Evaluation 2005-2010

Centrum Wiskunde & Informatica (CWI)

The Hague, 13 October 2011
Netherlands Organisation for Scientific Research

Content

1 Introduction

1.1 Scope and context of this review

This assessment concerns the research carried out at Centrum Wiskunde & Informatica (CWI) 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 organization, 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 one was specifically devised for CWI.

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

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

Site visits form an important part of evaluations and include interviews with the management of the institute, the programme coordinators, other levels of staff, and (usually, though not in the case of CWI) site visits to laboratories and facilities. CWI offered a tour of the institute's building and its new wing, and a demonstration of an advanced form of video-conferencing.

1.2 The Evaluation Committee

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

Prof. dr. Kees van Hee, chair	Technische Universiteit Eindhoven (NL)
Prof. dr. Carlo Ghezzi	Politecnico di Milano (IT)
Prof. dr. Gil Kalai	Hebrew University of Jerusalem (IL)
Prof. dr. Olivier Pironneau	Université Pierre et Marie Curie (FR)
Prof. dr. Keith van Rijsbergen	University of Cambridge (UK)
Dr. Marie-France Sagot	INRIA (FR)

A short curriculum vitae of each of the members is included in Annex 1.
The Committee was supported by NWO staff (Margreet Bouma and Marjolein Robijn).

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 Evaluation Committee received the self-evaluation report from CWI, together with the site visit programme and an explanatory letter referring to the secure CWI website and providing the codes for accessing that site; the secure website contained documents about the present and previous evaluations and a link to the CWI repository.

The self-evaluation report dealt with CWI's objectives , composition, quality and scientific relevance, scientific output, earning capacity, academic reputation, links with academia and its role in other networks and organizations ('combining forces'), societal relevance, viability, and future strategy. At the institute level, information was added concerning the progress made on the issues raised by the evaluation in 2005 and on the next generation of researchers, as well as a SWOT-analysis. At the level of the fifteen research groups, the presentation of the information was based on the CWI research cluster structure, organised around the topics of mathematics (applied analysis – MAC cluster), combinatorics and stochastics (PNA cluster) and computer science (software engineering – SEN cluster) and information systems (INS cluster).

The Appendix contained tables – statistics presented both at institute level and at the level of the research groups – on CWI staff (tenured, non-tenured, PhD students, support staff, visiting fellows), on research output from researchers on the CWI 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).

During the site visit, the Committee received further documentation on request: an overview of 'Senior researchers and tenure trackers at CWI', and statistics on 'Refereed articles/conference papers w.r.t. total research staff (FTE)'. All presentations given by the director, the research group leaders and the cluster leaders were printed and presented to the Committee at the start of the site visit.

The documentation supplied to the Committee included all the information required by the SEP, as well as answers to the additional questions raised by NWO.

1.4 Procedures followed by the Committee

The Committee proceeded in accordance with the Standard Evaluation Protocol 2009-2015. The assessment was based on CWI's self-evaluation document and the other documentation provided by the institute, as well as on the interviews with staff members and PhD candidates. The interviews took place during the site visit made on 12 and 13 May 2011. The programme of the visit is included in Annex 2.

The Committee met on the afternoon preceding the site visit to discuss and plan the interviews with CWI's Management Team, Governing Board, research group leaders, researchers, PhDs, postdocs, and support staff. They decided which of the PhD candidates and postdocs were to be interviewed, taking care to ensure a fair distribution across gender, research groups, CWI period, and nationalities. The Committee agreed on procedural matters and aspects of the assessment as described in the following paragraphs.

At a formal dinner in Amsterdam, the Committee met with Professor J.J. Engelen and Professor F.M.G. de Jong, respectively chair and member of the NWO Governing Board.

The interviews with the CWI Management Team, Governing Board, senior research staff, PhD candidates, postdocs and support staff took place during the site visit on 12 and 13 May 2011. Due to the large number of interviews, the Committee conducted these in two parallel sessions.

After completing the interviews, the Committee discussed the scores and comments with regard both to the institute and to the research group programmes. The Committee determined the institute's scores for the four main SEP criteria, the research group scores, and also the main preliminary findings and recommendations to be reported at its last two meetings.

At the end of the site visit, a meeting was held with the CWI director, the chair of the CWI Governing Board and the full CWI management team to report the Committee's main preliminary findings. The institute's and research groups' scores were printed and handed out to the group leaders before the plenary meeting took place. Finally, there was a plenary meeting at which the Evaluation Committee reported the main preliminary findings to all CWI staff.

In July 2011 a draft version of this report was sent to the CWI 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, organization, resources, and PhD training);
- *Productivity* (productivity strategy and the actual productivity);
- *Societal relevance* (such as societal quality, societal impact, valorization);
- *Vitality and feasibility* (strategy such as strategic planning, SWOT-analysis, robustness and stability).

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

5. Excellent
Research is world leading. Researchers are working at the forefront of their field internationally and their research has an important and substantial impact in the field.
4. Very good
Research is internationally competitive and makes a significant contribution to the field. Research is considered nationally leading.
3. Good
Work is competitive at the national level and makes a valuable contribution in the international field. Research is considered internationally visible.
2. Satisfactory
Work adds to our understanding and is solid, but not exciting. Research is nationally visible.
1. Unsatisfactory
Work is neither solid nor exciting, flawed in the scientific and/or technical approach, includes repetition of other work, etc.

2 Institutional framework of CWI

2.1 Mission

Centrum Wiskunde & Informatica is the Netherlands national research institute for mathematics and computer science. Since its inception in 1946, the mission of CWI has been to conduct pioneering research in mathematics and computer science, generating new knowledge in these fields and conveying it to society at large, and to trade and industry in particular. Quality is a guiding principle in realizing this mission. To achieve it, CWI has formulated four objectives:

1. To conduct advanced research of the highest level, in particular:
   - To initiate new lines of research,
   - To tackle hard questions of scientific and societal relevance, and
   - To carry out innovative contract research for industry;
2. To nurture a talent pool of academic staff and young researchers and be a meeting place for scientific discourse;
3. To establish contacts between the academic world, industry and government;
4. To accept a leadership role in science policy in the fields of mathematics and computer science.

In its 2007 policy document *A fundamental difference*, CWI outlined its strategy for the period 2007-2012. The main component of this strategy is the identification of four themes of high societal relevance that showcase CWI research to the general public. The strategy emphasizes that, in order to stay true to its mission, and contrary to societal trends towards research focused on the short term, CWI must remain committed to fundamental research with medium to long-term impact. It must also intensify its already good contacts with industry, the general public, the media and other leading organizations for applied and fundamental research.

2.2 Research

CWI research is mathematics inspired by computer science, directed at modelling, analysis, simulation, and optimization; and computer science inspired by mathematics, such as complexity and algorithms, software technology, and database architecture.

Disciplinarity is embodied in four research clusters focusing on applied analysis, combinatorics and stochastics, software engineering, and information systems. Each of the four CWI research clusters consists of three or four groups and is primarily an organizational entity managed by a senior staff member, who represents those groups in the Management Team. Computational science and data-intensive research are two universal methodologies that unite CWI research. In 2007 four themes with a high societal impact were chosen to serve as a source of inspiration for the institute's research and a showcase for its results. The themes are earth and life sciences, the data explosion, societal logistics, and software as a service.

The four CWI research clusters are:

PNA – **Probability, networks and algorithms**. Motivated by all four societal themes mentioned above, PNA research is positioned at the interface between mathematics and computer science. The cluster pursues research on fundamental topics in the fields of discrete and probabilistic analysis, modelling and optimization, complexity, cryptology, and on their societal applications. PNA currently hosts four groups.

SEN – **Software engineering**. SEN research focuses on software technology, evolutionary systems, and multimedia applications. Typical research questions concern the analysis and transformation of software systems, component-based development, competitive agents, and multimedia players.

The ambition is to cover the whole range of activities from fundamental concepts and prototype implementations to their validation in practice. SEN currently hosts four groups.

MAC – Modelling, analysis and computing. MAC research rests on scientific computing, dynamical systems, and system and control theory, with a growing interest in discrete and stochastic systems. The research approach ranges from fundamental to applied. Application areas include earth and life sciences, fluid and plasma dynamics, computational finance, and discrete tomography. MAC currently hosts four groups, including a cross-disciplinary group devoted to life sciences.

INS – Information systems. INS research focuses on information systems, covering the complete software stack from hardware to user experience. Leading research questions are self-organizing data structures and query processing paradigms in database systems; information extraction in (semi-)structured sources; model-driven visualization; and human-centred interface design. There is a strong emphasis on quantitative and experimental validation. At the end of 2010 INS hosted three groups.

2.3 Organizational structure

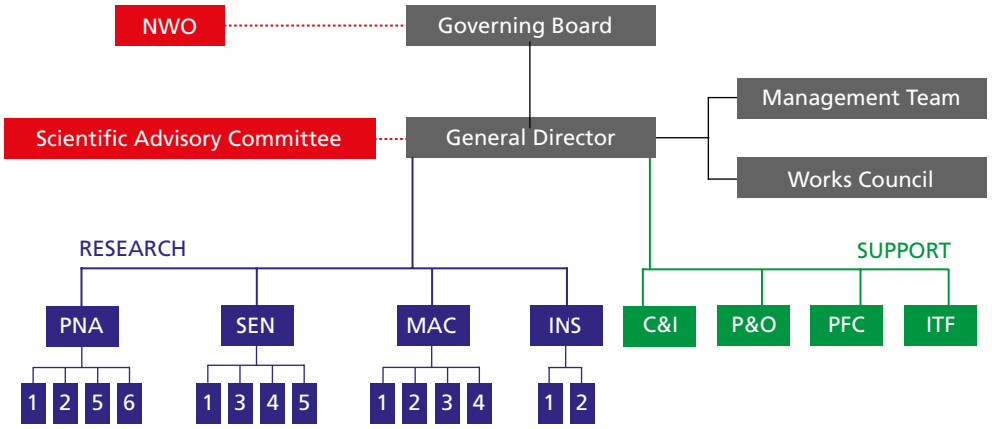

Figure 1 **CWI Management structure**

The research dynamics at CWI spring from the perceptivity and curiosity of the researchers. They form the most important element of the institute. The researchers are organized into *research groups* on the basis of their scientific disciplines (see the acronyms PNA, SEN, MAC, and INS, explained above). The institute's research policy is implemented at the group level. Each of the fifteen group leaders is responsible for the quality and coherence of the group's scientific output, for its financial health, and for its interaction with other groups. The research groups are managed within the four *clusters*. The support departments deal with Communication and Information; Personnel and Organization; Projects, Finances and Control; and Information Technology and Facilities.

2.4 Financial matters

CWI's operating budget derives from a direct grant from NWO, complemented by external funding via programme competitions and contract research. The funding model ensures that the base funding covers the salaries of permanent staff plus fixed overheads. Temporary staff is paid out of the relevant project funds.

To strengthen the knowledge transfer aspect of its mission and to expand its non-tenured staff, CWI ambitiously pursues further funding from existing as well as new and emerging sources. Forming alliances is an element of increasing importance in CWI's funding acquisition strategy. The BSIK/FES programme has been an important source of income since 2004. These projects expired at the end of 2009. Their successor will be funded at a much lower level than anticipated.

Table 1 **CWI funding 2005-2010 in k€**

	2005	2006	2007	2008	2009	2010
Funding						
Direct funding from NWO	10.255	9.874	10.063	10.392	11.350	11.464
Research grants	1.715	2.362	2.802	2.683	2.542	3.082
Contract research	3.387	3.229	3.381	3.078	3.647	2.300
Other	349	594	444	918	427	348
Exceptional income	0	0	0	513	0	0
Total funding	**15.706**	**16.059**	**16.690**	**17.548**	**17.786**	**17.194**

2.5 Staff

Table 2 **CWI staff 2005-2010 (in FTE-years)**

	2005	2006	2007	2008	2009	2010
Tenured staff	49.0	47.3	44.3	43.3	42.4	41.7
Tenured scientific programmers	9.0	9.2	6.9	6.7	6.7	6.7
Non-tenured staff	33.6	43.3	46.2	44.6	43.2	45.2
PhD students	58.0	63.8	62.2	57.4	53.6	53.1
Total research staff	**149.6**	**163.5**	**159.6**	**152.0**	**145.9**	**146.6**
Support staff	49.7	46.6	45.0	47.4	45.2	44.9
Visiting fellows	10.7	19.2	16.6	24.2	37.2	34.5
Total	**210.0**	**229.3**	**221.2**	**223.6**	**228.2**	**226.1**

3 Assessment of the institute

Beyond all doubt, CWI is a top scientific institute in the field of mathematics and computer science. The institute can be compared favourably with top institutes in the US and Europe. It is remarkable for a relatively small country to have such a high quality research institute. CWI can certainly be considered as one of the 'crown jewels' of NWO.

The quality of the research of the institute, both as a whole and at the level of clusters, is excellent: there are very interesting research topics, very strong researchers and excellent publications and other forms of scientific output like ISO standards and software products. It is a pity that research output in the form of innovative software and standards is considered second-class by some scientists and therefore special incentives are necessary to stimulate these activities. As far as we know CWI did not have such incentives in place. The Royal Netherlands Academy of Arts and Sciences is promoting innovative artefacts (i.e. man-made constructions) as an alternative form of scientific output.

The institute works on a great variety of very relevant topics, sometimes with rather small teams. However the portfolio of topics is coherent and there is synergy between them, even between topics at the interface of mathematics and computer science. Therefore the *academic reputation* of CWI is *excellent*. The details for each research group can be found in the next section.

The official mission of CWI has not really changed since its inception in 1946: "Pioneering research in mathematics and computer science, generating new knowledge in these fields and conveying it to society at large, and to trade and industry in particular". The current strategy is certainly in line with the first two elements of the mission statement, whereas the transfer of knowledge is focused on society at large and less so on trade and industry. The institute has chosen four societal themes. They are well-chosen and relevant but they should be pursued more coherently, by investing more in cross-group and cross-cluster efforts. (An illustration of the low influence of the themes today is the change in the SaaS theme after it turned out that SaaS is a buzzword. The name of the theme was changed, but this had no impact on the research activities.) As already indicated in the self-evaluation new and emerging societal themes should be considered: 'smart energy', identified by SEN4, is a good candidate for a cross-cutting theme.

The focus on fundamental research is reflected in the organizational structure. The main structuring dimension is the discipline, within which there are four clusters: PNA and MAC, mainly for mathematics and SEN and INS, mainly for computer science. The theme dimension plays a role only in proposals for larger projects. Each theme has a leader, but the role of the theme leaders is very limited compared to that of the cluster leaders or group leaders.

Societal relevance is a complex notion. It can be achieved by playing several roles: (1) agent for promoting mathematics and computer science in society, (2) standards developer, (3) incubator for junior and senior scientists, (4) centre or platform for mathematics and computer science for the Dutch universities, (5) consultant for problems of industry and society, (6) provider of software products and (7) incubator for spin-outs with products and services based on CWI research.

CWI is active in all these roles but the emphasis is on the third one. Fine examples of the different roles are: the timetabling of Dutch railways (PNA1, role 5), the ISO standard for Cramer-Schoup encryption (PNA5, role 2), the attack on the MD5 hash function (PNA5, role 5), the activities on behalf of W3C (SEN5, role 2), the tools relating to Rascal (SEN1, role 6), MonetDB (INS1, role 6) and VectorWise (INS1, role 7). The income from these societally relevant activities is limited. This is reflected in the fact that only 6% of the budget comes from private sector contract research (industry). Software products are 'given away' as open source software – a very generous policy.

Often, research topics are motivated by some practical problem. Sometimes, the researchers distil a formal (mathematical) problem from a practical question and solve that problem, while not solving the original practical difficulty. Accordingly, CWI research looks more societally relevant than it actually is. Sometimes research results seem to have high potential to become a product or service but in the end the institute fails to go the 'last mile'. In some cases a third party is involved to go that 'last mile'. Overall, the *societal relevance* of CWI is considered to be *very good,* certainly in comparison with peer institutes.

Taking into account that the main strategic focus of CWI is on excellent research, the internal *organization* of the institute is *excellent*. The size of the institute (200 FTE) seems to be close to optimal: large enough to cover a large research field and small enough to avoid bureaucracy. The ratio of permanent staff and tenure trackers (50) to postdocs (40), PhD students (65) and support staff (45) also seems to be optimal. The HR policy is to grow top researchers instead of recruiting them. The institute is very attractive to excellent young researchers. The working atmosphere is excellent both for young researchers (PhD and postdocs) and for senior researchers. Likewise, the guidance and supervision of *PhDs* is *excellent*, probably better than at universities because the supervisors are less involved in teaching or onerous managerial tasks.

The support staff is lean and mean but effective and efficient. The facilities are very good. The institute is financially healthy and *earning power* in terms of obtaining research funding is *excellent* where the Dutch government is concerned, while the institute's power to attract funding from the EU is rapidly increasing. The organizational structure is well-suited to a research institute: the research group plus group leader is the basic business unit. The cluster layer, the clusters each embracing three or four groups, seem to be superfluous. Often the synergy between groups within a particular cluster is not very strong and the cluster structure seems to hamper cooperation between groups in different clusters. The only reason for the cluster layer seems to be the span of control of the general director: for day-to-day management, it is not workable to have all the group leaders in a single management team. However there are other possible ways of restricting the size of meetings.

The institute has four tiers of leadership: the governing board, the general director, the management team (consisting of the general director and the cluster leaders), and finally the group leaders. The governing board operates at a distance, which means that they are more or less a sounding board for the general director. They have no contacts with the cluster leaders or the group leaders. They do not seem to participate actively in the strategy process, but their role as a sounding board is highly appreciated by the general director. The general director and the management team operate harmoniously and the result is an excellent internal organization.

The leadership is focused on maximising the performance of excellent scientists and is very successful in this respect. The *productivity* in terms of raising research funding and scientific output is, compared to peer institutions, *very good*.
With respect to external relationships, the leadership could be improved. The visibility of CWI in the eyes of society could be better. There have been several attempts to improve the institute's public image by hiring PR experts, but they have not been successful. The universal applicability of mathematics and computer science seems to be used as an excuse for invisibility. However, if CWI's results really are universally applied, then it must be possible to promote the label 'CWI inside' (like the well-known label Intel-inside). Also, the role CWI plays in the (Dutch) academic world is less prominent now than in the past. Some senior researchers at CWI play leading roles in certain national and international scientific communities, but the institute as such is not directly involved. CWI as an institute could be more active in acquiring new related activities, such the e-science laboratory. On balance, however, the institute's overall *leadership* – both internal and external – is considered to be *very good*.

CWI's strategy focus on excellent research means that the selection of the right researchers and action to enable them are the main drivers. The selection of research topics seems to be a bottom up process led by the group leaders and dependent on the availability of good people. The starting and ending of research topics seem to be strongly correlated with the availability of people: if the main researchers on a topic leave the institute to take up other appointments or to retire, the institute may decide to abandon the topic. If a good researcher is found in a new field, it may decide to start a new topic. This is why mathematical statistics and process algebra disappeared and why the existing life sciences activities were bracketed together in MAC4. This is a good strategy if excellent research is the ultimate goal of the institute. However, a more prominent societal role requires more elaborate strategy processes, starting with an analysis of society's mathematics and computer science needs and of the competitors in the market.

CWI would be well-advised to reconsider its strategy in a changing funding environment. In Europe, and in particular in the Netherlands, there are two strong tendencies: (1) valorization, which means that society expects economic, social or cultural value for its investments in research, and (2) severe budget cuts by government, because government spending systematically exceeds income. The latter trend means that there will be less governmental funding for research and the former that funding agencies will give priority to research that has direct societal applications. Although CWI has the capacity to make a shift towards greater valorization and so to attract funding from industrial contracts, this would require a change in culture and strategy of the institute. This presents a potential danger to the institute, since 66% of its income comes directly from NWO and 28% from research funding obtained in competition.

The evaluation of the institute as a whole is summarized in the following table:

Table 3 **Scores at institute level**

Quality	Excellent	5
A2 Leadership	Very good	4
A3 Academic reputation	Excellent	5
A4 Organization	Excellent	5
A5 Resources	Excellent	5
A6 PhD training	Excellent	5
Productivity	Very good	4
Relevance	Very good	4
Vitality & Feasibility	Very good	4
D1 Strategy	Good	3
D1 Robustness and stability	Very good	4

4 Assessment of the research programmes

4.1 PNA – Probability Networks and Algorithms

This cluster represents the most theoretical part of CWI. Its main objective is to develop the foundation of computer science and related mathematical disciplines, and to explore further applications and scientific connections. By its very nature, this work is part of an international and often interdisciplinary world-wide effort. All four research groups in this cluster are excellent. We will give a detailed description and evaluation of each individual group. All four groups are very diverse and there are attempts to enter new 'hot' areas of research. There is a substantial amount of collaboration between research groups in this cluster. In spite of the theoretical nature of the research, all four groups in the cluster are doing work of immediate societal relevance. The PNA cluster is rated as EXCELLENT overall.

4.1.1 PNA1 – Algorithms, Combinatorics and Optimization

Group description

This group takes the lead in mathematical programming and can show excellent achievements in discrete mathematics. It has started fruitful research related to computational biology and to algorithmic game theory and made remarkable contributions of societal relevance. There are currently 5 tenured researchers, and 2 additional part-time senior staff. The group has produced over 180 academic publications and 10 PhD degrees. The group holds one Spinoza prize, one NWO VIDI grant, one NWO VENI grant, and several other grants. Members of the group have been awarded prestigious international prizes and honours.

Overall assessment

The quality, productivity and relevance of the group are EXCELLENT. Its vitality/feasibility is VERY GOOD.

Mathematical programming: The researchers in this group have leading status in mathematical programming, which is one of the most important applied areas of mathematics and computers. In recent years the researchers have shifted their interest from integer programming to algebraic and semi-definite programming. Semi-definite relaxation plays an important role in both theory and applications. It is intimately related to PCP and the unique game conjecture, as well as to other areas of classic and quantum computation. Methods developed here have been used in relation to notoriously difficult mathematical problems such as computations of optimal codes and kissing numbers.

Matroid minors: An important long-term theoretical project is an extension of the Robertson-Seymour quasi-well-ordering theorem to matroids over any fixed finite field and proving Rota's conjecture asserting that there is a finite list of forbidden minors for representable matroids over every finite field. Major progress has been achieved over the last decade.

Introducing algorithmic game theory and combinatorial biology: members of the group extended their research to two recent hot areas in computer science: computational biology and algorithmic game theory. In both these areas this was a pioneering effort in the Netherland and it was successful.

Societal relevance

A major demonstration of relevance was provided by the design of the new Dutch railway timetable. The group is involved in several other projects regarding scheduling internships for medical students and bidding strategies for AdWords. It is also active in various educational and popularization projects.

Conclusions and recommendations

The group has a world-leading position in mathematical programming, bolstered by various breakthroughs over the years. It has made remarkable theoretical contributions to discrete mathematics. It is important to maintain this leadership status. The group has a strong record of identifying social and commercial applications. However, its ability to maintain world leadership in mathematical programming is challenged by the retirement of two distinguished members of the group. Future hiring will be crucial.

4.1.2 PNA2 – Probability and Stochastic Networks

Group description

The group has a very strong international position in probability theory and in stochastic operations research. There are currently 5 tenured researchers (one is in the process of leaving). The group has produced over 200 academic publications and 10 PhD degrees. It holds one NWO VIDI grant, several other NWO and non-NWO grants, and various industrial research contracts. Members of the group have been awarded prestigious prizes and honours. The group is the result of a merger between one research group studying theoretical probability and another studying applied stochastic models in networks and optimization.

Overall assessment

The quality and productivity of the group are EXCELLENT. Its relevance is VERY GOOD. Its vitality/feasibility is EXCELLENT.

Probability theory and models from statistical physics: Researchers in this group have made seminal contributions in the field of theoretical probability. New approximate zero-one laws have led to new unified insights for the model of percolation and related models coming from physics. Renormalization techniques have been used to achieve breakthroughs in relation to other problems regarding percolation.

Modern queueing theory: Queueing theory is fascinating but classical models which admit analytical solution are often unrealistic. Realistic models require a new research paradigm. These are studied in this group using diffusion approximations and other methods.

Stochastic geometry and images: The group has achieved strong results in stochastic geometry and related statistics. This is a very important and active area.

Stochastic operations research: Operations research in the presence of stochastic ingredients has always been a difficult task. Several of the group's research projects are in this demanding area and the group has shown very good results in this direction.

Societal relevance

The group is involved in a large number of projects with notable potential commercial and societal relevance. Those include ambulance scheduling and planning and optimization of call centres.

Conclusions and recommendations

The group certainly occupies a leading position in pure and applied probability and has shown strong achievements in this field. Sustaining excellence in the field of theoretical probability will be a major hiring challenge. The immediate applied projects are very welcome but a concern is always how to maintain scientific excellence in the face of the constraints imposed by real-life application and commercial contracts.

4.1.3 PNA5 – Cryptology

Group description

The group enjoys leading status in the cryptology and cryptography field. The design and study of cryptographic systems is an ancient concern but it is only in recent decades that it has become an area of deep academic study with unexpected connections to mathematics and computational complexity. A distinction can be drawn between cryptology, which studies the cryptographic methods used today, and cryptography, which studies theoretical relations between secure systems and computational complexity. Quantum information has led to new questions and new challenges in cryptography.

There are currently 3 tenured researchers and 3 additional senior staff. One tenured researcher is retiring in December 2011. The group has produced over 80 academic publications and 4 PhD degrees. It holds one ERC starting grant, one NWO VICI grant, two NWO VENI grants, and several other grants.

Overall assessment

The group's quality and productivity are EXCELLENT. Its relevance is VERY GOOD. Its vitality/ feasibility is EXCELLENT.

There are very few groups (in the world) which combine interests and strengths in cryptography and cryptology. PNA5 is such a group. Of course, interest and strength in quantum cryptography is a welcome bonus.

Among the group's research achievements are:
Cryptology: A remarkable achievement was the successful attack on the MD5 hash function. This has led to major changes in the industry. Another achievement was a recent world record in factoring, as part of the 'Number Field Sieve Project'.

Cryptography: The introduction of leakage-resilient cryptography was a major development in the field, turning the subject rapidly into a hot central topic.

Quantum cryptography: The introduction of the quantum-bounded storage paradigm was a major advance.

Conclusions and recommendations

The group has made excellent contributions in cryptology and cryptography - both classic and quantum. As with other research groups in this cluster, the width of its interests is remarkable, but also of some concern.

It is not clear (especially now that K. Pietrzak is leaving) whether the group can maintain its strength in cryptography, especially in terms of exploring theoretical aspects relating to computational complexity. It is important to maintain the institute's strength in FOCS/STOCS-style cryptography.

4.1.4 PNA6 – Algorithms and Complexity

Group description

The group moved from INS to PNA in 2010 and enjoys a leading status in theoretical computer science. It covers four topics: quantum computing; complexity and information theory; learning theory; and computational biology. The first topic is the one for which the group is possibly best known. This topic has some links with the second. While learning theory is a different topic in general, learning theory as done at CWI is mostly based on information theory and thus connected to the second topic. Computational biology is currently mentioned as an application of interest to

the three other topics (quantum, information and learning theory), but it is not the main subject of study. Research on it is conducted mainly in collaboration with PNA1 and MAC 4.

There are currently three tenured researchers, one temporarily assigned to PNA6. One CWI fellow retired in 2009. The researchers are excellent, high-achieving computer scientists. All three senior researchers hold part-time full professorships at Dutch universities. In the 2005-2010 period, the group obtained three Veni, two Vidi and one Vici grant from NWO. It was also awarded a Van Dantzig Prize.

Over the evaluation period, the group produced 184 publications in journals or refereed proceedings of conferences (one with a prize for best paper), as well as 13 book chapters, 5 PhD theses, and 144 other research outputs.

Overall assessment

The quality and productivity of this group are EXCELLENT. Its relevance is VERY GOOD, and its vitality/feasibility is VERY GOOD.

The group can show strong achievements in both classical and quantum algorithms and complexity, as well as strong results in learning theory.

Quantum information: A remarkable achievement was the demonstration that noisy quantum computation reduces to classical computation when the noise level is above 45%. Another important paper of great influence concerned a topic of great interest since the early days of quantum computing, namely the applications of quantum methods to classical results.

Classical computational complexity: An intriguing recent result by the group asserts that, under reasonable computational assumptions, NP hard sets are exponentially dense.

Machine Learning: Important methods for learning from data are being studied with special emphasis on minimum description length (MDL). Applications to forensic statistics are being explored.

Conclusions and recommendations

The group has greatest international visibility and leadership in the area of quantum information, and an excellent record in learning, complexity and information theory. It is clearly a dynamic group with a contagiously enthusiastic leader, although one concern may be the range of topics covered, and its rather highly theoretical character. Concerning the latter, although at least one application (of the work on Bayesian statistical inference to a forensic case) brought the theme quite some visibility in recent years, the theme's societal relevance is not obvious. This may be less of a problem than the one posed by the variety of subjects treated by a relatively small group of researchers. The members of the group seem to see this variety as an important asset that should be maintained. If they want to develop further, in particular to focus on learning theory, it may be advisable at some point in the future to explore the possibility of either regrouping forces inside the CWI to address this subject, or recruiting more people in the area and possibly creating a fully-fledged group to focus exclusively on learning theory while maintaining collaborations with the other groups in CWI.

Maybe because all senior members of the group hold part-time full professorships at Dutch universities and fundraising (NWO, EU, FES) was so successful , the number of PhD students per senior member appears higher than for some other groups: currently 6 for 2.4 FTE.
The group maintains strong interactions with the three other groups in the PNA cluster, and also with MAC4 as concerns computational biology. All such interactions can only be encouraged.

For now, the group as a whole appears to doing quite well, and some of the topics it treats, such as learning theory, hold great promise. Despite the concerns indicated above, the group should probably be trusted to develop as it sees fit, although it may become advisable in the longer term, if the topic of learning theory grows as hoped, to split it off to form a separate group. If human investment in the life/health sciences area increases to the extent recommended (see MAC4), a mixed theoretical-applied group on learning theory may also be a good option, making it possible to complement the mathematical and computational expertise currently available in MAC4.

4.2 SEN – Software engineering

This cluster represents a set of wide-spectrum research efforts in the area of software engineering, from the foundations of the discipline to its applications in different domains. Accordingly, the research products developed by the cluster range from traditional publications in journals and conferences to downloadable tools and demonstrators. The research approaches developed in the cluster are often applied in other fields, generating challenging interdisciplinary collaborations. Notable examples are in the areas of forensics, auditing, energy, economics, and interactive media. Several of these areas have a high societal importance. International visibility is very high for all groups.

The cluster is rated by the panel as EXCELLENT overall. Below, we articulate our assessment for each individual group. Internal cooperation within the cluster and with other CWI groups is quite good. This is an indication of the cluster's dynamic and open attitude.

4.2.1 SEN1: Software Analysis and Transformation

Group description

The group is led by Professor Paul Klint, who is also acting as cluster leader. The main focus of the group is on *software analysis* and *transformation*, to support the design, construction, and evolution of software systems. The approaches are founded on a strong background in languages, grammars, and logic.

The research team has gone in the past five years through a profound internal re-assembly process that has led to a rejuvenated team. Professor Klint, who is a well-known, respected and experienced scientist (he has recently been awarded a prestigious NWO TOP grant), is to be replaced as group leader by J. Vinju. The group has developed not only theoretical research, but also a number of tools that are widely available, and used both internally and externally (the META environment and more recently the RASCAL domain-specific language for meta-programming). The attractiveness of the group as a research environment is demonstrated by the excellent students and post-docs attracted to participate in research activities.

The availability of advanced software tools developed by the group has proved to be an effective way to achieve international visibility and thus attract both doctoral students and post-docs. The network of international cooperation is extensive. In particular, the group hosts the ATEAMS research group, which is part of a strategic cooperation between CWI and INRIA.

In the past, the group has acted as a nurturing environment for a generation of talented scientists who then moved to academia: three senior scientists moved to university positions. It has also had an impact on industry and the world of practitioners. A notable example is a spin-off company generated by the group. It is expected that new areas of influence will be achieved by the group in the coming years, especially in the areas of forensics and auditing, where the research approaches investigated through the RASCAL project may find an important reach-out. An effort is planned to make RASCAL widely accessible by integrating it within the Eclipse IDE.

The profound change in the internal structure of the group is indicated by the decrease in tenured staff from 5.7 in 2005 to 2.6 in 2010; the total research staff has decreased from 21.5 to 8.6. As observed, several (highly qualified) young scientists have left the group to pursue their careers in academia. Luckily, this trend has radically changed in 2011; the overall size of the group is now back to its original level. This of course generates concerns regarding the future ability of the group to maintain its high international visibility and compete successfully at an international level. Professor Klint, who is experienced and authoritative, will step down as group leader at the end of 2011. The designated new group leader (J. Vinju) still needs to consolidate his position in the research arena and to demonstrate his ability as a mentor of young researchers. On the positive side, the merger with INS3 may strengthen the group's research portfolio in the future, especially in the area of software visualization, which is very relevant to supporting programme understanding and, more generally, software evolution.

Overall assessment

The quality, productivity and relevance of the group are EXCELLENT. Its vitality/feasibility is VERY GOOD.

Conclusions and recommendations

The group has very high international visibility in the area of language and grammar-based software analysis and transformation. It has a remarkable ability to combine theoretically well-founded approaches with the design of practical tools. It has been able in the past to achieve strong interactions with industry and the world of practitioners. Its vitality is largely demonstrated by its ability to nurture the growth of a generation of excellent researchers who then left the group. It is important that these achievements and this role be maintained in the future.

The group is now in a transitional period that must be monitored very carefully. Future recruitment will be crucial to maintain the group's leadership status. The plans to apply the group's core technology for domain-specific languages to forensics and auditing look very promising. The focus on applications should be also sustained by new research foci on language fundamentals.

4.2.2 SEN3: Foundations of Software Engineering

Group description

The group focuses on foundations of software engineering: modelling and analysis of modern large and distributed software systems. These are explored in three main directions: component-based models and software architecture, formal models, and co-algebraic models of computation. Each of these thematic areas corresponds to a sub-group, each led by a tenured senior researcher (Arbab, De Boer and Rutten, respectively). The three thematic areas cover important topics. Cross-fertilization between the three areas and with other CWI groups is very good.

The group has been relatively stable in size during the period 2005-2010, with a slight growth in terms of non-permanent members (from a total of 10.9 FTE in 2005 to 13.5 in 2010). At the same time, overall productivity in terms of publications has gone up considerably. Although the group focuses on foundations, it has invested significant efforts in making its research results available and applicable in practice, through collaborations with industry and tool developments. As with many similar efforts undertaken internationally, the main challenge of the techniques developed by the group concerns scalability. Future applications to new domains (such as multicore programming, quality of service of distributed systems and systems biology) are foreseen.

Overall assessment

The group's quality and productivity are EXCELLENT. Its relevance and vitality/feasibility are VERY GOOD.

Component-based Models and Software Architectures: Professor Arbab and his collaborators continued research and developments centred on the Reo coordination language. Reo provides an innovative paradigm for composition and coordination of software components. Research proceeded in two main directions: firstly formalization and semantics and secondly tool development and practical application. The first resulted in excellent publications; the second led to an Eclipse plug-in and to collaboration with industry.

Formal Methods: Professor De Boer and his collaborators focused on proof methods for distributed object-oriented software. This work has a very important practical application to formal specification and proof of Java programmes. The approach has also been applied to a modelling language like UML and to services in the context of EU projects. Applications to software product lines are also being investigated.

Co-algebraic Models of Computation: Professor Rutten and his collaborators have been working on co-algebra as a general unifying computational theory. This work is mainly theoretical and has resulted in prestigious, frequently cited publications. It is potentially applicable in a large variety of practical areas. An example is the formalization of the Reo language mentioned above.

Conclusions and recommendations

The group is very well positioned in the international landscape. The quality of research is excellent. The group has been quite active in promoting its own approaches and embedding them in tools. This may result in further fruitful relations with industry. It will also be important to assess how the fundamental approaches developed by the group – which mostly stress formality and elegance – may in the end make a contribution to the practice of software development.

4.2.3 SEN4: Multi-Agent and Adaptive Computation

Group description

The group focuses on systems that require adaptive decision-making in multi-actor and uncertain environments. This requires a blend of different research topics, such as computational intelligence, evolutionary algorithms, decentralized architectures – multi-agent systems, sensor networks – and non-cooperative economic games – negotiations, auctions, market-based planning. The group also applies generic models of multi-agent and adaptive computation to target application areas, such as electricity networks, health care, logistics, electronic markets, and ambient environments. The group has decided to focus in future on models and techniques for the *smart energy* domain.

The group has decreased in size since 2005 (from a total of 17.8 to 8.9 FTE in 2010, which is mainly due to reduction of the PNA4 group that merged into SEN4). At the end of 2010, it included three tenured researchers, one of whom had recently joined the group from PNA4. The overall productivity of the group, in terms of quantity and quality of publications is very good. The current leadership has high promise in terms of group cohesion and the focus on a new and challenging problem domain (smart energy systems).

Overall assessment

The group's quality, productivity and relevance are VERY GOOD. Its vitality/feasibility is EXCELLENT.

Conclusions and recommendations

The group's research has a distinctive flavour in terms of its ability to combine multi-agent paradigms with optimization algorithms to support adaptive decision-making in multi-actor and uncertain settings. These issues are at the heart of several application areas with which the group has engaged in the past. To make an impact, however, a closer focus seems necessary in the future. The identification of smart energy systems as a challenge for the group's future research seems to be a move in the right direction.

The group might also strengthen collaborations within the cluster and with other research areas within CWI. For example, SEN3 might provide the underlying infrastructure – distributed objects and composition mechanisms – that might support a decentralized multi-agent adaptive environment supporting smart energy systems.

4.2.4 SEN5: Distributed and Interactive Systems

Group description

This group was formed in 2004, when its current leader (Professor Dick Bulterman) left INS0. Its research focus is on an experimental, systems-oriented approach to interactive, distributed multimedia systems and web technologies. The group also focuses on standards and knowledge transfer. The roots of its fundamental research focus lie in the area of temporal modelling and support for complex multimedia systems. The group has been a prime contributor to leading international research on multimedia specification languages. At the same time, large portions of its work have been relatively close to experimental developments of advanced multi-media applications. This is clearly indicated by the funding sources (which include W3C – the World Wide Web Consortium and several FP7 and ITEA projects) and the research outputs presented (which include open-source software and contributions to standards). The Committee was given an impressive live demonstration of the group's recent technological advances at the intersection between complex multimedia interaction and social networking.

The group's size in terms of tenured staff was 3.0 FTE in 2005 and 3.8 in 2010. Overall, the group almost doubled, from 5.2 FTE in 2005 to 9.8 in 2010. Research productivity followed a similar pattern. No PhD theses were produced in the period 2005-2010 because the group itself was formed only in 2004 and no theses were completed during the evaluation period. The publications produced by the group are good in terms both of quality and quantity. However, other research products, such as open-source software and contributions to standardisation bodies, seem to have had more impact.

Overall assessment

The group's quality and productivity are VERY GOOD. Relevance and vitality/feasibility are EXCELLENT.

Conclusions and recommendations

The group and, in particular, the group leader have very high international visibility. The group has been able to have an impact on the world of practice by developing research that has strong ties with leading edge technologies and emerging standards. This prevailing short to medium-term focus presents both weaknesses and threats in terms of the increased commercialization of the research agenda. The strong ties with W3C are a clear strength and demonstrate the great practical impact of the group's research agenda. At the same time, they produce a heavy dependency on W3C's future.

4.3 MAC – Modelling, Analysis and Computing

The cluster has four groups dealing with various applications of scientific computing and modelling, from astrophysics to life sciences. The unity of the group is around algorithms for partial differential equations, but the groups are not limited to that. MAC has a seminar of its own and scientists seem to know and understand what other members are doing. They also have scientific links with other clusters.
Nevertheless the unity of the group can be questioned for 2 reasons: group MAC1 has a subcritical small number of members and group MAC4 could be grown into a full cluster around biological and biomedical applications, given the importance of this area in general and its unfortunate under-development in the Netherlands.

The MAC cluster is rated as EXCELLENT overall.

4.3.1 MAC1 – Dynamical Systems and Numerical Analysis

Group description

The group has experienced a steady decline in staff numbers for various reasons, including the regretted death of Ben Sommeijer. Currently it has only 2 permanent CWI researchers. The current investigations of MAC1 are driven by the specialisms of the two members: numerical methods for meteorology, climate and energy. Numerical methods for Maxwell's equations stopped when Jan Verwer passed away.

Overall assessment

The quality of the results obtained is EXCELLENT. The productivity of this group measured in numbers of publications per researcher is significantly less than that of other groups, but the larger size of their publications compensates for this. For this reason, the productivity of this group was rated as VERY GOOD. Its societal relevance and vitality/feasibility are also VERY GOOD.

Numerical methods: Some numerical schemes for fluids are investigated with respect to the conservation of invariants such as energy and enstrophy; the studies are set in the framework of random data. The group is also interested in reduced order modelling, such as cloud parameterization or representative point vortices for meteorology. Numerical methods for partial differential equations were also investigated for their efficiency such as implicit explicit schemes.

Societal relevance: The critically low staff size and the ambition to have different application domains, meteorology , climate and energy emphasizes the necessity of strong existing links with other institutes, such as NIOZ (ocean internal waves), KNMI (cloud modelling) and KEMA (energy).

Conclusions and recommendations

The group urgently needs to hire a third member or to be reintegrated into another structure. When this problem is solved, the group should seriously seek industrial contracts (other groups in the world on such topics all have some industrial support); in this respect, going into energy resource management is a good idea. The group also needs to publish more; one way would be to attend more conferences and/or have more visitors.

4.3.2 MAC2 – Scientific Computing and Control

Group description

The group was started in 2001; its new leader, who joined in 2007, has had a strong and beneficial influence on the group by promoting financial mathematics. The group has 4 permanent staff members plus a former one now emeritus. The group has two subgroups, one in scientific computing (including financial mathematics and tomography) and one in system and control theory.

Overall assessment

Quality, productivity, relevance and vitality/feasibility are all EXCELLENT.

Tomography: A fast and robust solver has been devised for the tomography of crystals; the group is a world leader (one publication in *Nature*).

Financial Mathematics: The group is specialized in fast algorithms for the pricing of financial options and model calibration. It cooperates with Dutch and German banks. The group is also a world leader in the class of algorithms it investigates. New and advanced directions are being taken, such as CUDA implementations on GPU.

Modelling, Simulation and Control Theory: This is developed and applied to plasma instabilities in the ITER tokomak, wakes of wind farms and heights of primary dikes.

Numerical Methods: Efficient algorithms for nonlinear systems with stochastic noise.

Conclusions and recommendations

The group is excellent in all 4 topics; its societal impact is impressive; it has many contracts with the private sector. We recommend that this group should be given complete freedom to grow over the next five years. If it gets too big, it will be no problem to split it and create a financial maths group and a tomography group. If that happens, tomography could also be shifted to Life Sciences. Meanwhile, MAC2 could absorb MAC1.

4.3.3 MAC3 – Multiscale Modelling and Nonlinear Analysis

Group description

The group has 3 permanent staff members. It has a strong interest in discharge phenomena (lightning) and one member is a renowned expert on the modelling of this complex multiscale system; the aim is to tackle it by a combination of analytical and numerical tools. The group is also interested in coherent structures in nonlinear dynamical systems.

Overall assessment

Quality and productivity are EXCELLENT. However, the group's societal impact could be improved, although it is already VERY GOOD. The synergy between the two research topics could be improved. Where lightning is concerned, the group admits that it badly needs an expert in high performance computing (HPC). Nevertheless, the group's vitality/feasibility is rated as EXCELLENT.

Lightning: The modelling of the phenomena is the group's strong point but this is relevant to CWI only if it is associated with numerical simulations. Some very promising numerical simulations have been done. To do more, the simulation needs to be parallelized and run on a supercomputer. Applications to electrical parks and spikes in transformers are important. The group is in contact with teams dealing with these problems.

Numerical Methods and Analysis: Stability and robustness of numerical schemes are studied in the context of time-dependent problems, instabilities, bifurcation and chaos.

Conclusions and recommendations

The Committee agrees with the request for an HPC expert but feels that, unless the expert has strong interests in lightning, there is a risk that he will live his own academic life and not integrate properly into the group. The group might consider first developing closer contacts with the supercomputing centre next door.

4.3.4 MAC4 – Life Sciences

Group description

This group is fairly recent. It started on 1 January of 2009 and focuses on modelling, analysis and simulation of biological processes with the help of mathematics and computational science. The approach and techniques adopted cover a relatively wide range of areas: scientific computing, discrete and combinatorial algorithms, mathematical modelling, computational and theoretical biology, statistical learning, information theory, and neuroinformatics. In addition, the group expanded in 2009 into the area of neuroinformatics, with the recruitment of one tenured researcher from SEN4.

The group is big and is divided into seven sub-groups, as shown in the self-evaluation report. Each sub-group has a leader (PI, Principal Investigator; their names also appear in the report) and a more specific topic and preferred type of approach: algorithmic computational biology, biomodelling and biosystems analysis, combinatorial problems in biology, neuroinformatics, scientific computing for systems biology, systems biology of regulatory molecular networks, and statistical modelling and comparative genomics.

There are currently 3.2 tenured researchers and 2.5 tenure-track. The researchers, senior and junior, are excellent high-achieving mathematicians with expertise in combinatorics and optimization, computational scientists, or bio-mathematicians with expertise in theoretical biology and modelling. One senior researcher holds a full professorship at a Dutch university and one tenure-track researcher received a prestigious VIDI grant from NWO in 2010.

Since January 2009, the group has produced 56 publications in journals or refereed proceedings of conferences (including winning a best-paper award at one major bioinformatics conference), as well as 4 book chapters, and has had 19 other research outputs. Two PhDs have been defended since the group was created.

Overall assessment

The quality, productivity, relevance and vitality/feasibility of this group are all rated as EXCELLENT.

Recommendations

The group is young and highly dynamic, both in terms of seeking valuable interactions with researchers in the areas of biology and health, and in terms of obtaining funds, although these may dry up if:

1. The topics covered by the group remain under-developed in the Netherlands (see below), and
2. Members of the group do not more actively consider seeking funds outside the country.

There appear to be lively scientific interactions between the subgroups despite the breadth of topics and techniques concerned (each, however, in a very coherent way). The group also maintains good interactions with PNA6 and MAC2, which must be preserved. Some others could be worth developing or maintaining (for instance, with PNA1, SEN1, and INS2).

The number of PhD students seems a bit lower than for some other groups (currently 8 for 5.7 tenured or tenure-track researchers). This number may increase in the future if more senior researchers get involved in teaching at the universities. Currently, only one member of the group holds a full professorship. This appears to be planned for the near future and is strongly encouraged by the Committee; it will help make life sciences more attractive to mathematicians and computer scientists.

The group as a whole is doing very well, especially considering that the Netherlands continues to invest remarkably little in the life sciences, at least at the computational and mathematical levels. The group is thus relatively isolated in the country and even inside its cluster, apart from an interaction with MAC2. This may also explain why it covers such a broad range of topics.

Given the major role that CWI should play by being at the forefront of new research in the Netherlands, it would seem natural to expand this one group into at least three: two in computational biology (for instance, along the lines of two of the group's main areas of investigation: modelling for systems biology, and combinatorial and statistical algorithms for biology and health), and one in computational neuroscience. The new themes could then form a new cluster. This might help give the researchers involved in this important and internationally very active application area the increased visibility they deserve, and also enable the Netherlands to catch up faster in this somewhat neglected field of research.

4.4 INS – Information Systems

The cluster is divided into three groups: Database Architectures (INS1), Interactive Information Access (INS2), and Visualization and 3D User Interfaces (INS3). There were small variations in the grades assigned to each group but not enough to warrant reducing the overall rating of EXCELLENT for the cluster.
This cluster has seen some changes in its composition recently. The history of these changes (movements) is displayed clearly and carefully in the self-evaluation report (p. 12). We will comment only on some of the most recent changes.

The central research theme of INS is now databases, information retrieval, and web semantics. Because of the previous changes, the work on HCI and visualization is somewhat reduced. For example INS3 has been moved to SEN1, and the creation of SEN5 (Distributed and Interactive Systems) outside INS, has reduced the potential of HCI and visualization within INS. Moreover, the recent failure to appoint a specialist in imaging and tomography within INS is a missed opportunity, especially now that Arnold Smeulders is joining INS2. However, tomography is allocated to MAC2.

Overall, the cluster now seems somewhat unbalanced. INS1 is historically the strongest group, with high international visibility, whereas INS2 is now the 'new guy on the block' with high vitality and feasibility, and an ever-increasing international reputation.
As it stands, the cluster is somewhat below the average of the other clusters in terms of staff size. Given the uniform excellence of INS2, potential growth should probably be concentrated in INS2. This is timely, as DB+IR is a growth area of research.

The societal relevance of the work in the cluster is also excellent, substantially due to the three successful spin-off companies.

The INS cluster is rated as EXCELLENT overall.

4.4.1 INS1 – Database Architecture

Group description

This group has been highly successful under the leadership of Kersten. The MonetDB is widely distributed and much admired as innovative technology. With the recent change in leadership of the group there is a sense that the group's momentum has stalled slightly. The extent of its output in terms of publications is somewhat down compared with the average for the whole of CWI, which is partially compensated for by the group's intense involvement in software development and open source maintenance. The societal relevance of its work remains high, especially when one considers the successful spin-out of two companies based on its technology. The group has been internationally recognised for many years. This was confirmed recently by significant awards from VLDB and ACM SIGMOD.

Overall assessment

INS1 is rated as EXCELLENT for quality and relevance; and VERY GOOD for productivity and vitality/feasibility.

Recommendations

To sustain this level of recognition, the group will need to break some new ground on the theoretical side now that the MonetDB technology has matured. Kersten was a strong leader and the new leader has as yet no leadership track record. This requires attention from the management team.

4.4.2 INS2 – Interactive Information Access

Group description

Given the size of this group it is 'punching above its weight' at the moment. Its publication output is of high quality and significant in number. It has spun out a successful company.

Overall assessment

INS2 is rated as EXCELLENT for quality, productivity, relevance, and vitality/feasibility.

Recommendations

The group needs to be more successful in raising funds from the EU and other sources; this might be achieved by expanding the group beyond its present size, which appears suboptimal. Given that the group leader was until recently in INS1, the important collaboration between INS1 and INS2 should be encouraged. There is a sense of dynamic leadership. The research on web semantics in this group overlaps with the similar research in SEN5; there is an opportunity here for closer collaboration with SEN5.

4.4.3 INS3 – Visualization and 3D User Interfaces

Group description

The multiscale visualization research at INS3 is a driving theme in the visualization community and has many application domains. The size of the group is subcritical. Although its output has historically been high in terms of both quality and societal relevance, the group now seems to be looking for a new mission.

Overall assessment

INS3 is rated as VERY GOOD for quality, productivity, and relevance, and GOOD for vitality/feasibility.

Recommendations

It is not clear that moving this group to SEN1 is appropriate, since visualization is more than software visualization alone.

Table 4 | **Scores at group level**

PNA

Criteria	PNA	PNA1	PNA2	PNA5	PNA6
Quality	Excellent 5	Excellent 5	Excellent 5	Excellent 5	Excellent 5
Productivity		Excellent 5	Excellent 5	Excellent 5	Excellent 5
Relevance		Excellent 5	Very good 4	Very good 4	Very good 4
Vitality and feasibility		Very good 4	Excellent 5	Excellent 5	Very good 4

SEN

Criteria	SEN	SEN1	SEN3	SEN4	SEN 5
Quality	Excellent 5	Excellent 5	Excellent 5	Very good 4	Very good 4
Productivity		Excellent 5	Excellent 5	Very good 4	Very good 4
Relevance		Excellent 5	Very good 4	Very good 4	Excellent 5
Vitality and feasibility		Very good 4	Very good 4	Excellent 5	Excellent 5

MAC

Criteria	MAC	MAC1	MAC2	MAC3	MAC4
Quality	Excellent 5	Excellent 5	Excellent 5	Excellent 5	Excellent 5
Productivity		Very good 4	Excellent 5	Excellent 5	Excellent 5
Relevance		Very good 4	Excellent 5	Very good 4	Excellent 5
Vitality and feasibility		Very good 4	Excellent 5	Excellent 5	Excellent 5

INS

Criteria	INS	INS1	INS2	INS3
Quality	Excellent 5	Excellent 5	Excellent 5	Very good 4
Productivity		Very good 4	Excellent 5	Very good 4
Relevance		Excellent 5	Excellent 5	Very good 4
Vitality and feasibility		Very good 4	Excellent 5	Good 3

5 Supplementary questions by NWO

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

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)?
The mission statement (dating from the inception of the institute!) is still appropriate, except for the specific targets for knowledge transfer: trade and industry. Today the scope should be enlarged to include applications for other sciences. The focus of the institute is on excellent research and the transfer of knowledge, which can also be formulated as valorization. However, the research groups embrace valorization to highly varying degrees. CWI has made a conscious choice in favour of long-term research, but society may wish to prefer a more even balance between fundamental research and economic valorization across the institute. The institute certainly has the potential to perform more valorization activities, as demonstrated by the very good examples of societally relevant activities given in sections 3 and 4.

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 institute could play a more active role, in particular in the Dutch academic community. Today it is mainly considered as a very good incubator for Dutch professors, but this role is less important since it is also played by universities. CWI should look for other roles in which it can serve the Dutch academic world in a relevant way. (Section 6 gives some examples.) The strategy of the institute could be changed in order to obtain more funding from contract research, licensees and spin-offs and to become a platform for mathematics and computer science in Dutch society. This change should not diminish the emphasis on excellent research, but it should put additional emphasis on the other items.

The institute has many excellent international relationships with comparable institutes abroad, e.g. INRIA. Internationally the visibility of CWI is strong.

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?
Without any doubt NWO should continue to support the institute! It is a real jewel in the crown of the Dutch scientific world. Worldwide it is one of the leading research institutes in the field and over the years it has proved to be of great societal relevance to the Netherlands.

An alternative way to support the same type of research might be to give the research money to the universities, but that would be less effective, firstly because the money would then be spread thinly over many departments, making a concentration on important topics more difficult, and secondly because CWI has a very good organization, culture and reputation. So: Never change a winning team!

Is the institute doing enough to exploit its opportunities for cooperation with organizations outside the academic world?
The question suggests that NWO has certain expectations in this respect. It would be good if NWO were to formulate more explicitly what it expects from CWI in this sense. The observation of the Committee is that external relationships, in particular outside the academic world, could be better developed. This could certainly be improved. Section 3 analyses in detail the societal role that CWI could play. There are many opportunities for CWI to take a more prominent and relevant role outside the academic world. (Section 6 gives some examples.)

One question was devised for CWI specifically:
Since its previous external evaluation, CWI has worked to change its internal organization and has made progress in this respect. Is the internal organization of CWI now adequate to support the institute's mission?
Ten issues were raised in the last evaluation. (We refer to the self-evaluation report 2011.) The majority of the proposed improvements have been adequately implemented (1, 3, 4, 5, 6 and 7). We comment only on those issues that still need some attention:

a. Many irons in the fire
   An attempt has been made to tackle this problem by reducing the number of groups and the proliferation of themes. A few topics have been abandoned and the life sciences have been concentrated in group MAC4. However, we still identify subgroups within the groups and the themes do not play an essential role in the choice of research topics. So there are still many topics with relatively small groups of researchers focusing on them.

b. External scientific council; strategic plan
   The external scientific advisory board does not seem to play an effective role.

c. Publicity needs considerable boosting
   This is still an issue and may be even more urgent than it was at the time of the former evaluation.

d. Gender issue
   CWI has signed a national charter committing the institute to increase the percentage of women and this remains a major and important challenge.

In general, therefore, CWI has made a very good job of implementing the recommendations of the former review committee.

6 Conclusions and recommendations

First we summarize the conclusions that can be drawn from chapters 3, 4 and 5. Then we formulate some recommendations. Most of these conclusions and recommendations concern the institute as a whole. The recommendations for each group can be found in section 4.

6.1 Conclusions

1. CWI is an excellent research institute in the field of mathematics and computer science and in particular at the interface of the two fields. The research output is of excellent quality.
2. CWI is very well organized and the culture and strategy stimulate excellent scientific research. It is a very attractive place for excellent young scientists to grow.
3. The cluster layer in the management structure seems to be superfluous. A management team with a rotating delegation of group leaders might be an alternative to the cluster structure, but this is only one of several possibilities.
4. The strategic process is still too weak and should be improved. The governing board and also the external advisory committee should be more involved in this process.
5. The standard form of scientific output is publication in refereed journals and conference proceedings. This is important and will remain so in the future. However, it is not the only way to convey results to society: people in industry have little time to read and understand the results in this form, and if they did, it would take them a lot of time to convert them into practical solutions. Therefore, to establish direct societal impact other forms of output should be stimulated.
6. CWI can show impressive examples of societal impact, such as software products, consultancy projects and spin-offs. However, these forms of output are less rewarding for researchers because they take more time and do not contribute to the publication status of the researchers concerned. In order to increase these forms of output, the strategy should be adapted and a cultural change is necessary.
7. The selection of research topics is a bottom up process, led by group leaders. Although societally relevant themes are used to motivate the topics, there is no real strategy for selecting research topics. This is no problem if CWI will be able to find funding for fundamental research in the future, but this is far from certain.
8. CWI is in the position to bring more added value to the national agenda for research in mathematics and computer science by providing a platform for cooperation and synergy between the relevant university departments and their research programmes.
9. Some groups have changing leaderships and it is not clear that the new leaders have the same strengths. This concerns in particular the groups: SEN1 and INS1.
10. Some groups are subcritical in size: e.g. MAC1.
11. The productivity rating of some groups does not reflect the enormous effort devoted to innovative software: SEN5 and INS1.

6.2 Recommendations

1. CWI needs a more aggressive and more effective PR policy. If astronomy, for instance, can attract public attention and excitement by discoveries that have no real impact on daily life, then mathematics and computer science, which offer solutions to problems that really make a difference to society, deserve similar public attention. This is not only a problem for CWI; universities also suffer from this phenomenon; but CWI could play a central role in seeking to improve the public image of the field in the eyes of Dutch society.
2. CWI is encouraged to reconsider its role in the Dutch academic world. It could become a real centre or platform for mathematics and computer science. This requires a careful strategic study, which should involve the universities. Some potential roles are: (1) a common laboratory for scientific software tools, (2) a common incubator for spin-offs in the form of mathematical and computer science products, possibly in cooperation with the existing facilities in the universities, (3) a centre for the acquisition and management of large research projects involving multiple universities and enterprises, (4) a platform for the mathematics and computer science departments at universities in the Netherlands. (NB: IPN is a platform for research schools; university departments have no equivalent.)
3. CWI should devote more attention to the development of the products and services that could be generated from research results. Of course, not all research results can be transformed into useful software packages that can be used without knowing the underlying theory, or into patents or consultancy services, but it seems that opportunities in this area are left unexplored. The institute fails to go the "last mile". A simple policy change would be to require that all projects should produce a valorization statement or plan on completion.
4. If research funding diminishes in future, CWI should try to generate research funds itself by making a profit on products, services and spin-offs based on research results.
5. In order to realize more output in the form of products, services or spin-offs, CWI should not try to force the researchers to undertake this development themselves; this would distract them from their research and they are probably not good at it anyway (although senior scientists sometimes like to take a break and to promote their ideas). Instead, CWI should create an additional department to undertake development and valorization. The activity requires a different culture and a different structure. In fact, research groups should be organized by discipline while development groups should be organized by product/market combinations. Of course, there should be strong working relations between the departments.
6. Instead of, or in addition to, setting up an in-house department for development and valorization, CWI could establish strategic alliances with other institutes. Potential candidates are the new e-sciences laboratory, TNO and commercial organizations. This would require careful strategic consideration.

Annex 1 Curricula Vitae of Evaluation Committee Members

Chair

Prof. dr. K.M. (Kees) van Hee, Eindhoven University of Technology (TU/e), professor of computer science since 1984. He holds an MSc in mathematics from Leiden University and a PhD in operations research from TU/e. He worked for a total of 16 years in management and ICT consultancy. From 1994 to 2004 he was managing partner at Bakkenist Management Consultants and at Deloitte Consultancy. In 1991–1992 he was visiting professor at the University of Waterloo, Ontario. From 2005-2009 he was Dean of the department of mathematics and computer science at TU/e. He has published on Markov decision processes, operations research, modelling and analysis of software systems and Petri nets. He is co-author of the book *Workflow management; models, methods and systems.*

Members

Prof. Carlo Ghezzi is Professor and Chair of Software Engineering in the Department of Electronics and Information of the Politecnico di Milano. He has been the Rector's delegate for research, a member of the Academic Senate and of the Board of Governors, and a Department Chair. He has received the following awards: ACM Fellow, IEEE Fellow, SIGSOFT Distinguished Service Award, and member of the Italian Academy of Sciences (Istituto Lombardo). Moreover he is a member-at-large of the ACM Council and previously served as a member of the ACM Nominating Committee, and member of the committee for the ACM Software Systems Award. He is presently on the editorial board of the IEEE Trans. on Software Engineering, Communications of the ACM, Science of Computer Programming, Service Oriented Computing and Applications, Computing, and Software Process Improvement and Practice. Ghezzi has been on the evaluation boards of several international research projects and institutions in Europe, Japan, and the USA. He was a member of the panel in charge of assessing the research quality of Computer Science at all Dutch Universities over the period 2002-2008. His research has focused on software engineering and programming languages. He is especially interested in methods and tools to improve dependability of adaptable and evolvable distributed applications, such as service-oriented architectures and ubiquitous/ pervasive computer applications. He has recently been funded by the European Research Council under the prestigious 'Advanced Grants' programme for a research project on 'Self-Managing Situated Computing'.

Prof. Olivier Pironneau. Professor at Université Pierre et Marie Curie. Member of scientific council of Université Pierre et Marie Curie. President of CSCI (strategic committee for intensive computing). Member of the Académie des Sciences. He received his PhD at UC-Berkeley (with E. Polak), in Optimisation and Control, his Post-Doc. at the University of Cambridge with Sir James Lighthill (DAMTP), and his Thèse d'Etat at Université Paris VI with G. Duvaut and J.L. Lions (Shape Optimisation in Fluid Mechanics). In the past he has been awarded the Blaise Pascal prize and the Marcel-Dassault prize by the Académie des Sciences, the Ordre National du Mérite, and an Honorary Adjunct Professorship by the University of Houston. Since 2004 Pironneau has been an Associate Member of the Russian Academy of Sciences. Pironneau is the author or co-author of several books and publications. In 2005 he was co-author of the book *Numerical Methods for Option Pricing and Calibration*.

Prof. Gil Kalai. Professor at the Institute of Mathematics of the Hebrew University of Jerusalem. He also has a long-term position in the departments of Computer Science and Mathematics at Yale University, New Haven. Kalai is a mathematician working mainly in the field of combinatorics. Within that field, he works mainly on geometric combinatorics and the study of convex polytones and related objects, and on the analysis of Boolean functions and related matters.

Prof. C.J. Keith van Rijsbergen. Leader of the Information Retrieval Group in the Department of Computing Science at the University of Glasgow. Keith van Rijsbergen was born in Holland. He was educated in Holland, Indonesia, Namibia and Australia. He took a degree in mathematics at the University of Western Australia. In 1972 he completed a PhD in computer science at Cambridge University. After almost three years of lecturing on information retrieval and artificial intelligence at Monash University, he returned to the Cambridge Computer Laboratory to hold a Royal Society Information Research Fellowship. In 1980 he was appointed to the chair of computer science at University College Dublin; from there he moved in 1986 to the Glasgow University, where he is now. Since about 1969 his research has been devoted to information retrieval, covering both theoretical and experimental aspects. He has specified several theoretical models for IR and seen some of them with the design of appropriate logics to model the flow of information. He has been involved more recently in a K-space. He is a Fellow of the Royal Academy of Engineering, the Royal Society of Edinburgh, IEE, BCS and ACM. In 1993 he was appointed Editor-in-Chief of the Computer Journal, an appointment he held until 2000. He has served as a programme committee member and published a book entitled *Information Retrieval: Uncertainty and Logics*. His most recent book is *The Geometry of Information Retrieval*, CUP, 2004.

Dr. Marie-France Sagot started her research career in Brazil, the country of her birth, in 1988, at the Institute of Mathematics and Statistics of the University of São Paulo, city and state of São Paulo. Her background is in mathematics (mainly graph theory, discrete maths, combinatorics) and in algorithmics. She met biology when she moved to Paris, France (her second, paternal, country) to study for a Master in Theoretical Computer Science. She picked up biology during her PhD studies (1993-1996). She has worked at the Université de Marne-La-Vallée, the Institut Pasteur, and INRIA. She is currently Research Director at INRIA, France, and also Visiting Research Fellow at King's College London and Visiting Researcher at the Instituto Superior Técnico (Lisbon, Portugal). Fifteen of her PhD students have already defended their theses. She has been a member of evaluation committees in seven European countries and in Canada, Israel and the USA.
On the pages of her personal INRIA website she shows the result of many collaborations; quite a few research collaborations have blossomed into lifelong friendships. As Bamboo project team leader, Sagot was selected by the ERC in 2009 in the 'experienced researcher' category. Exploring symbiosis, a phenomenon that some consider a key factor in evolution, her Sisyphe project fully meets the definition of research 'at the frontiers of knowledge'.

Annex 2 Programme of the Site Visit, 11-13 May 2011

Members of the Evaluation Committee CWI

Carlo Ghezzi	CG
Kees van Hee (chair)	KvH
Gil Kalai	GK
Olivier Pironneau	OP
Keith van Rijsbergen	KvR
Marie-France Sagot	MFS

Wednesday, May 11

16:30	18:30	Closed session (synchronising planning & approach)	
19:30	22:00	Welcome dinner, Jos Engelen and Franciska de Jong (Board NWO)	

Thursday, May 12

08:00	08:30	Transport, arrival							
08:30	09:30	Governing Board CWI (Chair Van Laarhoven, Kok, Roelofs)			L015				
09:30	11:00	Director & Management Team			L015				
11:00	11:10	Short break							
11:10	11:40	Support departments (C&I, P&O, PFC, ITF)			L015				
11:40	12:00	Tour							
12:00	13:00	Lunch (closed session full committee)			L015				
		group	**leader**	**committee**		**group**	**leader**	**committee**	
13:00	13:30	PNA1	Laurent	GK OP MFS	L015	INS1	Manegold	CG KvH KvR	L120
13:40	14:10	PNA5	Cramer	GK OP MFS	L015	INS2	De Vries	CG KvH KvR	L120
14:20	14:50	PNA6	Buhrman	GK OP MFS	L015	INS3	Van Liere	CG KvH KvR	L120
15:00	15:10	Short break							
15:10	15:40	PNA2	Zwart	GK OP MFS KvH	L015				
15:50	16:20	Postdocs & PhD students (5-6)		GK OP MFS	L015	Postdocs & PhD students (5-6)		CG KvH KvR	L120
16:30	17:00	PNA	Van der Mei	full committee	L015				
17:00	17:30	INS Hardman/Kersten		full committee	L015				
17:30	18:00	Closed session full committee							
18:00	18.30	Transport							
19:30	22:30	Short walk; dinner (+ closed session)							

Friday, May 13

08:00		Transport; arrival							
		group	**leader**	**committee**		**group**	**leader**	**committee**	
08:30	09:00	MAC1	Frank	GK OP MFS	L015	SEN1	Klint	CG KvH KvR	L120
09:10	09:40	MAC2	Oosterlee	GK OP MFS	L015	SEN3	De Boer	CG KvH KvR	L120
09:50	10:20	MAC3	Ebert	GK OP MFS	L015	SEN4	La Poutré	CG KvH KvR	L120
10:30	10:40	Short break							
10:40	11:10	MAC4	Klau	GK OP MFS	L015	SEN5	Bulterman	CG KvH KvR	L120
11:20	11:50	Postdocs & PhD students		GK OP MFS	L015	Postdocs & PhD students		CG KvH KvR	L120
12:00	12:30	MAC	Koren	full committee	L015				
12:30	13:00	SEN	Klint	full committee	L015				
13.00	13:15	Closed session full committee							L015
13:15	14:00	Lunch with Director & (small) Management Team							L015
14:00	17:00	Closed session full committee							L015
17:00	17:30	Plenary with Director & Management Team							L015
17:30	18.00	Wrap up (presentation main preliminary findings to CWI)							Turing room