON has maintained a very well motivated, loyal and happy staff across all departments.

3.3 Societal relevance

First and foremost, of course, ASTRON exists to push back the frontiers of human knowledge through the science of radio astronomy. Beyond this, however, the institute is an exemplar internationally of the positive and creative pursuit of additional benefits to society.

ASTRON works in synergy with the region and with Dutch industry in general to stimulate industrial growth. Of 100 M€ for LOFAR, 50% went to procurements, of which almost all were in Dutch industry (with subcontracts to other parts of the world, of course). Of the remainder, 30% went to meet direct labour costs in Dutch companies, not counting ASTRON's own 15 M€ in labour costs. The remaining amounts were contributions in kind.

ASTRON has been of major assistance to the Province of Drenthe's Department of Economic Affairs, helping it to enhance innovation in the region. In 2000, the Department was looking for regional strengths and found it difficult to identify them because of the relative lack of high technology industry in the province. LOFAR has proved a unique asset. It has cemented and intensified collaboration with ASTRON, giving rise to considerable technology. One case of particular note is the Sensor Universe Foundation, which is now a focal point for technology development and inward investment, involving companies, universities and institutes across the region. Another is INCAS³, a scientific institute that matches doctoral students and postdocs with engineers to create a bridge between the fundamental knowledge and the practical applicability of sensor systems. The Dome initiative, a collaboration between IBM and ASTRON that centres on fundamental research in nano-photonics for extreme-scale data storage and retrieval, promises to deliver further industrial spin-off. For ASTRON, the Dome project is also directly helpful in strengthening the relationship with IBM at a time when negotiations over extending the Blue Gene arrangement are ongoing.

The Committee was impressed by the degree to which there had been spin-off from an institute focused on delivering basic science; this is highly unusual internationally. Passive radar was identified as a future potential 'killer application' and, more generally, the Committee suggests that ASTRON should work with companies and other consortia members to look for additional future applications of its cutting-edge technology.

Overall, the Committee was impressed with what has been achieved in the area of societal relevance, particularly through LOFAR. The benefits have accrued both to ASTRON and to commercial companies (particularly SMEs) in the region, with many jobs being created or safeguarded, either directly or through the attraction of additional contracts outside radio astronomy, due to enhanced technical capability. It is no surprise that national government now recognizes this as an outstanding relationship in the Netherlands and a true highlight of this region. It promises a great deal for the future in terms of similar benefits accruing in connection with the SKA. Also of note are the use of an antenna in the WSRT array to assist in the validation of the first Galileo satellite launch and the wider benefits that LOFAR has produced, for example, in certain areas of agriculture and environmental monitoring.

ASTRON's schools' and public visitors' programmes have been developed further since the last review. The Committee sees scope for further enhancement here and supports ASTRON management in its efforts in this regard.

3.4 SWOT analysis

The SWOT analysis in the self-assessment document appears correct. It shows that it is essential for ASTRON both to sustain a strong R&D department and to harbour a group of astronomers with critical mass to participate in instrument development, calibration and commissioning if the institute is to fulfil its mission and guarantee its future health.

One weakness noted in this analysis, and referred to above, is the 'remote' location. This is sometimes considered a disadvantage. We agree with this, as it complicates the life of staff members, who often live far away, for example for the sake of their spouses. Of even more concern is the fact that the graduate students spend most of their time at their host universities. This deprives them of some esprit de corps and the postdocs and permanent staff of their constant presence. Nevertheless, a healthy scientific atmosphere exists at ASTRON, with coffee breaks and lunches providing opportunities for science-related conversation, and many seminars, colloquia and scientific conferences taking place.

4 Assessment of the research programmes

4.1 Astronomy Group

The Astronomy Group (AG) has been created since the last evaluation. Previously, astro-nomical research was carried out by staff astronomers within the context of the work programmes of other divisions. In the new structure, they are dedicated to the conduct of this research, although they still interact with, and provide services for, the other divisions. The AG has a dual responsibility – both to conduct world-class scientific research (including competing effectively for the award of research grants) and to provide scientific support for instrumentation and help construct the science cases for ongoing developments such as LOFAR and future opportunities such as the SKA. The fact that the AG has its own representation within the management team reinforces the new emphasis on scientific quality. The AG has recruited both tenure track and younger staff, and has been highly successful in competing for grants.

The panel very much welcomed this new initiative. As well as directly helping to build the international reputation of ASTRON, it helps to keep ASTRON facilities at the cutting edge of discovery by ensuring that scientific motivations and requirements are directly to hand. The members of the AG are well integrated into the facility teams, so this dual function seems to have been achieved. It is a good sign that, as well as publishing peer reviewed papers, members of the group have appeared at a variety of international conferences. They have also established fruitful collaborations with university staff in NOVA.

Although the total number of staff at the institute has shrunk since 2005 from 178 to 139, the astronomy group has expanded from 12 to 20 members (9 tenured).

The group has achieved some impressive scientific results, such as the detection of HI in clusters at interesting redshifts ($z = 0.2$); starting to unravel the magnetic structure of the interstellar medium through novel use of polarization methods; follow-up of gamma-ray burst sources; the study of HI as a probe of gas accretion onto galaxies, as well as outflows and feedback; and the beginnings of very interesting work studying transient sources with VLBI. Much of their best work is directly connected with ASTRON facilities but also uses competitive external facilities. This is a healthy approach.

Compared to the best groups in the world, the AG does not yet have the very highest rates of production and citation. However, this is largely because of the youth of both the group and its members. The gradient is impressive. We note that the number of refereed papers published by ASTRON doubled between 2008 and 2010, and in the last year has exceeded 110; this is due in large part to the output of the AG. We felt therefore that, judged purely on scientific performance and impact over the full duration of the review period, the AG deserves a score of 4 (Very good). However, considering that the Group has been formed during the latter part of the period now under review (post-2008), and based also on the Group's current performance and future promise, the AG deserves a score of 5 (Excellent). If the gradient continues, at the next review we would fully expect a straight score of 5.

The AG has just recently approached critical mass. The panel felt it was important that it should not be allowed to fall below the present level, which would endanger its growing international research profile. The Committee was impressed by the quality and productivity of this group, and we commend the AG leadership on this success.

Programme assessment for the Astronomy Group: 5 (Excellent)

4.2 Radio Observatory Group

LOFAR

LOFAR, the LOw Frequency Array, is a highly innovative radio telescope operating between 10 and 250 MHz. It exploits high performance computing to improve the sensitivity of observations. Among its principal scientific goals are: to determine and explore the Epoch of Reionization (which occurred when the universe was roughly 500 million years old), to map individual young galaxies, to detect the highest energy cosmic rays as they hit the Earth's atmosphere, to study pulsars, to monitor solar weather, to map cosmic magnetic fields, and to probe intergalactic gas. Its design differs from that of conventional radio telescopes with steerable antennae. Instead it uses an enormous array of simple dipoles that can observe any point in the sky by introducing suitable electronic delays in the signals they measure before combining them. This technique allows several directions to be observed simultaneously. The project is now eight years old. It has made great strides and confounded its critics.

The array is centred near to the Westerbork array but has subarrays in Germany, UK, France and Sweden, with several more on the way. The full design comprises over fifty stations and three-quarters of these are now completed. Two types of antenna are being used, for lower and higher frequency observing. These will be useful for finer angular resolution observations. The signal processing is dependent upon an IBM Blue Gene computer located in Groningen, which provides about 30 Tflops of computing power. Digital beamforming and interference excision has been demonstrated and a start has already been made on the science programme. The results presented to the Committee are highly encouraging.

LOFAR is an ambitious and difficult project not only in dataflow and software terms, but also in terms of its hardware and science. The Committee heard presentations and visited the LOFAR core to give it a perspective on these issues. Every antenna produces data at Tb/s rates, a speed at which it is effectively impossible to transmit, let alone store and analyze it. Much of the problem is solved by electronics components at the stations, which do the filtering and beamforming, outputting 3Gb/s from each station. When in full operation, it is expected that LOFAR will produce 80 Gb/s for transmission to the correlator supercomputer in Groningen. This corresponds to ~300PB/year. However, only 2PB/year can be stored. Although this may soon increase to 5PB/year, difficult decisions will still have to be made concerning the structure of the intended Long Term Archive (LTA). Bringing the data flow system into operation to the point where basic data products such as maps can be routinely produced has clearly been a major challenge. Although this has been achieved later than the originally optimistic predictions, the LOFAR team is to be congratulated for clearing this major hurdle. We noted that there is an intention to replace the Blue Gene computer in 2014. This will be a very important step, which we trust will go well.

Going beyond basic data flow to a full set of advanced data products, user tools, and open and user-friendly LTA is the next serious challenge. This is true of any survey-style facility, but especially true of LOFAR because of its multiple possible operational modes – many different products, tools, archive structures, and styles of interface will be required. It was clear to the panel that the LOFAR team understands these issues in general, but the volume of work should not be underestimated. As well as software development, the coming years will also require substantial operator and scientist effort to deal with issues such as quality control and calibration. The volume of work is very sensitive to the system's ease of use for general users. We therefore recommend that the LOFAR team should be careful not to promise more than it can reasonably deliver, and that it should deliver products and tools in a carefully staged and prioritized manner. Since there seems to be good communication between the LOFAR team and the Key Science Project groups, we recommend that LOFAR should work closely with these groups to deliver an agreed sequence of data products and tools that will help them produce science, and consequently that general user tools should be given lower priority, even though they are of great eventual importance.

WSRT, APERTIF, EMBRACE

The Westerbork Synthesis Radio Telescope (WSRT) had its last major upgrade during the period of the 1999 – 2005 review. Since then, a programme of continuous, more minor, improvements has been undertaken. These have enabled the WSRT to maintain its position as a front-rank radio observatory whilst LOFAR is being brought on-stream. However, the development of APERTIF promises to significantly extend the competitive lifetime of WSRT well into the LOFAR era.

The transfer of WSRT staff to Dwingeloo in 2008 appears to have gone smoothly and to be seen as beneficial to all concerned. The shared operation with LOFAR seems to be efficient, but the team of 3 operators appears to be the minimum required for round-the-clock operations.

The observatory serves a diverse community. Although around 60% of its proposals came from within the Netherlands, the majority of the PIs are drawn from the wider international community. The oversubscription rate reached a worrying low of around unity in 2007, but has recovered to a healthier factor of around 2 in the last few semesters.

In terms of the total number of refereed journal papers produced in the period, the productivity of WSRT has been comparable to that of MERLIN, although it has lagged well behind that of the VLA, for example. However, the overall quality of the papers produced is high, with a disproportionate fraction of WSRT publications featuring in the top 10% of papers in the field of radio astronomy internationally.

The observatory continues to excel in studies of HI and polarization with science highlights in such areas as the structure of the Interstellar Medium, pulsars, X-ray binaries, gamma-ray burst follow-up, and the evolution of the HI content of galaxies. Overall, the user community appears to be happy with its experience of the facility. The new NorthStar application tool, developed locally, was singled out for particular praise, as was the frequency flexibility, stability and general operation of the observatory, including the friendliness of its staff and the support given to users. The only criticism concerned the unsophisticated archive, which makes it difficult to retrieve data efficiently in some circumstances.

WSRT is also recognized as a fundamental component of EVN. It was the first site to be linked by fibres as a precursor to eEVN and has been central to the production of several recent science highlights, such as the investigation of jet formation in Cyg X-3. Although this review does not formally cover JIVE, there are obviously many mutual benefits to the co-location and we hope it will continue.

The APERTIF upgrade promises greatly to enhance the capability and extend the competitive lifetime of the WSRT. By its spectacular enlargement of the telescope's field of view, it will dramatically expand its capabilities as an effective survey instrument, with scientific applications ranging from deep surveys of the northern sky in HI, OH and polarized continuum emission, to efficient searches for pulsars and transients.

The APERTIF development encompasses unparalleled advances in the field of antenna broadband feed arrays, of beam synthesis for RFI mitigation and digital beamforming and processing. These are recognized worldwide and give confidence in the viability of this innovative concept to be extended to other WSRT dishes.

In preparation for SKA dense array systems, the EMBRACE project includes the design, production and testing of a 300 m² array producing two beams in the 500 Mz to 1500 MHz range. With a mix of analogue and digital beamforming for two independent beams, this development project again includes unique developments in fast antenna analysis and optimization, low cost antenna technology, as well as innovative signal processing, again making use of the heritage of LOFAR and APERTIF.

APERTIF's innovative concept and technology (which may have further growth potential at higher bands) will bring WSRT back into the top league of facilities worldwide. Ingeniously, APERTIF also provides very relevant heritage for SKA higher bands focal array fed reflector antennas.

EMBRACE, a considerable advance in the field of wideband arrays, is directly applicable to the dense arrays foreseen for the SKA but also to a self-standing National or European instrument of a new generation.

Both the APERTIF and EMBRACE developments help to put ASTRON in a strong position to play a major role in critical parts of the SKA development programme.

VLBI/JIVE

Dutch radio astronomers working at Dwingeloo have long been active in the technique of Very Long Baseline Interferometry (VLBI). The European observations are organized by the European VLBI Network (EVN) and the central processing facility is located in the Joint Institute for VLBI in Europe (JIVE). Signals from all over Europe and beyond – as far away as China – are combined to resolve extremely fine scale with angular resolution equivalent to that needed to discriminate an object as small as the operating wavelength located on the other side of the Earth.

Indeed the baseline of the observations need not be limited to the Earth; orbiting radio telescopes have been successfully used to give even finer imaging and JIVE astronomers are active in the Japanese VSOP telescope and the Russian RadioAstron telescope, which was launched in July. The VLBI technology has become much more capable following the introduction of direct data communication between telescopes throughout Europe using fibres, as opposed to indirect communication using magnetic tapes. The scientific productivity of EVN in general and JIVE in particular remains high and the technical innovation achieved through them will be extremely valuable to the SKA, as will that achieved in the LOFAR and APERTIF projects.

SKA

The long-term goal is for Dutch radio astronomers to play a major role in the international Square Kilometre Array – a large array of radio telescopes that will have a combined collecting area of a square kilometre – on the basis of the technical progress that is being made with LOFAR and the other ongoing developments. They will be extremely well-positioned to do so, especially in relation to smart antennas (like dense arrays +FPA), calibrations of the arrays, and software. They should position themselves swiftly as soon as a choice is made between the two candidate sites in Australia and the Republic of South Africa. Dutch astronomers are already actively collaborating on prototype telescopes at both sites. The timescale for completing the full SKA depends upon international financing and addressing the enormous computing challenge that the project presents. Even if the SKA takes a long time to complete, Dutch radio astronomers will have access to LOFAR. This is currently the dominant low frequency radio facility in the world and is likely to remain so for several years, as long as it can remain on an upgrade path, developing increasingly sophisticated analysis techniques.

Programme assessment for the Radio Observatory Group: 5 (Excellent).

This reflects the 'Very good' past performance of WSRT and is based also on what can be expected from the very novel facilities and instruments being deployed, especially APERTIF and LOFAR.

4.3 Research and Development Group

The Research and Development (R&D) department is central to the success of ASTRON's mission. In the 2005 – 2010 period, the R&D Laboratory successfully conducted the end-to-end system and technology research, development and testing, to validate the two breakthrough telescope concepts pioneered by ASTRON: the sparse and dense multibeam Aperture Array (AA) antennas (LOFAR) and the Focal Plane Array (FPA) reflectors (APERTIF + APROPOS).

In spite of the scepticism of many, it has succeeded in developing the innovative yet affordable technologies and techniques required to make this happen. As a result, the excellence of the ASTRON R&D department is now recognized worldwide. This further consolidates ASTRON's and the Netherlands' leadership in the field of world radio astronomy.

Given the heritage of LOFAR and APERTIF and the successful development of the EMBRACE demonstrator, the R&D department and ASTRON have clear potential to successfully evolve similar instruments at low and high frequencies at national, European and/or world level within the SKA project, where ASTRON is now uniquely well positioned to expand its major role.

In support of LOFAR, APERTIF + APROPOS and SKA/EMBRACE, the Research and Development department has generated world-leading achievements and publications / PhDs of top scientific and technical quality and of high relevance to radio astronomy and beyond. Some are listed below:

System:	LOFAR AA end-to-end system conception, design, monitoring and control LOFAR cost versus performance successful optimization APERTIF FPA concept development and validation, with a successful PDR
Antennas & RF:	New advances in sparse and dense Aperture Array theory Modelling and optimization of wideband Vivaldi array elements Fast modelling of very large arrays New definitions for low noise receiving systems High performance, low cost broadband antenna array and feed elements Advances in room-temperature Low Noise Amplifiers
Beamforming:	Advanced focal feed array synthesis yielding 75% aperture efficiency and overlapping beamforming techniques (APERTIF) Advanced chip and opto-electronic beamformers Combined RF and digital multiple beamforming (EMBRACE)
Processing:	Real-time streaming signal processing with adaptive RFI removal LOFAR new procedures and software algorithms for calibration and imaging Successful and timely development of LOFAR processing / scientific software 'Filter software' Design and production of a generic multi-purpose, re-programmable digital board (UniBoard) with up to 4 Tops capability New dynamic pipeline processors

During the visits to the R&D department and the interviews with its staff, the Committee gained an impression of high professionalism, competence and quality, and of an excellent working atmosphere. The department is divided into small specialized R&D groups for system, antennas, microwaves, photonics, digital and embedded signal processing, computing and advanced

algorithm development and mechanical engineering. Communication across levels seems to be easy.

The number of staff in the R&D department has decreased from 95 in 2005 to 56 in 2010. It is felt that the department is becoming 'thin' in some key areas (such as antennas, with only 3 staff left) and that this might jeopardize the end-to-end capability of ASTRON for further developments of Aperture Array and Focal Plane Array instruments.

Like the other groups in ASTRON, the R&D department seems to do well at securing outside investment and innovation subsidies, EC programme funds and substantial semi-commercial contracts.

With an average of 5 R&D employees pursuing doctorates, the PhD training in the department focuses on complex instrument-related technical topics, mostly concerning Aperture Array telescopes, such as RFI mitigation, embedded signal processing, dense array fast analysis, calibration and imaging or supercomputing. A number of Masters and Bachelor students are also co-supervised by ASTRON R&D staff. The department regularly organizes specialized workshops and courses as part of their training.

Regarding its productivity strategy, the department seems to correctly prioritize the support it provides for ASTRON facilities, to address the critical needs and software developments of the programmes, and to focus PhD research and publications on fundamental issues such as relevant array theory or novel calibration or RFI mitigation techniques. The productivity of the R&D department is astounding, not only in terms of publications and PhD research, but more especially with regard to its success in developing and validating two entirely new telescope concepts of major complexity within just a few years.

The department contributes to the training of top level engineering students, much needed by Dutch and European industry and academia. It conducts regular outreach activities and has excellent visibility in the engineering community and in the media.

New LOFAR stations are almost exclusively procured from LOFAR consortium partners: a not inconsiderable contribution to the local economy and to Dutch exports. Valorization of the department's research results in other sectors seems to have potential and this might be explored further with potential partners.

The strategy of the R&D department, in line with that of the institute as a whole, is to maintain its unique end-to-end instrument research and development capability based on the heritage of LOFAR, APERTIF and EMBRACE:

1. To provide expert support for the LOFAR and APERTIF developments as required.
2. To keep its lead by innovating further in the area of AA and FPA telescope concepts and systems, front end technologies and processing/computing techniques.
3. To develop a dense Aperture Array demonstrator at centimetre wavelength of a collecting area of approximately 2000 square metres, preferably as a key player and coordinator of the SKA AAVP Programme, but otherwise as an independent effort.

The Committee feels that this strategy is sound and should be fully supported.

Programme assessment of the Research & Development group: 5 (Excellent).

5 Supplementary questions by NWO

Generic questions by NWO

In this section we answer the generic questions put by NWO.

1. **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 their use)?**

Yes to both questions, as can be seen from all our comments above. During the last review period, ASTRON has positioned itself to fully utilize its new world-class facility, LOFAR; to play a major role in the international SKA; to upgrade existing facilities to be state-of-the-art; and to capitalize on the science achievable with these facilities.

2. **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 new challenges?**

The world leadership of ASTRON in the system optimization, technology and verification aspects of Aperture Arrays and Focal Plane Array telescopes and their use is clearly recognized in the Radio Astronomy community and beyond. The key staff members of the ASTRON R&D department are internationally prominent in their field.

The pioneering achievements, publications and PhD research mentioned above bring ASTRON considerable respect and an excellent worldwide reputation in academia, research institutes and industry that goes well beyond radio astronomy, encompassing the fields of systems, antennas, beamforming, signal processing and computing.

'International importance': this has been clear for a long time, with 50% of published papers using WSRT data being authored by foreign users; however, the institute's international importance is about to increase dramatically both in terms of recognition and also more formally, since ASTRON is trying to make its facilities an official European Research Infrastructure Consortium (ERIC). This has been about a year in the making, thanks to LOFAR, APERTIF and SKA research initiatives. ASTRON is also partnering Australia and South Africa in developments on the path to the SKA, the next major international project.

'Right policies': The International LOFAR Telescope structure is good. Five partners (four foreign partners and ASTRON) are already members. Many other countries are on the brink of membership and an ERIC structure is being considered. The APERTIF evolution of WSRT and the development of top level SKA-oriented research are also good policies.

In addition, ASTRON hosts JIVE and has good interfaces with this group. Together, in the future, they can become a prominent centre of excellence for the SKA.

Postdocs and scientists come from a wide range of countries, which is another sign of the international nature of the enterprise.

3. **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?**

'NWO support': Yes, ASTRON is at the forefront of discovery and has great societal impact.

It is difficult to imagine how it could be more productive or return greater value on the investment.

4. **Is the institute doing enough to exploit its opportunities for cooperation with organizations outside the academic world?**

'Exploit cooperation outside academia': Yes, it does exploit such cooperation. An excellent example is Dome, an important initiative being undertaken with IBM, with whom ASTRON is also cooperating on Blue Gene, which is critical to data analysis. Also, ASTRON has developed valuable industrial partnerships, from which the partner companies are benefitting greatly. ASTRON is thinking more about how to do this and how to transfer its intellectual property to industrial partners.

ASTRON-specific questions

Four questions to be answered by the Committee were devised for ASTRON specifically:

1. **In the context of the increasing scale and international character of scientific infrastructure (such as the development of the global Square Kilometre Array), what is ASTRON's longer-term strategy for the development and exploitation of its in-house observing facilities (WSRT and LOFAR)? And what implications does this have for the support role of the institute and for its national and international position within the field?**

'In-house observing facilities': WSRT will be used for about a decade to conduct surveys of international relevance using APERTIF (20 years' worth of proposals were submitted in the first round). This facility will be complementary to the eVLA. The WSRT telescopes may need maintenance before the end of the decade. This makes APERTIF implementation more urgent. Further upgrades are unlikely.

LOFAR, which has great promise, could be a major instrument, certainly for a decade and possibly well beyond, until SKA1 is in full operation. Upgrades will be considered, perhaps near the end of the decade.

It is not yet fully apparent how ASTRON will contribute to the SKA, but it is clear that it will play a significant role. ASTRON wants to cover the work packages on aperture array and on calibration of arrays and software. Depending on the evolution of the SKA in the next decade, the institute could strive to become a centre of excellence in the Netherlands for SKA science.

2. **In 2008, ASTRON revised its mission to focus more specifically on radio astronomy and established new strategic priorities for the longer term. Is ASTRON's current internal organization adequate to support this mission and strategy? This question is asked in the light of the opening of the international LOFAR Telescope in 2010, the embedding of LOFAR in ASTRON, and ASTRON's scientific and strategic ambitions within the SKA.**

Yes, see above.

3. **What are the consequences of the exploitation of LOFAR for the institute and what will be its impact on ASTRON's strategies?**

The exploitation of LOFAR will become a central part of the responsibilities of the institute, and it is very important that the scientists here are leaders in LOFAR science, e.g. leading Key Programmes. To operate LOFAR properly and to respond to the demands of the community for data reduction and archiving is a huge task. It will require a substantial budget that is stable over LOFAR's prime lifetime. After all the investment in development and construction, it is critical that the base budget be sufficient to exploit the capabilities of this important facility to the full.

Much depends on how well LOFAR measures structure in the Epoch of Reionization. Of course, this depends mostly on nature but also on how well the interference mitigation works at very low signal to noise ratios. Early success will justify an increased science effort. On the other hand, if the signal is not well detected, it will take the SKA to make this measurement, and investments should be made in focused technology development on the SKA.

4. How does ASTRON organize contacts with national and international users of its research facilities?

ASTRON has a Time Allocation Committee (TAC) and a Users Committee (UC), both of which are working well. The International LOFAR Telescope (ILT) has an international consortium. The ASTRON innovation of 'busy weeks' is an example of service to the community (imaginative and positive).

Formal agreement with Germany on LOFAR includes software participation, which is already happening at the level of postdoctorates and developers; in ILT, more active cooperation can take place.

APERTIF survey proposals have attracted a great deal of international attention.

The Governing Board put the following generic questions to be answered by the institutes during their self-evaluation:

- What is the 'earning power' of the institute? By 'earning power', NWO means the institute's capacity to recruit resources, assume Principal Investigator roles, etc.; 'earning power' is therefore a measure of proven quality and scientific excellence gained in competition (and as such need not be expressed in purely financial terms).
- What 'consolidation of strengths' is the institute achieving? By 'consolidation of strengths', NWO means cooperation with universities and other players at national and international level. What links does the institute have with universities? Such links can be expressed, for example, in terms of the number and nature of professorships, FTEs, numbers of PhD students in trainee researcher / trainee research assistant posts, and numbers of doctoral studies successfully completed.
- Does the institute have strategies for taking its work in new directions in the medium term (approximately the next ten years)?

The Committee considers that the replies provided by ASTRON to these questions are sound. The institute has been extremely successful in attracting external funding, and also in obtaining individual awards, despite acute competition. Its research work is interlinked with that of universities; staff members teach at them and/or visit them regularly, as do postdocs; graduate students spend their time primarily at the universities. ASTRON astronomers often play a leading role in scientific collaborations involving the Dutch universities. In terms of taking new directions, ASTRON is just on the brink of reaping the fruits of its investment in revolutionary radio astronomy techniques; at the same time, it must find a way of becoming an important partner of the SKA and still maintaining its extraordinary capacity for independent technical and scientific research.

6 Conclusions and recommendations

6.1 Conclusions

The overall assessment of ASTRON is Excellent. The institute remains an international leader in radio astronomy. The new low-frequency radio facility, LOFAR, for which it is the lead institution, is a major triumph in the making. It represents a complete reinvention of the techniques of radio astronomy and appears to have overcome the very challenging issue of human-created noise. Various technical innovations applied to an older facility, the Westerbork Synthesis Radio Telescope, promise to transform it into a state-of-the-art survey instrument. Still more technical work builds toward the next-generation facility, the Square Kilometre Array. Through its consistently forward-thinking research and development arm, ASTRON has positioned the Netherlands to be a major force in radio astronomy.

The scientific rewards following from these advances will be great, particularly if LOFAR succeeds in measuring the clumping of neutral hydrogen in the Epoch of Reionization, before stars and quasars fully ionized the intergalactic gas. A reinvigorated Astronomy Group stands ready to participate in these scientific investigations. Excellence in an observatory requires scientific as well as technical leadership, and we believe, although young and only recently assembled, the Astronomy Group is well on its way to establishing itself in the top tier of international radio astronomy. In support of this conclusion, we note that ASTRON scientists have published many high impact scientific results since the last review. The demonstrated strengthening of the scientific enterprise plays an essential part in keeping instrumentation and its use at the cutting edge.

The near-term future of radio astronomy in Europe is epitomized by ASTRON, with a revitalized WSRT, a well-linked European Very Long Baseline Interferometry network, and especially, the new LOFAR capability. The longer-term future rests on the SKA. Even though the Netherlands has a strong tradition in radio astronomy, it is still remarkable that such a small country can play a leading role in the large international collaboration to build the SKA. Yet, through careful strategic thinking, a very high level of technical competency and steady effort, ASTRON has positioned itself well to be a significant player in the SKA, ready to take on two of the key work packages.

Indeed, the new age of the ‘software telescope’ has arrived, with tremendous advances in the capabilities of radio telescopes being realized through software. A clear example is WSRT, which is being refitted with focal plane arrays and sophisticated correlator electronics. In this way, ASTRON has succeeded in keeping its workhorse facility at the cutting edge, with an enormous – more than an order of magnitude – increase in mapping speed. That this approach is inherent in the design of the SKA telescope means ASTRON is particularly well positioned to remain a leader in radio astronomy through the coming decade.

The prospects for government finances in Europe are unusually uncertain these days. Understandably, planning beyond the near term has to be done for a range of very different financial outcomes and this complicates staffing plans in the next years. In this context, it is particularly notable that ASTRON has made impressive strides in collaboration with industry (the ‘valorization’ of ASTRON R&D). In any case, while we recognize the difficulties of the present fiscal climate, we feel strongly that ASTRON’s budget is well justified at its present level. Future activities, such as a significant contribution to the first construction phase of the SKA, will constitute a major part of the Dutch national roadmap for research infrastructure. Should the SKA proceed more slowly than expected (the current, very ambitious schedule has first construction occurring in 2015), ASTRON is very well placed to proceed more slowly on the SKA while continuing to exploit the novel capabilities of LOFAR. In addition, the excellent collaboration between ASTRON and local industry offers many opportunities for adapting radio astronomy expertise to other applications, and we encourage the institute to maintain its leadership along these lines.

6.2 Recommendations

ASTRON is on the right path on all important issues. We commend the staff, the management team and the directorate on their impressive achievements. Our recommendations constitute steps to maintain and build on this strong foundation.

It is critical that LOFAR should produce good science, demonstrating its high potential to scientists around the world – even before the facility is fully commissioned. Ideally, we expect a steady stream of ‘early release’ press releases. Scientific leadership from ASTRON is essential to making this happen. The LOFAR team must be careful not to over-promise what it will deliver. Since there seems to be good communication between the LOFAR team and the Key Science Project groups, we recommend that LOFAR should work closely with these groups to deliver an agreed sequence of data products and tools that will help Key Project scientists produce excellent science quickly; for this reason, general user tools should initially have lower priority.

It is important to maintain ASTRON leadership in radio astronomy at the world level and to consolidate the role that ASTRON, and Dutch industry, will play in future programmes like the SKA. The Astronomy Group should be sustained at roughly its current size (9 staff, 11 postdocs, 6 PhDs), since it would be difficult to provide effective international leadership and to have a strong scientific impact with a smaller number of staff. We do think the number of graduate students could and should be increased, perhaps through an agreement with NOVA and Dutch universities. Students could have co-advisors in the universities and at ASTRON, and could be paid by NOVA.

Technology developed for advances in Dutch radio astronomy should be leveraged for the national good through collaborations between ASTRON and industry. Already this has been a successful undertaking and we see every advantage in building on this foundation. Although NWO is currently the most important source of funding, it is likely to be increasingly important to develop additional funding sources in future, and industry could play a key role, as new opportunities arise from ASTRON’s unique technical advances and expertise.

Given the increasing importance of software in telescope design and operation, the software engineering part of ASTRON may need to expand.

We recommend that ASTRON plan for an uncertain fiscal climate in Europe, including a range of possibilities for future staffing. Building on present collaborations with Dutch industry provides a possible hedge against decreasing government funding.

ASTRON management should think about formal career development for scientific staff, as part of its mission to valorise its activities. Many ASTRON students and postdocs are likely to go on to important careers in the Dutch industrial sector as well as in academia, so building the skills of young scientists will benefit both industry and academia, as well as the students themselves.

We note that ASTRON does not have an ideal gender balance in a field (astronomy) with a relatively large participation by women. This problem is no doubt exacerbated by the geographical remoteness of the site and by general social barriers. However, since ASTRON is clearly an innovator, we urge the institute to innovate in this area as well, perhaps starting with a survey of the child care needs of the (entire) staff.

Outreach efforts at ASTRON could be enhanced. As one of the premier scientific enterprises in a country full of scientifically literate citizens, we believe ASTRON should be able to sustain higher visitor levels. Using existing resources, greater impact can be obtained by leveraging outreach efforts to teachers.

Annex 1 Curricula Vitae of Evaluation Committee Members

Dr C. (Catherine) Cesarsky is the High Commissioner for Atomic Energy in France, advisor to the government on science and energy issues. She was born in France, received a degree in Physical Sciences at the University of Buenos Aires and graduated with a PhD in Astronomy in 1971 from Harvard University (Cambridge, Mass., USA). Afterwards she worked at the California Institute of Technology (CALTECH). In 1974, she became a staff member of the Service d'Astrophysique (SAp), Direction des Sciences de la Matière (DSM), Commissariat à l'Energie Atomique (CEA) (France). She led the theoretical group of the SAp (1978 – 1985), was Head of SAp (1985 – 1993), and Director of DSM (1994 – 1999). She was then ESO Director General from 1999 until 2007.

Dr Cesarsky has pursued her research activities in several areas of modern astrophysics. The first part of her career was mostly devoted to the high-energy domain; she later turned to studies of star formation and of the evolution of galaxies. She received the COSPAR (Committee on Space Research) Space Science Award in 1998. Cesarsky was president of the International Astronomical Union (IAU) (2006 – 2009). She is a member or foreign member of several national and international science academies (F, US NAS, SE, UK, Academia Europaea) and she is a 'Commandeur de la Légion d'Honneur'.

Professor M. (Michael) Bode is Professor of Astrophysics and Director of the Astrophysics Research Institute at Liverpool John Moores University (Liverpool JMU). After obtaining his PhD from Keele University he was employed at the University of California Los Alamos National Laboratory. Later he returned to the UK to take up a Research Council Advanced Fellowship at the University of Manchester. Subsequently, he took up a lectureship at what is now the University of Central Lancashire, becoming Professor of Astronomy there in 1991. In 1992, he moved to Liverpool JMU as Head of Physics, subsequently serving as Assistant Provost (Research) for the university. He then went on to found what is now the LJMU Astrophysics Research Institute and held a PPARC/STFC Senior Fellowship there from 2003 – 2007. He is a past Vice President and Secretary of the Royal Astronomical Society and has chaired many Research Council committees, both national and international, including the Astronomy Grants Panel and MERLIN Steering Committee. Most recently, he was a member of STFC's Science Board, and is now chair of the research council's Advisory Panel for Science in Society. In 2006, he was appointed on behalf of the major European astronomy funding bodies to lead the development of the ASTRONET Infrastructure Roadmap – a plan for the development of European astronomy with a 20 year horizon (published in 2008). Bode's current research centres on understanding the explosions of novae and their wider importance. He has been leading the development of the Liverpool Telescope on La Palma and the RoboNet global network. He is very active in the promotion of astronomy to the public and its utilisation in enthusing young people about the study of science, mathematics and technology in general: he helped to found the UK's National Schools' Observatory and the regional 'Spaceport' visitor centre projects and currently chairs the NSO Board.

Professor R. (Roger) Blandford, astronomer and astrophysicist, is currently Pehong and Adele Chen Director of the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), Professor at the Stanford Linear Accelerator Center (SLAC) and Luke Blossom Professor in the School of Humanities and Sciences at Stanford University, USA. Blandford earned his BA, MA and PhD degrees at Cambridge University. Following postdoctoral research at Cambridge, Princeton and UC Berkeley, he accepted a faculty position at Caltech in 1976 where he was appointed the Richard Chace Tolman Professor of Theoretical Astrophysics. In 2003, he moved to Stanford.

Blandford is a fellow of the Royal Society and the American Academy of Arts and Sciences and a member of the National Academy of Science. In addition, he was the chair of Astro2010, the decadal survey that helps define and recommend funding priorities for U.S. astronomy research in the upcoming decade. His research interests include black hole astrophysics, cosmology, gravitational lensing, cosmic ray physics and compact stars.

Professor A. (Andrew) Lawrence is Regius Professor of Astronomy, University of Edinburgh. He works at the Institute for Astronomy, which – together with the UK Astronomy Technology Centre – forms the Royal Observatory Edinburgh (ROE). Lawrence received his PhD in 1980 in X-Ray Astronomy. He was Head of the Institute for Astronomy from 1994 to 2002, and Head of the School of Physics at the University of Edinburgh from 2003 until 2008. In 2008 – 2009 he was a sabbatical visitor at the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) at Stanford in California. Lawrence has published over 200 articles and reports in scientific journals, specializing in multi-wavelength study of active galaxies, observational cosmology, and large scale surveys and data processing. He is a Fellow of the Royal Society of Edinburgh, Fellow (and former Vice President) of the Royal Astronomical Society and Trustee (currently Chairman) of the Royal Observatory (Edinburgh) Trust. He is also currently the chairman of the Astronomy Grants Panel for the UK Science and Technology Facilities Council.

Professor M. (Meg) Urry is the Israel Munson Professor of Physics and Astronomy at Yale University, Director of the Yale Center for Astronomy and Astrophysics, and Chair of the Physics Department at Yale. Prior to moving to Yale in 2001, Prof. Urry was a senior astronomer at the Space Telescope Science Institute, which runs the Hubble Space Telescope for NASA. Her scientific research focuses on the growth of supermassive black holes and how they co-evolve with galaxies. She has published over 170 refereed articles in scientific journals and she chaired the Galaxies Across Cosmic Time study for the Astro2010 decadal survey of astronomy and astrophysics in the U.S. Prof. Urry is a Fellow of the American Academy of Arts and Sciences, the American Physical Society and American Women in Science, and a recipient of the Annie Jump Cannon prize of the American Astronomical Society. Professor Urry is also known for her efforts to increase the number of women in the physical sciences, and her popular science articles appear on cnn.com.

Professor (Antoine) Roederer retired from ESA in 2008 and is now Scientific Advisor at the University of Delft – IRCTR. He is a specialist in innovation and development of antennas. After receiving a PhD in Electrical Engineering (honours) from the Université de Paris VI in 1972, he joined ESRO, the predecessor organization to ESA, in 1973. There, he initiated R&D and project support for space antennas and for many years supervised it. In 1993, he became Head of the Electromagnetics Division at ESA. He was European representative of the IEEE Antenna and Propagation Society, where he has held several functions, including IEEE Distinguished Lecturer in 1995 – 1996. He has also been active in the British IEE and in the French SEE from which he received the Ampere medal for his work. He has been Chairman of the EU COST 260 Project on Smart Antennas. He was the initiator and chairman of the Millennium Conference on Antennas and Propagation, AP 2000, precursor of the large EUCAP conferences. He was one of the founders and advisors of the EU Network of Excellence on Antennas, ACE. Roederer has authored or co-authored over 150 papers and holds 20 patents in the field of antennas. In 2005 he received a Doctorate Honoris Causa from the Technical University of Delft for his contributions to the field of antennas and to the antenna community in Europe. He is a Life Fellow of the IEEE.

Annex 2 Programme for the Site Visit

Tuesday, 18 October 2011

16:30 hours	Closed session of the Evaluation Committee at Hotel Wesseling (Dwingeloo)
18:30 hours	Short transfer to Restaurant De Herberg (Fluitenberg) and welcome dinner with the NWO Governing Board
21.30 hours	Return to Hotel Wesseling (Dwingeloo)

Wednesday, 19 October (first day of the site visit):

Institute and main research lines

Brief presentations by Management Team members and questions from the panel

9:00 hours	Mission, institute highlights	Prof. Michael Garrett (General & Scientific Director)
10:00 hours	Societal impact, valorization	Dr Marco de Vos (Managing Director)
10:30 hours	Coffee break	
10:45 hours	Astronomical research	Prof. Raffaella Morganti (Head Astronomy Group)
11:15 hours	Radio Observatory	Dr Rene Vermeulen (Director Radio Observatory/ILT)
11:45 hours	Technical R&D	Dr Albert-Jan Boonstra (Head R&D)
12:15 hours	Lunch/Closed session	

Tour of science, technology and laboratories

Panel meets astronomy/technical staff, postdocs and PhDs.

Cesarsky, Bode and Urry visit:

Control room:

Dr Michael Wise (Project Scientist LOFAR)

Dr Antonis Polatides (Head of User Support & Operations)

Digital lab:

Raj Thilak Rajan, MSc (PhD student in signal processing)

Ir. Gijs Schoonderbeek (Digital Designer)

Dr Adam Deller (Postdoc, Long-baseline astronomer)

Photonics lab:

Dr Peter Maat (Photonics researcher)

Dr Joeri van Leeuwen (Junior staff astronomer)

Blandford, Lawrence and Roederer visit:

Mechanics workshop/NOVA Group:

Ir. Johan Pragt (Head Mechanics)

Ir. Ramon Navarro (Head NOVA Opt/IR instrumentation group)

Ing. Gabby Kroes (Lead engineer)

CAMRAS – Dwingeloo 25-m telescope:

Paul Boven (CAMRAS member/Network Specialist, JIVE)

	JIVE Correlator Room:
	Dr Huib-Jan van Langevelde (JIVE director)
	+ interview with full Committee, at 14.30 hr (Hooghoudt room)
14.40 hours	Closed session
15.00 hours	Four presentations of highlight results
	Prof. Ger de Bruyn (Senior Staff Astronomer): 'From WSRT to LOFAR (E-oR): a path with challenges'.
	Dr Jason Hessels (Junior Staff Astronomer): 'Pulsar and Fast Transient Studies with LOFAR and Other Next-Generation Radio Telescopes'.
	Dr ir. Stefan Wijnholds (Technical Researcher): 'The model based approach: a new view on Imaging'.
	Raj Thilak Rajan, MSc (PhD student in Digital Signal Processing): 'Signal processing for OLFAR (Orbiting Low Frequency Antennas for Radio astronomy; a summary of recent results.'
16:00 hours	Transfers to WSRT and LOFAR (with Management Team and selected staff)
16:30 hours	WSRT tour attended by <i>Bode, Roederer and Urry</i>
	EMBRACE:
	Prof. Arnold van Ardenne (Coordinator ASTRON SKA Project Office)
	Ir. Dion Kant (System engineer Aperture Array development)
	Dr Ilse van Bommel (Project scientist Aperture Array Verification Programme)
	APERTIF:
	Prof. Tom Oosterloo (Senior staff astronomer, co-PI APERTIF)
	Ir. Wim van Cappellen (Head Antenna group, project mgr APERTIF)
AND	
16:30 hours	LOFAR Core tour attended by <i>Cesarsky, Blandford and Lawrence</i>
	Dr Rene Vermeulen (Director Radio Observatory/International LOFAR Telescope)
17:15 hours	Transfer back to Hotel Wesseling, Dwingeloo
17.45 hours	Closed session
19.30 hours	Dinner at Hotel Wesseling

Thursday, 20 October (second day of the site visit)

Stakeholders, staff and governance

Interviews and meetings

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|-------------|---|
| 9:00 hours | Interview with business partners and regional stakeholders

Alexander Brink MSc BA (Finance and Grants manager IBM Benelux)
Monique Leijn MA (Economic Affairs, Province of Drenthe),
Peter Visser (Director Neways electronics)
Dr Erik Zoutman (Director S&T software company) |
| 9:30 hours | Interview with selected LOFAR/WSRT users

Dr Bob Campbell (eVLBI, JIVE)
Prof. Marc Verheijen (Kapteyn Astronomical Institute, Groningen)
Dr Emanuela Orru (Radboud University, Nijmegen)
Dr Maaïke Mevius (KVI, Groningen)
Dr John Swinbank (Astronomical Institute Anton Pannekoek, Amsterdam)
Drs. Reinout van Weeren (Leiden Observatory) |
| 10:00 hours | Poster session (PhDs and postdocs) next to the Colloquium Room |
| 10:30 hours | Open Door Session in the Colloquium room |
| 11:00 hours | Interview with SAC representatives

Dr Sean Dougherty (NRC-HIA, Canada)
Prof. Ralph Wijers (University Amsterdam)
Prof. Leon Koopmans (University Groningen) |
| 11:30 hours | Meeting with ASTRON Board representative

Prof. Karel Gaemers (Chair)
Prof. Johan Bleeker
Sipke Swiersta, MA |
| 12:00 hours | Interviews with PhDs and Postdocs (Committee divides into two groups) |
| 12:30 hours | Lunch with ASTRON directorate |
| 13:15 hours | Closed session preparing for the preliminary feedback and the evaluation report |
| 16:30 hours | Preliminary feedback to the ASTRON directorate and Chair ASTRON Board |
| 17:00 hours | End of site visit |
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Annex 3 Interviews with PhDs and Postdocs

PhD students – interviewed by Committee chair *Cesarsky* and members *Blandford*, *Lawrence*:

PhDs Astronomy Group

(first name, last name, flm – starting date at ASTRON (university) – research topic)

- *Andre Offringa*, m – April 2008 (Groningen*) – Radio Frequency Interference & LOFAR
- *Thijs Coenen*, m – April 2009 (Amsterdam*) – Pulsar searches with LOFAR
- *Katinka Gereb*, f – Sep 2010 (Groningen*) – Neutral hydrogen and radio sources: surveys in preparation for APERTIF
- *Aleksandar Shulevski*, m – Oct 2010 (Groningen*) – Life cycle of radio sources with LOFAR
- *Yvette Cendes*, f – just started (Amsterdam*) – Transients (AARTFAAC student)

PhDs Research & Development

- *Parisa Noorishad*, f – from 2009, (Groningen*) – Dense Aperture Array calibration
- *Arash Owrang*, m – 1 Sept 2011 (University of Amsterdam*) – Fast imaging on large astronomical data streams

Postdoctoral researchers – interviewed by Committee members *Bode*, *Roederer*, *Urry*:

Postdocs Astronomy Group

(first name, last name, flm – starting date at ASTRON (university) – research topic)

- *Ilse van Bemmelen*, f – 1 Sept 2010 – Multi-wavelength studies of active galaxies (dust, HI)
- *Adam Deller*, m – 21 Feb 2011 – Pulsar astrometry, VLBI, wide field, software correlator (NWO Veni fellow)
- *Valeriu Tudose*, m – 1 Mar 2009 – Radio emission from transients (e.g. XRBs); physics of jets
- *Neeraj Gupta*, m – 15 Jul 2010 – Atomic and molecular gas content of galaxies, calibration techniques
- *Alicia Berciano Alba*, f – 1 Mar 2010 – ALBA gravitational lensing and sub-mm galaxies
- *Gyula Jozsa*, m – 1 Apr 2008 – Kinematics and dynamics of galaxies (AG/RO)

Postdocs Radio Observatory (Support Scientists)

- *Rebecca Mc Fadden*, f – 1 May 2010 – Cosmic rays (LOFAR support)
- *Ashish Asgekar*, m – 15 June 2009 – Diffuse Ionized Gas in the Galaxy (LOFAR support)

* University where they graduate.

Annex 4 List of acronyms

AA	Aperture Array
AAVP	Aperture Array Verification Programme
APERTIF	APERture Tiles In Focus, a focal plane array upgrade project for the WSRT
APROPOS	A back-end (correlator) project complementing APERTIF
EMBRACE	European Multi-Beam Radio Astronomy Concept (a dense aperture array demonstrator)
EVLA	Expanded Very Large Array
EVN	European VLBI Network
FPA	Focal Plane Array
HI	Neutral Hydrogen
ILT	International LOFAR Telescope
JIVE	Joint Institute for VLBI in Europe
LOFAR	LOw Frequency Array
LTA	Long Term Archive
MERLIN	Multi-Element Radio Linked Interferometer Network
NOVA	Netherlands Research School for Astronomy (federation of five Dutch universities)
PDR	Preliminary Design Review
PI	Principal Investigator
RF	Radio Frequency
RFI	Radio Frequency Interference
SKA	Square Kilometre Array
SME	Small and Medium Enterprises
SWOT	Strengths, Weaknesses, Opportunities and Threats
VLBI	Very Long Baseline Interferometry
WSRT	Westerbork Synthesis Radio Telescope