Evaluation 1999-2004

Institute Netherlands Foundation for Research in Astronomy (ASTRON)

The Hague, September 2005
Netherlands Organisation for Scientific Research

Contents

1 Introduction

1.1 Scope and context of this evaluation

This assessment covers the research carried out since 1999 at the ASTRON Institute Netherlands Foundation for Research in Astronomy. The evaluation was commissioned and organised by the Netherlands Organisation for Scientific Research (NWO). ASTRON submitted a self-evaluation report covering the period 1999–2004. This was approved by the Governing Board of NWO in May 2005.

This external assessment follows the Standard Evaluation Protocol 2003-2009 for Public Research Organisations (SEP).

The aims of the assessment system are:
- Improvement of the quality of research through an assessment carried out according to international standards of quality and relevance.
- Improvement of research management and leadership.
- Accountability to higher levels of research organisations and funding agencies, government and society.

The committee was asked to produce a reasoned judgement on the mission, strategy and performance of the institute. The SEP calls for an evaluation both of the research institute itself and of the research programmes it conducts. The research institute must submit details of the results achieved in each research programme over the previous six years (including quantitative data about staff input, key publications and a list of publications), a short outline of the mission statement of each programme, and details of any changes expected to occur in its research profile. Site visits form an important element of every evaluation. They include interviews with the management of the institute and its programme directors, as well as visits to laboratories and facilities.

1.2 The evaluation committee

The evaluation committee was appointed in December 2004 by the Governing Board of NWO, after consultation with ASTRON and with the NWO Council for Physical Sciences. Its members are:

Prof. Jos Engelen	(chair) CERN (CH)
Prof. Jocelyn Bell Burnell	Oxford Astrophysics (UK)
Prof. Malcolm Longair	Cavendish Laboratory, Cambridge (UK)
Prof. Joseph H. Taylor	Physics Department, Princeton University (USA)
Prof. David Williams	CERN (CH)

A short curriculum vitae of each of the members is included in Appendix 1. The committee was supported by NWO staff: Patricia Vogel, Ron Dekker and Foekje Grootoonk.

All members of the committee declared that their assessment had been free of bias, personal preference or personal interest, and that it had been reached without undue influence by the institute, the programme or other stakeholders.

Any existing professional relationships between committee members and programmes under review were reported and discussed in the committee meeting. The committee concluded that there were no conflicts of interest.

1.3 Data supplied to the committee

The documentation included all the information required by the Standard Evaluation Protocol, as well as answers to the additional questions addressed to ASTRON by NWO. It comprised:

- The ASTRON self-evaluation report, including key publications.
- The ASTRON Annual Report 2002, giving a general overview of ASTRON's scientific activities and some research highlights.
- The SKA report.
- A bibliometric study by the CWTS at Leiden University.
- Summary tables on the ASTRON budget, personnel and output (publications).

1.4 Procedures followed by the committee

The committee proceeded in accordance with the Standard Evaluation Protocol 2003-2009. The assessment was based on the documentation provided by the institute and on the interviews. The interviews took place during the site visit made in June 2005. The programme of the site visit is included as Appendix 2.

The self-evaluation report, the annual report and further documentation were sent to the committee in the month before the site visit.

The chair and secretary of the committee established a timetable for the site visit. The committee met on the afternoon preceding the site visit to discuss and plan the interviews with ASTRON's management, researchers, Governing Board and advisory bodies. The committee agreed procedural matters and aspects of the assessment as described in the following paragraphs.

At a formal dinner in Giethoorn, the committee had the opportunity to meet with prof. dr. P. Nijkamp, chair of the Governing Board of NWO.

The interviews with ASTRON's management, Governing Board, research staff and users of ASTRON facilities (Contactraad, EW-Programme Committee, JIVE) took place during the site visit on 6 and 7 June 2005. Interviews and discussions were conducted by the entire committee.

After the interviews, the committee discussed the scores and comments for the institute and the research programme, and determined the final assessment.

At the end of the site visit, a meeting was held with ASTRON's director and the chair of its Governing Board to report the committee's main findings.

In August 2005, a draft version of this report was sent to ASTRON's director for factual correction. The report was subsequently submitted to the Governing Board of NWO and accepted in September 2005.

1.5 Aspects and assessment scale

The committee used the ratings specified in the the Standard Evaluation Protocol: excellent (5), very good (4), good (3), satisfactory (2) and unsatisfactory (1).

EXCELLENT

Work that is at the forefront internationally, and has had and most likely will have an important and substantial impact in the field. The institute is considered to be one of the international leaders.

VERY GOOD

Work that is internationally competitive, and has made and is expected to make a significant contribution to the field. The institute is considered to be an international player and to be one of the national leaders.

GOOD

Work that is competitive at the national level, and has made and most likely will make a valuable contribution to the field, both nationally and internationally. The institute is considered to be internationally visible and a national player.

SATISFACTORY

Work that is solid but not exciting, has added or will add to our understanding and is in principle worthy of support. But it is considered of less priority than the work in the above categories. The institute is nationally visible.

UNSATISFACTORY

Work that is neither solid nor exciting, possibly flawed in the scientific and or technical approach, a repetition of earlier work, etc. Work not worthy of pursuing.

2 ASTRON

2.1 Mission

The ASTRON Institute was founded in 1949 to exploit the then new technology of radar and radio communications to allow exploration of the heavens at radio frequencies. Since that time its mission has broadened. Its goal is now defined as 'enabling discovery in astronomy through innovative instrumentation and facilities management'. The organisation is a foundation under Dutch law and at the same time an institute of the Netherlands Organisation for Scientific Research (NWO). Nearly all ASTRON personnel are employed by NWO.

ASTRON has a Governing Board that is responsible for setting global policy at the institute. Its membership reflects the institutional composition of the astronomical community in the country, augmented by several external experts in areas of importance to ASTRON.

Day-to-day management is the responsibility of the director, who is also Professor of Observational Astronomy at the University of Groningen. Director, division directors and the director of JIVE make up ASTRON's management team.

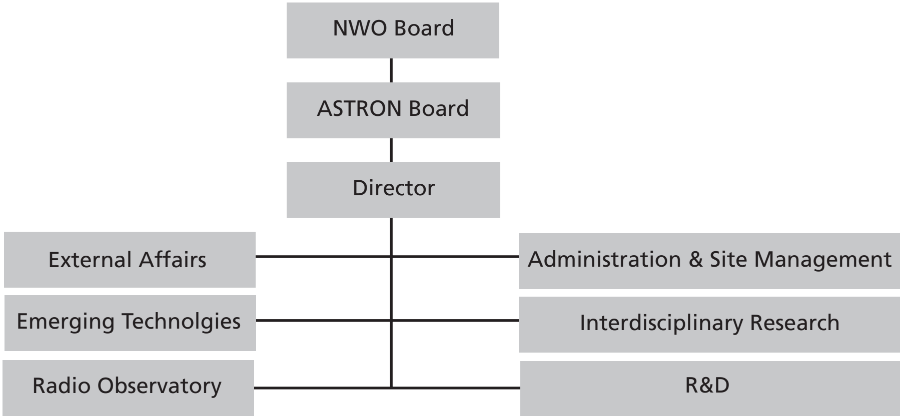
2.2 Research

During the evaluation period ASTRON's research programme comprised four main activities:

1. Technology and Instrumentation (R&D Division). Two main suites of technology are supported:
   - Signal reception and processing (in the broadest sense) in radio astronomy, including the design of next generation radio telescopes.
   - Instrumentation for optical-infrared astronomy, with emphasis on the thermal infrared.
2. Radio Observatory (Westerbork Synthesis Radio Telescope). The main lines of observational research pursued at the Observatory include:
   - studies of galaxy structure and evolution
   - studies of pulsars and other compact objects
   - studies of the magnetic universe
   - studies in astroparticle physics.
3. Hosting of international activities
   - The Joint Institute for VLBI in Europe (JIVE).
   - The global project office of the Square Kilometre Array radio telescope project.
   - The secretariat for the European Science Foundation's standing committee on radio spectrum management (CRAFT).
4. Positioning in the wider society aiming at exploiting its technological expertise in the (semi) commercial sector.
   - ASTRON currently undertakes activities under contract to national and international institutions and to local industry. Where possible these activities are selected specifically to underpin ASTRON's astronomical programme.

2.3 Organisational structure

The organisational structure of the institute is:



2.4 Financial matters

As the ASTRON budget evolves, its structure changes each year. In 2004 the budget consisted of the basic NWO subsidy of around M€ 6.7 and a project income of M€ 27.5, of which about M€ 22.8 derived from the LOFAR project and € 4.7 from other projects.

2.5 Current staff

During the evaluation period ASTRON's staffing increased by 38%. Support staff decreased, whereas R&D experienced a sharp increase.

ASTRON staff 1999-2004 (in fte)

Department	1999	2000	2001	2002	2003	2004
R&D	38.1	43.2	56.8	61.9	75.3	95.3
WSRT	26.9	28.5	28.8	31.5	35.5	39.8
SUPPORT	62.9	59.4	51.0	44.7	44.7	41.0
Total	127.9	131.1	136.6	138.1	155.5	176.1
JIVE	17.3	19.3	21.2	22.8	22.1	22.4

For the institute as a whole, permanent staff account for 65% of total staff, for the fast-growing R&D department the figure is 56%.

ASTRON Staff 2004 by type of contract (in fte)

Department	Permanent	Temporary	Total
R&D	53.7	41.6	95.3
WSRT	27.1	12.7	39.8
Support	34.1	6.9	41.0
Total	114.9	61.2	176.1

3 Assessment of the institute

3.1 Overall assessment of the institute

Overall assessment of the institute	5

The overall assessment of the institute ('excellent') is based on past performance, the future vision embodied in LOFAR and the important technological role played by the institute in terms of Dutch astronomy.

LOFAR will dominate the institute's activities in future years and will lead to changes in its management (see also below). The large investment funds made available for LOFAR dominate the institute's basic budget at present and great care is required in managing the construction period and the transition to the exploitation period.

3.2 Governance and management structure

Formally speaking, ASTRON falls under the jurisdiction of the Governing Board of NWO, its main employer and funding agency (but not, currently, the main source of income).

ASTRON's Board is the management layer between the General Board of NWO and ASTRON's director. The General Board retains a considerable distance, exercising practically no direct influence on ASTRON's policies. ASTRON's Board is composed of representatives of the Dutch astronomical
community, plus two members representing specific technical expertise relevant to ASTRON.

ASTRON's director is helped by a management team of six persons with rather different backgrounds and responsibilities in the organisation.

Comments

It should be clear from the outset that ASTRON's management has proved very successful in running a radio astronomy infrastructure of international standing, in building up and maintaining a technical infrastructure of national significance and in starting up a new project, LOFAR, that represents the next step in radio astronomy on an international scale.

Nevertheless the way in which ASTRON is governed and managed, briefly outlined above, gives rise to the following observations.

Management team

The management team is organised rather informally. Roughly speaking one would expect such a team to consist of a general (executive) director and of two or three additional directors responsible for finance, human resources and the scientific programme. In practice these and other areas of importance to ASTRON are represented in the management team (7 persons in total), resulting in a team that is not very homogeneous and whose members do not have clearly defined managerial roles.

The two most important departments of ASTRON are the Radio Observatory and the R&D division. They should be prominently represented in the directorate, preferably by one director, overseeing both. Finances and Human Resources should be represented by a second director. Together with the general director this would lead to a directorate of three. This directorate could nominate a body (Management Board) that met the directorate regularly to advise and inform on other areas of relevance. Looking at the present management team these areas would be: External Affairs, Emerging Technologies and Interdisciplinary Research.

Furthermore, the LOFAR project leader will play a very important role in the coming years and should also be a member of the Management Board.

ASTRON Board

It is striking that the ASTRON Board is not advised by an independent (international) Scientific Advisory Committee. This is very unusual and highly undesirable. We understood that the Board itself does not feel the need for such independent advice, because of its composition. We do not agree. There should be a clear distinction between the development of scientific policies, where independent advice is indispensable or at least very valuable, and their implementation within the assigned budget. It did not become very clear to us how the Board actually manages the definition of ASTRON's scientific programme and how the corresponding resources are assigned. Because of the relative independence of the NWO Board, the relationship between the programme and the resources seems to be rather 'ad hoc'.

Contactraad (Council of Users)

The committee met with representatives of the 'Contactraad', an ad-hoc committee representing the users of ASTRON and, more generally, the Dutch astronomical community.

It should be noted here that ASTRON's mission is cited (in the self-evaluation document) as: 'enabling discovery in astronomy through innovative instrumentation and facilities management'. Although ASTRON has the ambition to be agenda-setting within the terms of this mission, it does not regard setting the scientific agenda of Dutch astronomy in general as one of its goals. The committee feels that ASTRON, through its scientific management, should strive to play a more active and visible role in this respect.

Although generally satisfied with and supportive of ASTRON, the Contactraad expressed concerns about the future ability of ASTRON to continue to support developing and producing instrumentation for optical telescopes. It was recognised that this concern was very largely due to budgetary constraints and ASTRON's priorities (Radio Observatory; LOFAR), but the concern was nevertheless expressed as a signal to NWO, with a request to increase ASTRON's funding. This would have to come as an increase to the funding of astronomy in the Netherlands, because the funds could not be found elsewhere. In the opinion of the committee this confirms the need for ASTRON's more explicit presence in discussions on a national research policy in astronomy.

3.3 Gender (im)balance

The Evaluation Committee was concerned about the low number of females working amongst the Science and Technology staff. The plenary meeting with staff showed that this was also of concern to those women, some of whom had moved to ASTRON from other countries for potentially short stays, and had been disappointed by the poor level of child-care provision in that area of The Netherlands, a country which has a high international reputation in many aspects of work-life balance. We saw little evidence that this overall topic is of wider concern in ASTRON, or that it is being addressed. Greater diversity in the staff body would give ASTRON greater strength, and for that reason we commend action.
ASTRON is already a powerful body both in the region and in Netherlands Science and Technology and it could benefit many parties by showing leadership on this issue of gender balance.

4 Programme Assessments

4.1 R&D/Technology

Current theme leader: M. de Vos
Total staff: 38.1 fte (1999) – 95.3 fte (2004)

Programme assessment	5

Remarks on the R&D/Technology evaluation

ASTRON's evolving mission requires that a major portion of its effort be aimed at technology research and development. To be effective in enabling discoveries in astronomy, the institute seeks to play a leading role in the development of instrumentation for astronomy at radio, optical, and infra-red wavelengths. The evaluation committee was favourably impressed by ASTRON's contributions in these areas, and also by its work now underway. Major efforts are also being put into the development of the future research facilities LOFAR and SKA, as described in another section of this report.

During the review period two important instruments were developed for the European Southern Observatory, both in cooperation with other European partners. VISIR provides diffraction-limited imaging in the atmospheric windows between 8 and 26 microns, as well as long-slit spectroscopy with high sensitivity and a wide range of spectral resolutions. Designed and built in cooperation with Service d'Astrophysique at Saclay, France, the instrument first saw use on the UT3 8-meter telescope in early 2004. MIDI is the Mid-infrared Interferometric Instrument. It combines two beams, either from two 8 m unit telescopes or from the 1.8 m auxiliary telescopes, to provide interferometric fringe amplitudes. It was designed and built by a collaboration comprising Dutch, French, and German participants; ASTRON's contributions include the beam combiner, filter wheel, spectral dispersers, collimators and cameras. Routine operations began in early 2003.

In the radio domain, ASTRON has responded to the needs of the Westerbork Radio Observatory's user community by developing a broad-band (160 MHz) IF system with eight tunable sub-bands and a matching pulsar back end. These instruments are being used successfully at Westerbork. Significant effort has been put into the development of adaptive algorithms for mitigating radio frequency interference. These techniques are extremely important for LOFAR and ultimately for SKA; some successful tests have been done at Westerbork, and further experience will be gained with it there. Additional technology projects include studies of the potential for photonic beam-forming techniques that might be used for LOFAR and the SKA, extremely high capacity data transport over fiber-optic cables, aperture arrays of large numbers of broad-band antennas with electronic steering, and collaborative development of a mid-infrared instrument for the James Webb Space Telescope.

The evaluation committee considers the ASTRON research and development efforts to be well motivated and effectively carried out. We were impressed by the demonstrations we witnessed and the staff members we spoke to, and the management structure built on core competency groups, technical support groups and the mechanical workshop appears to work well. Hindsight shows that the 1998 Road Map was sound, and the prognoses set out in "Technological competence requirements 2005-2010" appear to be well thought out. In our judgment, ASTRON has made sensible decisions on such matters as to what technologies need to be closely monitored (but not actively engaged in), what competencies need to be developed or acquired in house, and when it makes sense to use commercial off-the-shelf equipment.

4.2 WSRT

Current theme leader: W. Baan
Total staff: 26.9 fte (1999) – 39.8 fte (2004)

Programme assessment	4

Remarks on the WSRT evaluation

The Westerbork Synthesis Radio Telescope (WSRT) had a very comprehensive upgrade between 1994 and 2003. It is now one of the largest and most sensitive aperture synthesis telescopes (especially in the mid-range of frequencies) and should remain so for the rest of this decade, until the National Radio Astronomy Organisation's Very Large Array upgrade is complete. The frequency flexibility of the telescope is impressive and congratulations are due to all involved with that development. The RFI removal techniques, essential to broad-band operation, are also a most welcome addition. Ingenious and innovative observing strategies have been devised to further extend the capability of the telescope and several of these promise to be very productive.

It is important that the investment made in the upgrade is realised, and attempts to grow the user community are to be commended. The user community appears well satisfied with the service and support it receives from ASTRON.

It seems likely that as LOFAR comes on line the emphasis will shift, initially to a combined WSRT-LOFAR observatory, and then perhaps with LOFAR being the dominant component.

The Dutch community has been well served by WSRT; it is the leading radio astronomical centre in the country and an international player with standing comparable to similar institutes in other countries. The recent upgrades and innovations will allow some exciting science – for example the observation of HI in AGN. Also the observation of HI around the epoch of reionization would provide a new and useful cosmological probe.

Scientific highlights

The astronomers of ASTRON play a full role in the exploitation of the science which results from the facilities for which they are responsible. The examples given as appendices to the self-evaluation report give a good impression of the ways in which the staff astronomers have made excellent contributions to key astrophysical and cosmological problems. As examples of the types of astronomy which were found to be particularly impressive, we would highlight the following.

The distribution function of HI column densities in the vicinity of M31

These observations are of importance since these are consistent with being the residual clouds of neutral hydrogen out of which the baryonic structure of galaxies formed. It is most impressive that the distribution function is a very good match to that determined by absorption line studies of neutral hydrogen clouds. The latter provide a direct link to the study of the evolution of the population of Lyman-a absorbers as a function of redshift, which is one of the most important tools for pinning down the early formation of galaxies as we know them.

Interstellar scintillation and the structure of the distant quasar J1819+3845

This is a very elegant analysis of a clever technique for gaining information both about the intrinsic structure of quasars and scales of structure in the interstellar medium. This analysis points the way for the discovery of other such sources and so to further knowledge about the small scale structure of the scattering medium and the sources themselves.

The sky mapped with the prototype LOFAR Array

The observatory is to be congratulated on producing the first all-sky maps using the prototype LOFAR Array. The map of the sky at low radio frequencies showing low surface brightness radio features such as the North Polar Spur and a number of the brightest discrete sources is a real achievement. It also demonstrates the potential of these techniques for the full LOFAR project.

The detection of ultra-high energy cosmic rays by the prototype LOFAR Array

One of the most exciting results reported during the visit was the detection of the radio emission from extensive air-showers with energies of the order 10^{17} eV. The emission is essentially the curvature radiation associated with electrons and positrons created in the air-showers associated with the bending of their paths by the Earth's magnetic field. The success of this method of detection was due to the ability of the LOFAR Array to detect bursts of radio emission on the nanosecond scale. Being an all-sky detector, this provides a new way of scanning the whole sky continuously for ultra-high energy cosmic rays. The importance of associating such an array with the Pierre Auger Array in Argentina is very clear.

JIVE

JIVE is an independent foundation and so the project was not strictly part of our review – it will be reviewed by ESF early in 2006. However we recognise the synergy between JIVE and the rest of ASTRON, especially WSRT. The presence of JIVE scientists (resident and visiting) helps create a critical mass of astronomers at Dwingeloo, and brings in more research students. This facilitates a two-way process in which **astronomical** aspirations drive technological developments and, conversely, the astronomers become aware of the technological impact on the potential of WSRT and JIVE. Importantly, it also encourages the resident astronomers at ASTRON to remain competitive and at the forefront of research.

JIVE is a unique international facility, with major upgrades recently to several of the largest participating telescopes, and new radio telescopes being built in Italy and Spain. The development of e-VLBI, which will see all the telescopes linked by very wide-band fibre optics, leading to on-line, real-time VLBI as a standard operational mode, is to be welcomed.

4.3 LOFAR

Current theme leader: E. de Geus
Total staff: - (1999) – 26 fte (2004)

Programme assessment	5

The LOFAR project

The biggest new project, which is dominating ASTRON's programme, is the LOFAR project. This project began as a pure astronomical project to map the sky at long radio wavelengths and search for signatures of the early phases of galaxy formation when a much greater fraction of the baryonic matter in the Universe took the form of neutral hydrogen clouds.

This was an expensive project, but by good fortune its scope was enhanced to encompass other aspects of sensor technology of direct value to the northern region of the Netherlands. The astronomy programme has strongly benefited from the need to develop enhanced infrastructure and attract high technology to the northern Netherlands. Funding for the project has accordingly been secured outside the normal funding channels for pure science and ASTRON is to be congratulated in securing these resources for a technically challenging project. It is also gratifying that the project will be of direct importance socially in the northern Netherlands. This is exactly the image which pure science should project – the willingness to use expertise in science and astronomy for the direct benefit of society.

We recognise that, in discussing the project, we should give equal weight to the seismological, agricultural and weather monitoring aspects of the programme. We regard these studies as very important, but we are not experts in these areas. Though commending these initiatives in the strongest terms, we will therefore concentrate upon the astronomical side of the LOFAR project.

Astrophysics objectives

The object of the project is to carry out systematic and highly sensitive surveys of very large regions of sky at low radio frequencies. As radio astronomy has developed, most observatories have moved to higher and higher frequencies to obtain the advantages of high angular resolution and the superb new ranges of technology which bring these instruments close to their fundamental limits. In this sense, the low frequency sky has been somewhat neglected, partly because of the problems of the ionosphere and partly because of radio interference. Now, however, these limitations can be overcome by the new technologies developed by the scientists and engineers at ASTRON. By avoiding interfering narrow radio channels and observing at very high data rates, these limitations can be overcome. We were shown the first all sky maps made at low radio frequencies and these demonstrate that the prototype systems can achieve the advertised goals for the project. The potential for new science was clearly demonstrated by the detection of high energy cosmic ray showers by radio means, thanks to the extremely short time scales over which the data from the whole sky is continuously monitored – about 1 nanosecond.

The prime goal of the surveys will be to understand the low frequency sky in much greater depth than ever before. The case has been made that many of the steep spectrum low frequency radio galaxies are likely to be among the most distant galaxies observable. In addition, a vast array of new processes may come into play at these low frequencies, where coherent effects are likely to be much more important than at higher frequencies. The crown jewels of this project would be the detection of highly redshifted neutral hydrogen emission associated with the formation of baryonic structures through the crucial re-ionisation phase of the Universe. This must have happened between redshifts of between around $z = 6$ and 20 and so the need is to be able to search for these vast neutral hydrogen clouds at certain unknown frequencies in the frequency bands $1420/(1 + z)$ MHz, that is, in the 60 to 200 MHz wavebands. Such emission has not yet been detected, but it would be a key result for cosmology.

The current state of the project

The first phase of the project is well underway. Two of us visited the site of the compact array and were impressed by the excellent progress which had been made in demonstrating the feasibility of the low frequency part of the system which operates between about 30 and 70 MHz. Maps are already being made successfully by the prototype array. The challenge is to complete the first phase of the project over the next 18 months. This involves completing the first phase of the array, which will consist of a compact core area and 45 remote stations, each station equipped with 100 High Band (120 – 200 MHz) and 100 Low Band antennae, as well as the other types of sensor for the applied science areas. In total, for the astronomical part of the programme alone, this involves the deployment of 3200 High and 3200 Low band antennae. This is a very considerable challenge. Then, over the next two to three years, two additional rings of stations, each with about 2000 stations, will be deployed, increasing the sensitivity and angular resolution of the LOFAR system.

In parallel with the deployment of the arrays, a complex system of data transfer and analysis is being developed in collaboration with IBM and the participating universities. This is a really challenging task, but there is already very considerable expertise in handing such vast data sets within the Netherlands.

Evaluation

This is a very exciting project and we fully support the aims and objectives of the entire programme. From the point of view of radio astronomy, there are clearly many challenges. The schedule for the next 18 months is very challenging. While we are convinced that the Low Band array can certainly be constructed on this timescale, the High Band array is more of a challenge since the platforms on which such arrays are located are more complex than Low Band arrays and have to be manufactured in as large numbers. The success of this programme will depend upon very strict project control if it is to meet the projected timescales. There is no question, however, about the outstanding professionalism of the technical teams at ASTRON and we are optimistic that there will be a working array in 18 months' time. At the same time, there might be some delay in the High Band array.

We also note the challenge of involving the university groups in the software exploitation phase of the project. This will involve strong buy-in from these groups and a need to move into the scientific areas which will be exploited by the LOFAR project.

We would also remark upon the fact that Dutch astronomers see the LOFAR project as being central to their ambitions to be the centre for European involvement in the Square Kilometre Array. LOFAR is undoubtedly a very strong card to be played in the discussions which will lead to the development of a realisable SKA. We strongly encourage ASTRON to hold to these ambitions.

ICT issues

Progress in electronics, bringing smaller pixel sizes, more information per pixel, and improved time resolution, is leading to huge increases in the volume of both the raw and processed data that has to be handled by many different scientific disciplines. LOFAR is a clear example of this trend and it will generate data volumes some 5,000 times those typically produced today by the Westerbork Synthesis Radio Telescope.

This trend towards a “wave of data” is widespread, and will affect almost all scientific disciplines. In general the capture and online processing of the raw data tends to be well understood by the instrument scientists and handling that part of the increasing data volume poses few problems. However, the handling of the processed data can be more problematic, since over a very short period of time this can progress from being a “below-threshold” activity – which just happened automatically at various university computer centres and on researchers' desktops – to becoming a "mission-critical" activity with a potentially strong impact on the scientific productivity of the instrument.

The risks that need to be addressed are:

- that not enough attention is paid in advance to the ways in which the science will be extracted from the processed data;
- that computer centres are faced with new data storage, data access and data processing loads which they may not have anticipated;
- that insufficient resources (investment, operational funding and personnel) are foreseen overall for an activity which did not need specific attention in the past;
- that the challenges are under-estimated and that, as a consequence, this area does not receive enough attention from the scientific leadership.

Various other disciplines, notably particle physics, which faces a major data explosion with the start-up of LHC in 2007, but also earth observation, biology and multiple engineering disciplines, have decided to use grid technology in facing up to this challenge. In the Netherlands there is considerable grid expertise available on the Watergraafsmeer campus, with NIKHEF and SARA playing significant roles in several different projects and across multiple disciplines.

The high-level architecture adopted by LOFAR creates a distinction between the Joint LOFAR Operations Centre (JLOC) in Groningen, where all the antenna data will arrive via optical fibre for correlation, and the decentralised Science Centres (SCs), which will take data relevant for their research from the JLOC and handle the subsequent storage, processing and analysis. It is anticipated that the respective roles of the JLOC and SCs will be specified in formal service level agreements.

During our site visit we were able to obtain a clearer picture of some issues of timing and scale. LOFAR should start its very first operations (perhaps commissioning would be a better term) at the end of 2006, and full operation could be achieved in the course of 2009. The data volume will increase by a factor of around 5,000 compared to WSRT. Today, one key LOFAR system, the parallel self-calibration using black-boarding, runs about 10 times slower than will be required during normal production operation. That is not in itself a cause for concern, but does indicate the serious optimisation that will have to be carried out over the next 1-2 years.

Caveat concerning our recommendations

Much of the detailed planning for the ICT aspects of LOFAR remains a task for the future. Under the circumstances it is difficult for the review committee to estimate the potential seriousness of the inevitable ICT problems that will occur between now and 2009 – we have had neither the detailed information nor the time available to make an informed judgement.
General comments
The overall approach to ICT issues which has been outlined to us by LOFAR is plausible. By "overall approach" we mean the decision to base the data stream processing on a Blue Gene/L machine installed in Groningen, and the proposal to "outsource" the various scientific analyses to the Science Centres.

On the other hand, and this is perhaps not unusual at this stage of the project, not all of the resources needed for these facilities have been assured. As cited in various documents: "Funding for JLOC is not yet fully secured" and (concerning the SCs) "The universities are (still) considering the level of service that they want to provide" and "Two universities have taken steps to secure structural funding, but this is not yet assured".

One danger of this JLOC/SC model, with its rather clear differentiation of roles, is that the decentralised SCs may lead to an unnecessary duplication of effort. The proponents of LOFAR (i.e. ASTRON) must remain responsible for pushing the overall scientific computing strategy for the project, even if responsibility for the SCs ultimately devolves away from Dwingeloo/ Groningen.

However, it does seem clear to us that a serious attempt should be made to engage with those organisations on the Watergraafsmeer campus (primarily NIKHEF and SARA) which are heavily involved in the introduction of grid technologies in the Netherlands. Collaboration by all of the teams involved may well be the best way to prepare a convincing case for extra funding. As regards LOFAR it might make good sense to base one or more SCs on the Watergraafsmeer campus.

Detailed comment

Blue Gene/L cannot be considered a standard "commercially available" computer, but rather an extremely interesting machine supported by the considerable resources of IBM's T.J. Watson Research Centre. This might mean that at some point in the future the price model and/or availability of upgrades and/or future versions of the machine could become dependent on external factors, such as the overall profitability of IBM as a company, or a decision to fully commercialise Blue Gene. We offer this comment not in any negative sense, but as a cautionary factor that needs to be borne in mind over the longer term.

Recommendations

The ICT plans for LOFAR are at an early stage. ASTRON needs to devote more effort to ensuring that those plans are implemented in such a way that they enable the full exploitation of LOFAR's huge science potential. Areas needing attention include:

- resource planning for the JLOC and SCs (for staff and money, as well as for initial investments and operations). Good resource planning will depend crucially on agreed estimates of data volumes and data flows;
- monitoring the progress of all aspects of the data handling chain, including calibration, CLEANing, and subsequent data handling.

In the area of ICT there appears to be an obvious potential benefit if LOFAR, the JLOC in Groningen and the organisations based at the Watergraafsmeer campus are able to collaborate closely on grid technologies, especially in areas such as metadata annotation and data management in the broadest sense. LOFAR should push for such collaboration, and should be supported by all other interested parties.

The "classical" challenges of implementing the LOFAR project on time and in budget are significant, but scientists of high calibre know how to handle those challenges and we can all see the potential science returns. With LOFAR, however, astronomers are probably confronted for the first time with a situation where some of the ICT challenges are as equally important, and as potentially "mission-fatal" to the project science, as the "classical" challenges. ASTRON would be wise to appoint a "LOFAR ICT Director" who is largely freed from other management tasks for the next 3 years or so. In addition ASTRON should consider establishing a "LOFAR Data Handling Policy" body, which would meet regularly (say 3x per year initially) to review progress being made on the key ICT issues.

5 Answers to the questions put to the committee by NWO

There are some questions posed by NWO in addition to the Standard Evaluation Protocol. The first set (1-3) comprises general questions (asked at all evaluations), the second (4-7) set focuses on ASTRON.

1 What is and what could be the position of the institute in the near future, compared to leading institutes in the world that operate within the same field?

Nationally ASTRON is an important player, internationally ASTRON is comparable to other international organisations of this nature. If successful, LOFAR will lead to international distinction.

2 Should NWO continue to support the mission of the institute and for what reasons?

Through its mission and performance the institute is central to Dutch research in astronomy, which itself is of a high international standard. NWO should therefore continue to support the institute's mission.

3 Are there more effective ways for NWO to support the same type of research and/or facility?

No. ASTRON is essential to university research and vice versa. With this institute NWO provides the infrastructure that goes beyond the scale of individual universities.

4 What is your view of the analyses (made by the management of the institute) of the consequences if these institutional activities were to be discontinued?

Because of the highly hypothetical character of the question, the committee was unable to provide an answer. No analysis was given to the committee, so the question is not applicable.

5 Will ASTRON have to choose between activities (including WSRT) over the next six years, in order to develop and exploit LOFAR successfully? If so, what will this entail?

There is a viable scientific programme for WSRT for the coming years. A certain period of overlap with LOFAR operations is inevitable.

LOFAR is now dominant in the investment budget. How the operational costs will be financed is still not entirely clear. The programme will continue to evolve. WSRT continuation depends on successful outreach. So, in the committee's opinion this will become clear within the next six years.

6 Are current and future housing facilities adequate, given ASTRON's ambitions?

The situation certainly is very tight. With LOFAR activities ramping up the situation will become even more critical.

Part of the staff is already housed in temporary buildings. We have not made a quantitative assessment of the housing needs, but this point should (and will) be followed up by the management.

7 How important are ASTRON's activities and portfolio of projects to the Dutch research community, especially when taking into account the volume of projects funded by the private or non-profit sector?

ASTRON's activities and portfolio of projects are obviously of prime importance to the Dutch astronomical research community. Its significance as a (technological) centre of excellence clearly goes beyond that. LOFAR promises to become significant for other scientific disciplines and other applications.

6 Conclusions and recommendations

In conclusion, ASTRON provides a high quality research infrastructure to the international astronomical community. ASTRON fulfils its mission excellently.

Recommendations

1. LOFAR represents an important new step in radio astronomy. This project is also essential for the future of ASTRON. A project of this size and importance is never 'business as usual' and its successful execution will require a professional and clearly structured project management, well connected to the ASTRON management that, in turn, should be well connected to the Dutch scientific policy bodies dealing with the multi-facetted astronomical agenda in the Netherlands. This should lead to 'guaranteed' support for the LOFAR project throughout its lifetime and certainly during the coming five crucial years.

In addition we would make the following more detailed recommendations:

2. The large investment funds made available for LOFAR dominate the institute's basic budget now and great care is required in managing the construction period and the transition to the exploitation period.

3. We suggest replacing the management team with a smaller team of directors (general director; scientific and R&D director; finances and human resources director).

4. We suggest that a management board be formed to advise the directorate. Its members would be drawn from the present management team plus the LOFAR project leader.

5. The ASTRON board should nominate an international scientific advisory committee.

6. In addition to the general recommendation regarding the organisation of LOFAR's project management, we would draw particular attention to the project's very challenging ICT aspects. We think these need more attention and detailed recommendations are given in the relevant section of this report.

Annex 1: Evaluation committee

Jos Engelen

Professor of High Energy Physics at the University of Amsterdam. Former director of NIKHEF, the national institute for high energy physics and nuclear physics in the Netherlands. Currently Chief Scientific Officer and deputy Director-General of CERN, the European Centre for Particle Physics. Has conducted experiments studying soft strong interactions, hard photoproduction and deep inelastic scattering. Has contributed to the realisation of a large underwater telescope for cosmic neutrinos. Is presently responsible for CERN's scientific programme, with a high priority for experiments at the Large Hadron Collider, a 14 TeV pp collider to become operational in 2007.

Jocelyn Bell Burnell

After three years as Dean of Science at the University of Bath she 'retired' in 2004, and moved to a Visiting Professorship at the University of Oxford and a Professorial Fellowship at Mansfield College, Oxford. For ten years she was Professor of Physics at the Open University, and had a year as a Distinguished Visiting Professor at Princeton University, USA.

She started her academic career by failing the Northern Ireland equivalent of the 11+. After gaining a creditable number of O and A levels she went on to read a Physics degree at Glasgow University, Scotland. This was followed by a PhD in Cambridge (UK) in Radio Astronomy. During her time there she was involved in the discovery of pulsars, opening up a new branch of astrophysics - work which was recognised by the award of a Nobel Prize to her supervisor.

Marriage to a peripatetic husband meant she worked subsequently at the University of Southampton (in gamma ray astronomy) and at University College London (in X-ray astronomy) before returning to Scotland in the early 80's to a job in infrared astronomy at the Royal Observatory, Edinburgh. Latterly she held a management job there, running the James Clerk Maxwell Telescope in Hawaii as a facility for astronomers in British, Canadian and Dutch universities. For most of this period she worked part-time while raising a family. She has chaired, served on, or serviced more Research Council Boards, Committees and Panels than she wishes to remember, and has also chaired a European Community Committee. She has been President of the Royal Astronomical Society.

She has used telescopes flown on high-altitude balloons, launched on rockets and carried on satellites, and built a radio telescope which was firmly grounded in Cambridgeshire. Later in her career she could be found in Hawaii panting for breath at 14000' and using the UK's infrared or millimetre waveband telescopes.

The Oppenheimer prize, the Michelson medal, the Tinsley prize and the Magellanic Premium have been awarded to her by learned bodies in the US and the UK's Royal Astronomical Society has presented her with the Herschel Medal. UK and US universities have conferred honorary doctorates on her, and she holds an Honorary Fellowship in New Hall, Cambridge. She was made a CBE in 1999 and that year also won the Edinburgh Medal for services to science and society. She became an FRS in 2003, and FRSE in 2004 and was elected a Foreign Associate of the US National Academy of Sciences in 2005.

The public appreciation and understanding of science have always been important to her, and she is much in demand as a speaker and broadcaster. In 1999 she toured Australia giving the Women in Physics Lecture. Her appointment to the Open University doubled the number of female professors of physics in the UK. She hopes that her presence as a senior woman in science will encourage more women to consider a career in science.

In her spare time she walks, gardens, listens to choral music and is active in the Religious Society of Friends (Quakers).

Malcolm Longair

Research interests: Emission from dust in the distant universe. Observational cosmology. Galaxy formation. Gravitational lensing.

Date of birth: 18 May 1941

Currently Jacksonian Professor of Natural Philosophy and Head of Cavendish Laboratory, University of Cambridge, UK.

PhD, Radio Astronomy Group, Cavendish Laboratory, University of Cambridge, UK, 1967.
Royal Society Exchange Visitor, Lebedev Institute, USSR Academy of Sciences, Moscow, Russia, 1968-69. Worked with academicians V. L. Ginzburg and Ya. B. Zeldovich.
Fellow, Clare Hall, University of Cambridge, UK, 1967-80.
Currently Professorial Fellow and Vice-President, Clare Hall, University of Cambridge, UK.
Jointly held the posts of Astronomer Royal for Scotland; Regius Professor of Astronomy, University of Edinburgh. Director, Royal Observatory, Edinburgh, 1980-90.
Deputy Head, Cavendish Laboratory, University of Cambridge, UK, 1991-97.
Visiting Professor, California Institute of Technology, 1972; Princeton Institute for Advanced Studies, 1978; Harvard-Smithsonian Astrophysical Observatory, 1990; Space Telescope Science Institute, 1997.

Has received numerous awards, including the first Britannica Award for the Dissemination of Learning and the Enrichment of Life, 1986. Delivered the Royal Institution Christmas Lectures for Young People on television on the topic *The Origins of our Universe* in December 1990.

President, Physics Section, British Association for the Advancement of Science, 1991-92.
Received the Science Prize of the Saltire Society-Royal Bank of Scotland Annual Award, 1994.
Selby Fellow, Australian Academy of Sciences, 1995. Took a lecture demonstration entitled *Measuring the Fundamentals* round all the state capitals of Australia.

Chairman of the Gemini Board, an international project to build 8-metre telescopes in the Northern and Southern hemispheres, 1994-95.
Chairman, Space Telescope Science Institute Council, 1995-96.
President, Royal Astronomical Society, 1996-98.

Was made a CBE in the 2000 New Years Honours List.
Research interests include high energy astrophysics and astrophysical cosmology.
Has written eight books and many articles on this work.

Joe Taylor

Professor of Physics, Princeton University
Nobel Prize for demonstration of gravitational radiation using a radio pulsar.

Professor Taylor (born 1941) is an American astrophysicist and winner of the 1993 Nobel Prize in Physics, shared with his former student Russell Alan Hulse, for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation. Taylor has used this first binary pulsar to make high-precision tests of general relativity. Working with his colleague Joel Weisberg, Taylor has used observations of this pulsar to demonstrate the existence of gravitational radiation in the amount and with the properties first predicted by Albert Einstein. The Nobel Prize he and Hulse shared was the first ever given for work in General Relativity.

Taylor was born in Philadelphia and educated at Haverford College (B.A. Physics 1963) and Harvard University (Ph.D. Astronomy 1968). After a brief research position at Harvard, Taylor went to the University of Massachusetts, eventually becoming Professor of Astronomy and Associate Director of the Five College Radio Astronomy Observatory. In 1980, he moved to Princeton University, where he is currently the James S. McDonnell Distinguished University Professor in Physics, having also served for six years as Dean of Faculty.

Taylor's thesis work was on lunar occultation measurements. About the time he completed his Ph.D., Jocelyn Bell discovered the first radio pulsars with a telescope near Cambridge, England. Taylor immediately went to the National Radio Astronomy Observatory's telescopes in Green Bank, West Virginia, and participated in the discovery of the first pulsars discovered outside Cambridge. Since then, he has worked on all aspects of pulsar astrophysics.

In 1974, Hulse and Taylor discovered the first pulsar in a binary system, named PSR B1913+16 after its position in the sky, during a survey for pulsars at the Arecibo Observatory in Puerto Rico. Although it was not understood at the time, this was also the first of what are now called *recycled* pulsars: neutron stars that have been spun-up to fast spin rates by the transfer of mass onto their surfaces from a companion star. The orbit of this binary system is slowly shrinking as it loses energy because of emission of gravitational radiation. The predicted rate of shrinkage can be precisely predicted from Einstein's theory, and over a thirty-year period Taylor and his colleagues have made measurements that match this prediction to much better than 1% accuracy. There are now scores of binary pulsars known, and independent measurements have now confirmed Taylor's results.

In addition to the Nobel Prize, Taylor has been recognised with many other awards, including the first Heineman Prize of the American Astronomical Society, the Draper Medal of the National Academy of Sciences, the Tomalla Foundation Prize, the Magellanic Premium, the Carty Award for the Advancement of Science, the Einstein Prize, the Wolf Prize in Physics, and the Schwartzchild Medal. He was among the first group of MacArthur Fellows. He has served on many boards, committees, and panels, co-chairing the Decadal Panel of that produced the report *Astronomy and Astrophysics in the New Millennium* that established the United States's national priorities in astronomy and astrophysics for the period 2000-2010.

David O. Williams

David Williams was born in 1944 and studied Physics and Computer Science at the University of Cambridge. He moved to Geneva in 1966, to work at CERN, the European Laboratory for Particle Physics, initially as a scientific programmer working on the development of software for the analysis of bubble chamber photographs.

He has held a number of technical and managerial positions at CERN, and was head of the Computing and Networks division from 1989 until 1996. Those eight years roughly corresponded to the transition from central IBM mainframes and Cray super-computers to a completely distributed computing environment for the acquisition, processing, management and analysis of the 100s of Terabytes of data which are produced by the experiments operating at the CERN accelerators, and to the provision of a reasonably coherent desk-top environment for the more than 10,000 staff and researchers from around the world who use CERN's computing facilities on a daily or less frequent basis.

To the external world, one of the most visible outputs of the division during this period was surely the World Wide Web. Created by Tim Berners-Lee and collaborators, it has exploded far beyond its origins at CERN, and arguably represents one of the most significant economic paybacks ever generated for society in general by a laboratory engaged in fundamental scientific research.

The world-wide nature of CERN's user community has meant that it has been both a major user of the Internet and a significant contributor to its development. David Williams has been active in trying to foster the overall development of the Internet in Europe, not just as a tool for scientific research, but as a motor for Europe's overall economic development. He has been responsible for a number of reports in that field, including "The Need for High Bandwidth Computer-based Networking in Europe" (Joint statement of the Academia Europaea and the European Science Foundation, 2000) and "Networks for Knowledge and Innovation" (ISBN-90-77559-01-9), the summary report of the SERENATE project (www.serenate.org), in December 2003.

In June 1999 he was elected as President of the Trans-European Research and Education Networking Association (TERENA www.terena.nl) for a four-year term.

He is a member of the UK's eScience Steering Committee, and of the related Technical Advisory Group. He is also a member of the JISC's Steering Committee for the UKLight project. He chairs the eScience Advisory Board of the UK's Central Laboratory for the Research Councils (CCLRC).

In 2005 he was appointed to an Honorary Professorship at the University of Edinburgh.

His primary responsibility at the present time is the overall coordination of CERN's relations with the European Union.

Annex 2: Programme of the ASTRON site visit

Sunday 5 June		
17:00	Closed Session at Hotel (synchronising planning & approach)	
19:00	Departure for restaurant	
19:30	Welcome dinner with chair NWO	

Monday 6 June		
7:45	Departure for WSRT Westerbork	
8:15	ASTRON management	
	H. Butcher and E. de Geus	Introduction to ASTRON (past performance)
9:15	WSRT	
	W. Baan:	Past 6 years at the radio observatory & future plans
9:40	Tour of facility with a number of highlights	
	H. Holtes	MFFE, correlator, network
	R. Vermeulen	Data flow (vol en mgt), user support
	R. Vermeulen	VLBI at WSRT
	R. Braun	Innovative observing strategies
	B. Stappers	Pulsar observing at WSRT
10:45	Customers WSRT	
	H. Röttgering	GB-EW Programme Committee
11:00	Travel to Dwingeloo	
11:30	ASTRON Management Team	
	Butcher, De Geus, Determan, Van Ardenne, Baan, Van Enst	
12:30	Lunch	
	H. Butcher	Introduction on future ambitions and plans of ASTRON
13.30	Discussion with ASTRON staff	
	Plenary meeting	
14:30	**Projects LOFAR (incl. GRID)**	
	E. de Geus	Organisation of project, including finance
	M. de Vos	Overview of project, incl. data management
	J. van Enst	Multi-disciplinary applications
	S. Wijnholds, E. Lawerman	Demo of on-line observing with prototype system
15:30	**SKA**	
	A. van Ardenne	EU SKA Design Study (SKADS) project
16:15	**Optical**	
	E. van Dishoek	MIRI at JWST
	R. Waters	MIDI at VLT
17:00	Meeting with delegation Contactraad	
	E. van den Heuvel (chair Contactraad) and Th. v.d. Hulst (chair of the ASTRON Board)	
17:30	Transport to hotel	
18:30	Informal drinks and thoughts on draft recommendations (closed session)	
20:00	Dinner (committee only)	

Tuesday 7 June		
7:45	Departure for Dwingeloo laboratory	
8:00	**Tour**	
	H. Butcher	Introduction
	Technology tour:	
	K. vd Schaaf	HPC for LOFAR en SKA
	P. Maat	Photonics data transport
	R. Nijboer	Algorithm engineering and calibration matters
	A.J. Boonstra	RFI suppression
	W.v.Cappellen/M. Ivashina	Array antennas
	A. Gunst	Embedded processing in LOFAR
	T. Oosterloo	Beyond CLEAN: “peeling”
	G. Kroes	Mechanical engineering highlights
	Science tour:	
	G. de Bruyn	Local magneto-ionic medium
	H. Falcke	Astroparticle physics
	B. Stappers	Pulsar science
	T. Oosterloo	Bearded galaxies; galaxy evolution
	R. Braun	Future science plans for WSRT
	M. Garrett	Deep VLBI surveys
10.30	JIVE	
	Mike Garrett, director	
11:00	Governing Board ASTRON	
	Th. vd Hulst (chair), J. van Gorkom, J. Kuypers, G. Miley	
12:00	Open programme	
12:30	Lunch with H. Butcher & E. de Geus	
13:30	Closed session committee	
16:15	Closure with director & chair Governing Board ASTRON	
16:45	Departure	