Evaluation 2011-2016

CWI
Centrum Wiskunde & Informatica

Amsterdam/Utrecht, Januari 2018

Content

1 Introduction

1.1 Scope and context of this review

This evaluation concerns the research carried out at Centrum Wiskunde & Informatica (CWI), the Netherlands' national research institute for mathematics and computer science, in 2011-2016. The evaluation was commissioned and organised by the Netherlands Organisation for Scientific Research (NWO) and supported by Dialogic Innovation & Interaction and Birch Consultants. The external evaluation follows the Standard Evaluation Protocol 2015-2021 (SEP, amended version September 2016). It is the protocol for research assessment in the Netherlands as agreed upon by NWO, the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Association of Universities in the Netherlands (VSNU). The primary aim of the assessment procedure is to reveal and confirm the research quality, relevance to society and viability and to provide recommendations to improve these aspects. In addition, the procedure includes considerations with regard to PhD programmes, the research integrity and diversity of the (scientific) staff.

An international Evaluation Committee was established and asked to produce a reasoned evaluation of the institute and its research programmes, in accordance with the SEP. Prior to the external evaluation, CWI submitted a self-assessment document covering the period 2011-2016 including a strategic forward look. This report was approved by the NWO Executive Board on 10 April 2017. The self-assessment report and addendum included a SWOT analysis and a full set of statistics and tables at institute level concerning input (funding and staff) and output (refereed articles, non-refereed articles, books, book chapters, PhD theses, conference papers, professional publications, publications aimed at the general public, standards, and other output) for the six years prior to the evaluation. With regard to the fifteen research groups a short description of their work was presented and a selection of their top achievements during the evaluation period. The appendices also informed about the CWI multilevel valorisation strategy and application domains; they also contained a narrative and lists of public-private partnerships, CWI's spin-offs and CWI software products. The self-assessment report therefore offered a concise picture of the institute's and research groups' work, ambitions, output and resources in accordance with the guidelines provided by the SEP. A site visit formed an important part of the evaluation and included interviews with the management of the institute, leading researchers, other levels of staff, and a tour of the laboratories and facilities.

1.2 The Evaluation Committee

The Evaluation Committee was formally installed by the NWO Executive Board represented by prof.dr. J.C. Schouten on 18 October 2016. The Committee members were:

prof. I. Gijbels (Chair), Ing. F.M. (Fred) Boekhorst, Prof. Y. (Yannis) Ioannidis, Prof. H. (Hélène) Kirchner, Prof. K. (Klara) Nahrstedt, Prof. dr. A.C. (Andrew) Yao, Prof. I. (Irad) Yavneh.

A short curriculum vitae of each of the members is included in Annex 1. The Committee was supported by NWO C.M. (Margreet) Bouma and Dialogic Innovation & Interaction R.A. (Robbin) te Velde.

Before the site visit all members of the Committee signed the Statement of Impartiality and confidentiality (SEP appendix C), by means of which they declared 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

Six weeks prior to the site visit the Evaluation Committee received the self-assessment report of CWI together with the site visit programme and an accompanying letter. The documentation supplied to the Committee included all the information required by the SEP as well as by the additional questions raised by NWO.

Prior to the site visit the Committee was informed about the Dutch science policy and the organisation of scientific research in the Netherlands, about (the transition of) NWO and the governance structure of the NWO research institutes. The Committee also received additional information that it requested about how the provided h-indices relate to the scientific age (i.e. years since PhD degree) of the CWI members. In this request special reference was made to the mentioning of the h-index in the self-evaluation report, p.7 and p.11.[1]

During the various sessions of the site visit, the Committee received extensive and detailed information from all participants (PhD's, post docs, senior staff). Further documentation was provided about the composition of the Scientific Advisory Council[2] and about the number of prizes and grants recently awarded to CWI staff members[3].

1.4 Procedures followed by the Committee

The Committee proceeded in accordance with the Standard Evaluation Protocol 2015-2021. The assessment was based on the CWI self-assessment report and the other documentation provided by NWO, the institute, and the interviews.

The interviews took place during the site visit made from 19-20 October 2017. The programme of the visit is included in Annex 2. The Committee met in a kick-off meeting on the afternoon and evening preceding the site visit (October 18) to discuss and plan the interviews with CWI.

During this meeting the Committee met with prof. dr. J.C. (Jaap) Schouten, member of the NWO Executive Board and portfolio manager of CWI. By means of powerpoint presentations the Committee was informed about NWO, the NWO 'transition', the governance with regard to the NWO institutes, as well as about the Dutch science system. The Committee agreed on procedural matters and aspects of the assessment as described in the Standard Evaluation Protocol. As requested the Committee already received from CWI a list of PhD candidates, postdocs, tenured and non-tenured scientific staff to be interviewed and they agreed with this list.

The interviews with the CWI Governing Board and Directorate, the CWI Management Team, senior research staff, PhD students, postdocs, tenured and non-tenured staff, support staff and a CWI Fellow took place during the site visit on 19-20 October 2017. All interviews were conducted by the entire Committee.

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[1] See Annex 3. Tables 6, 7, 8 and 9, as well as Figure 4. The tables have been anonymized for this report.

[2] See https://www.cwi.nl/about/organization/scientific-advisory-committee

[3] See Table 5 in Annex 3.

After completing the interviews the Committee discussed the comments on the institute and its research programmes and determined the final assessment and the scores.

At the end of the site visit, the Committee met with the CWI Governing Board, CWI Directorate and Management Team and a representative of the NWO Executive Board to report on the Committee's main findings. Finally, the Committee Chair reported on the Committee's main findings to the entire CWI community.

On December 7 2017 a draft version of this report was sent to the CWI director for factual correction and comments. The report was subsequently submitted to the NWO Executive Board.

1.5 Aspects and assessment scale

The Standard Evaluation Protocol 2015-2021 required the Evaluation Committee to assess three main aspects of the institute and its research. These are (as described in the SEP):

1. *Research quality.* The committee assesses the quality of the institute's research and the contribution that research makes to the body of scientific knowledge. The committee also assesses the scale of the institute's research results (scientific publications, instruments and infrastructure developed by the institute, and other contributions to science).
2. *Relevance to society.* The committee assesses the quality, scale and relevance of contributions targeting specific economic, social or cultural target groups, of advisory reports for policy, of contributions to public debates, and so on. The point is to assess contributions in areas that the institute has itself designated as target areas.
3. *Viability.* The committee assesses the strategy that the institute intends to pursue in the years ahead and the extent to which it is capable of meeting its targets in research and society during this period. It also considers the governance and leadership skills of the institute's management.

These three main evaluation criteria were rated according to a four-category scale, as specified in the SEP. The verdict was given in qualitative form, though a quantitative figure was added, as requested. The scale is as follows: 1. World leading/excellent; 2. Very good; 3. Good; 4. Unsatisfactory (see Annex 4).

The Evaluation Committee considered three additional topics. These are:

1. *PhD programmes.* The Evaluation Committee considered the supervision and instruction of PhD candidates.
2. *Research integrity.* The Evaluation Committee considered the institute's policy on research integrity and the way in which violations of such integrity are prevented.
3. *Diversity*. The Evaluation Committee considered the diversity of the institute. It is precisely the presence of mutual differences that can act as a powerful incentive for creativity and talent development in a diverse institute.

These topics were considered only in qualitative terms.

In addition to the topics above NWO formulated three questions for all NWO institutes and one specific question for CWI:

1. What is the institute's added value in the national context and its international position?
2. How does the institute stimulate and facilitate knowledge utilization and open access?

3. How does the institute's structure, size and financial policy contribute to its mission?

4. For CWI: The impact factor of a journal is not a good metric for the impact of a scientific publication, especially not during a movement to open access. What other metric(s) can we use to measure the impact of a scientific publication?

2 Institutional framework of CWI

Centrum Wiskunde & Informatica (CWI) is the Dutch national research institute for mathematics and computer science and is part of NWO.

2.1 Mission

CWI's mission is: *"to conduct pioneering research in mathematics and computer science, generating new knowledge in these fields and conveying it to society at large, and to industry in particular."*

Fundamental, curiosity-driven research is the base of this mission, but it is also motivated by societal relevance. Knowledge transfer and 'valorisation' thus play an important role in CWI's work.

CWI's objectives are:

1. conduct advanced research of the highest level, tackling important questions of scientific and societal relevance, and initiating new lines of long-term research;
2. develop talent, both of junior researchers (PhD) and of senior researchers (full professorship);
3. be a centre and meeting point for contacts within academia, industry and government;
4. play a nationally leading role in science policy in the fields of mathematics and computer science.

CWI has founded 24 spin-off companies since 1956.

2.2 Research

Research at CWI is organised into fifteen research groups:

- *Algorithms and Complexity* - Designing software for future computers, in particular using fundamentally different quantum techniques like superposition, interference and entanglement.
- *Computational Imaging* - Developing the next generation of 3D imaging – enabling scientists to look further into objects of all kinds.
- *Cryptology* - Investigating how cryptologic methods can contribute to solving security issues, for example through encryption, digital signatures and secure computation.
- *Database Architectures* - A leading database systems research group, active in the broad area of data management systems and infrastructure for supporting data science.
- *Distributed and Interactive systems* - Facilitating and improving the way people access media and communicate with others and the environment, in areas such as wearable technology and smart textiles, immersive media, languages and infrastructures.
- *Formal Methods* - Technological foundations that underpin software engineering and service-oriented computing, adding stability and reliability to those foundations and the third-party applications built on them.
- *Information Access* - Developing methods and techniques to better support users in accessing information. Working together with social scientists and humanities researchers on technology to interpret complex data better.

- *Intelligent and Autonomous Systems* - Studying generic and fundamental mechanisms that enable the emergence of various degrees of organization, intelligence and autonomy in complex systems, and apply them to concrete problems of societal relevance.
- *Life Sciences* (as of 2017: *Life Sciences and Health*) - Creating fundamental knowledge and applied solutions in the broad field of life sciences, promoting understanding of how biological processes work in detail.
- *Machine Learning* - Focusing on how computer programs can learn from and understand data, and then make useful predictions based on it, using insights from statistics and neuroscience.
- *Multiscale Dynamics* - Combining scientific computing with model reduction and machine learning, with particular focus on plasma dynamics in lightning and space weather, and in high voltage and plasma technology.
- *Networks and Optimisation* - Developing algorithmic methods to tackle complex optimization problems by combining techniques from mathematics and computer science, with applications in planning, scheduling and routing.
- *Scientific Computing* - Investigating and developing methods that contribute to a better understanding of hard-to-predict developments in vital areas such as climate, energy, and finance.
- *Software Analysis and Transformation* - SWAT studies software systems: their design, their construction, and their inevitable evolution. Our mission is to learn to understand software systems and to improve their quality. We focus on complexity as the primary quality attribute of software systems.
- *Stochastics* - Developing and studying probabilistic, operational and statistical models to model, describe, and improve communication, energy, information, logistics, and transportation systems.

2.3 Organisational structure

CWI was founded in 1946 and is – in their own words – the birthplace of the European internet in 1988. The institute is located in Amsterdam, but has a strong international focus. For the institute's organisational structure, see Figure 1.
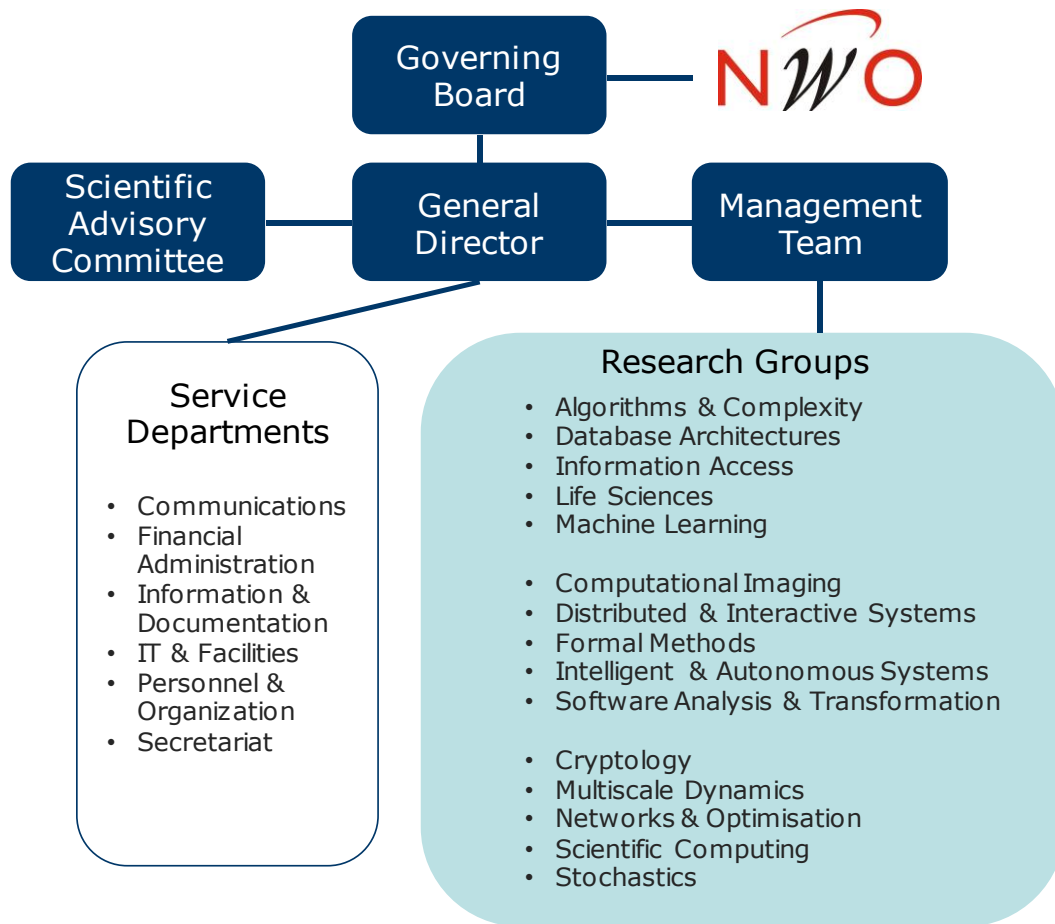
Figure 1. Organogram CWI, 2017

In 2016, a new body was established as part of the updated valorisation strategy. The Valorisation Team (VT) monitors and initiates valorisation opportunities. Up to 2016, theme coordinators monitored these activities within the institute.

2.4 Financial matters

CWI has three types of funding: basic funding by NWO, external funding (national and international programme competitions; research grants and contract research) and bonus funding (see Figure 2). About 60% of the budget consists of basic funding, which roughly covers the fixed costs of the institute. Bonus funding from NWO was intended for strategic purposes, such as investing in public-private partnerships and starting a new research group. The total budget is about 18 M€.[4]

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[4] See Table 1 and Table 2 in Annex 3.

Figure 2. Funding of the running budget (k€)

2.5 Staff
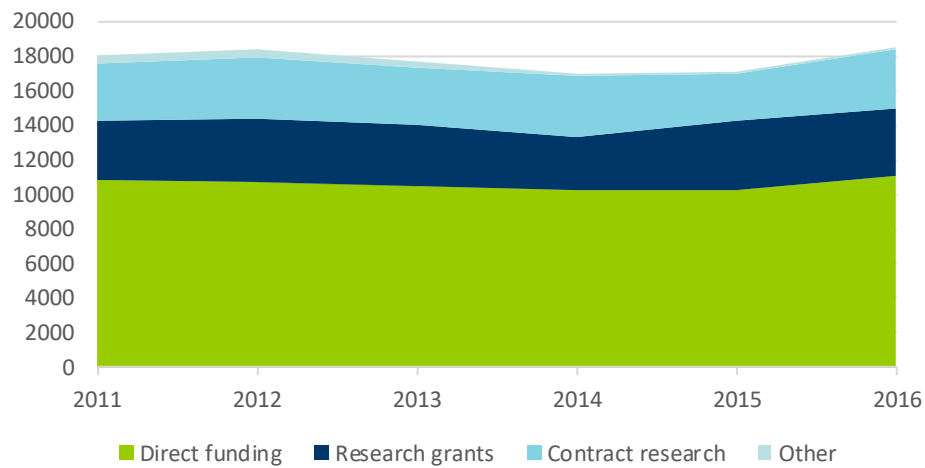
CWI is home to 177 researchers (161.6 fte in 2016, see Figure 3). PhD candidates make up a little over 40% of the research staff in fte. The CWI staff also includes visiting fellows (6.4 fte in 2016) and 40 support staff members (36.7 fte in 2016).[5]
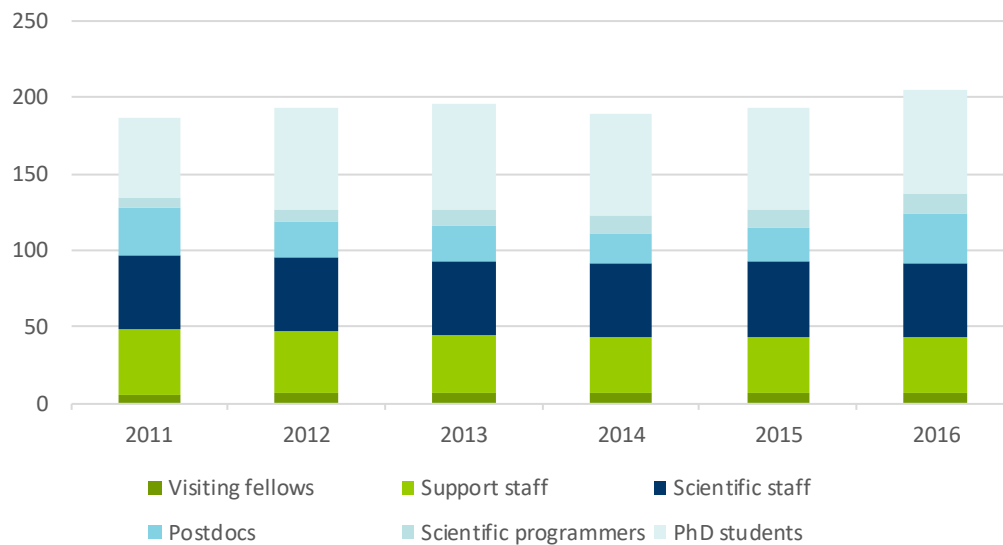

Figure 3. Personnel composition (FTE)

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[5] See Table 3 in Annex 3.

3 Assessment of the institute CWI

3.1 Strategy and targets CWI

In the update of the strategic plan in 2016, CWI has selected five cross-cutting themes along which they aim to invest in future years (e.g., via hiring tenure track researchers). These themes were chosen, in 2016, after discussions with a broad basis, and are based on the strengths of the research at CWI, and on developments in science and society. The Committee feels that with the focus on these themes, and research topics such as digital finance and blockchain technology, control theory and security and privacy, CWI has made a good strategic choice. CWI, being a research institute for mathematics and computer science, offers a unique constellation to foster natural synergies. Due to the Institute's limited size, interactions amongst the several research units take place in various formats (reading groups, informal seminars, discussion groups, joint PhDs, etc.). New opportunities for synergies between research areas may pop up (such as by considering networks in life sciences, and exploiting interactions between networks and data science). A topnotch research environment such as present at CWI can also benefit from advice from their scientific advisory committee, at various moments of their strategy development, if they feel feedback from international peers may yield a welcome input.

A strategic ambition of CWI is to create an optimal research environment to attract also the best researchers. The Institute seems to be very successful in this, with very good recent tenure track hiring, and an international diverse group of young researchers (PhDs and postdocs). The Institute clearly is a breeding and fostering ground for top talent.

The Institute is very much concerned with continuously safeguarding the balance between application-oriented and fundamental research. This positioning is valuable and should be supported by national authorities. Although the Institute's major strength and focus is on fundamental research, its research is very relevant to the society, and often leads, on short or longer terms, to opportunities to valorize the top-research output. Such valorization should be encouraged and supported.

3.2 Research quality

CWI has a standing reputation as a first-class international research center in mathematics and computer science. During the site visit, the Committee examined the research quality of the Institute during the period 2011-2016, with the following findings:

1. **Top of Their Fields**: In the last six years, each of the 15 research groups of CWI has conducted research at the highest level in their fields. For example, just to show the breadth and depth of CWI's research, the proof of the forty-year-old Rota's conjecture on matroids caused a great sensation in discrete mathematics; so did the proof of the 20-year old conjecture by Yannakakis for theoretical computer science. Even more widely reported was the announcement of the first explicit collision instance found for the cryptographic hash function standard SHA-1, which finally brought to conclusion one of the famous code-breaking sagas in modern times.
2. **Better Theory and Better Practice**: One of the core beliefs at CWI is that better theory leads to better practice. This approach is effective in their successful software production and acknowledged for example by the academic and industrial take-up of MonetDB or Rascal. Even in the seemingly intractable field of software development, formal verification methodology has led CWI researchers to identify and repair a sorting program in a popular Java software library. CWI has a sterling record in

carrying out principled research in data science and turning the results into successful enterprises.

3. **Interdisciplinarity at Work**: Mathematics and computer science have always been a powerful enabler of all sciences. CWI hosts some of the best computational science groups, and their work has led to better climate modeling and forecasting, innovative new tomography, faster genomic algorithms, etc., all important and urgent scientific issues facing the world today.

4. **Anticipating the Future**: CWI has a flat organization model (a non-hierarchical organization, with focus on actions within research groups), with an efficient decision process, which gives them two advantages.
   a. Each group can effectively seize new opportunities in their expertise and related fields. For instance, there is a great need for real-time 3D/4D tomography whose applications range from medical procedures to artwork restoration; and CWI researchers recognized that this can be best addressed by computational methods, not just by hardware alone.
   b. The Institute's management can create new groups efficiently and timely. The establishment of the quantum group is a far-sighted decision that is already paying off in a huge way. The European Platform for Quantum Software started by CWI researchers, and specifically the QuSoft institute (spanning CWI, UvA and VU), has already become one of the most dynamic drivers of the nascent quantum software technology.

5. **Quantitatively the research output from CWI** is quite constant over the years. Demonstrable recognition of the quality of the research output is provided in Table 4 in Annex 3. The h-index is among the measures that are used to quantify the research output achievements of an individual researcher. The use of this and alike indices only makes some sense when compared among researchers in similar disciplines and at comparable stages of their careers. Table 6, Table 7, Table 8 and Table 9 in Annex 3, listing the ratio of h-index and years after PhD, for top CWI-researchers and non-CWI researchers, reveal that CWI hosts top researchers, in senior and junior staff. See also Figure 4 in Annex 3.

In conclusion, CWI conducts top research, with high international influence on the relevant research fields, and leadership recognized by international peers.

The quantitative assessment of the criterion "Research quality" is therefore: Score 1.

3.3 Relevance to society

NWO has defined societal relevance of their Institutes by means of so-called valorization indicators, such as:

- Strategic cooperation in PPP's
- Strategic cooperation through contract research
- Software-related output
- Spin-offs generated
- Co-publications with non-academic partners
- Press releases

CWI has rebalanced strategic cooperation with Industry from direct contracted research towards PPP's as that mechanism offers better opportunities for long term research with Industry engagement. The other indicators of valorisation are on-average stable over the last 6 years. See Table 12 and the list of CWI spin-offs in Annex 3.

While the evaluation committee believes the above indicators to be valid indicators of societal relevance, it would not do justice to CWI to base the societal relevance on just those indicators.

The Committee observed that CWI is consistently delivering project-results in societally relevant themes with a very high scientific impact. This is evidenced qualitatively as well as quantitatively in the self-evaluation document as well as by the presentations delivered during the audit. As a consequence, results are taken up in a variety of ways such as contributions to Standards, delivery of breakthrough Software components and solutions, generations of spin-offs, but also long-term research on various aspects of Quantum Computing, thus preparing us for the next wave in computing.

CWI focuses on long-term trailblazing research with impact (scientific, societal, industrial) and the Committee believes that the Institute has found the sweet spot where they deliver true scientific- and societal impact. However, the Committee also believes that the Industrial impact can be enlarged if and when more effective communication to (potential) stakeholders is done. It is important to note that during 2017 (outside the self-evaluation period reporting) significant steps are already taken to improve the outreach, and more steps are planned in cooperation with the Valorisation team.

A further important point is to close the gap between the trailblazing research results and the engineering efforts still needed to increase accessibility of those results by Industry. While there are already many examples of good Industrial collaboration and uptake, the Committee feels that the potential Industrial uptake can be enhanced further through the involvement of software engineering companies to go 'the extra mile'. The Committee recommends to maintain the current long-term research focus and to augment it by organizing an eco-system of partners, willing and able to take results from CWI and perform demand-driven contracted product development. The Valorisation team confirmed this to be a good direction that they already embarked on a couple of months ago.

Another great example of societal relevance is the education performed by CWI. In the review-period, 58 people obtained a PhD degree (see Table 11 in Annex 3).

The salaries and other costs related to the training of these young researchers need to come from external funding. In addition, it is a regular procedure that the PhD bonuses from the Ministry of Education, Culture and Science go to the university that awards the PhD degree (instead of to the research institutes where the PhD students do most of their research, i.c. CWI). In the reporting period 12 PhD students were funded by industrial partners (see Table 10 in Annex 3).

In conclusion, the CWI conducts research that makes outstanding contributions to society (on short, middle or long-term).

The quantitative assessment of the criterion "Relevance to society" is therefore: Score 1.

3.4 Viability

1. **Viability of themes**: CWI research is organized through themes which came together via discussions between the management team, group leaders and members of groups. The themes are viable and represent well the research excellence of CWI. The research theme structure of CWI also allows for nimble group organization since there are mechanisms for new groups to emerge, as well as some groups to merge.

2. **Viability of research portfolio**: The CWI research portfolio is focused on basic research and it yields very strong results. It is very important that the current financial support (from NWO) for basic research continues for CWI and the CWI leadership continues to ensure the financial health of their research portfolio (see also Section 3.6).

3. **Viability of performance metrics**: Mostly, the viability metrics in the form of performance metrics show the researchers' strengths and the groups' strengths. It would be beneficial if new viability metric(s) could be added which show what is the value added by the performed research. One possible viability metric to show research relevance to society is tracking of PhD students and postdocs employment after they leave CWI. See also Section 3.6.

4. **Viability regarding industry engagement**: CWI research groups engage with industry, but viability of industry engagement could be strengthened via increased public relation actions of their industry-adopted results. CWI research is highly relevant to society and industry, and it would be beneficial to be more forceful in publicizing the CWI research' viability, impact and relevance.

5. **Viability of governance and leadership**: CWI has a flat-structured governance and leadership which enables nimble governance of the research environment. The present governance structure allows new groups to emerge and some groups to merge if needed. The management team of researchers around the director of CWI provides strong support to the director to make higher level decisions where group decisions are left to the group leaders. This structure enables also the group leaders to grow into future leadership positions. The close collaboration between group leaders and director/administrative leadership regarding new hiring positions works well for individual groups and across groups as the recent excellent hires show. Approaches to international leadership of CWI researchers (TPC membership, chairing and leading A+ international conferences, workshops and participation in panels and keynotes) are viable, and CWI's research leadership is widely recognized. One improvement in CWI leadership and governance viability would be to encourage more female researchers to lead CWI groups. The management team has two female researchers in leadership roles (out of 5), but only 1 group is led by a female researcher (14 groups are led by male colleagues).

In conclusion, CWI is excellently equipped for the future, with all necessary ingredients to ensure viability being present.

The quantitative assessment of the criterion "Viability" is therefore: Score 1.

3.5 Considerations regarding organisation, management policies and staffing

3.5.1 PhD programmes

The answers from the PhD candidates interviewed reflect an excellent atmosphere, resulting from a strong and unique combination of very good supervision and respect for autonomy of PhD students.

There are opportunities for students to meet together in the yearly PhD meeting and social events. They can be involved in multidisciplinary projects, work with different institutes, universities and industry in collaborative projects.

The PhD supervisors teach their students both by example, through their own behavior, but also by working with them closely and pointing them away from any possible slips (regarding

proper attribution, conflict of interest, accurate reporting, software documentation, repro-ducibility, and other issues) when they write their first papers or when they get involved in reviewing papers for journals and conferences. In addition, CWI offers training courses for PhD students on topics such as "Scientific Paper Writing", "Data Management", "Research Ethics", "Proposal Writing", and others. This is an example of best practices for the other institutes and universities in NL. The Committee strongly encourages CWI in this initiative and even to further disseminate such practices. Ethics and research integrity for example are concerns for researchers in general, not only in mathematics and computer science. Promoting them at the institution level (CWI and NWO) avoids relying only on supervisors.

CWI is attractive for PhD students because of the excellent reputation of the institute, the quality of supervisors and the good working environment. CWI should go on recording where their PhD students come from and where they go after. This information contributes to meas-ure the impact of the institute.

CWI offers the possibility for students who want to have an academic career to have a teach-ing experience at a university, but this may depend on the supervisor's contacts with universities.

CWI should be aware that the relatively long PhD duration (although not uncommon for The Netherlands) could be a disadvantage in international competition (PhD duration in several European countries is shorter, e.g., 3-4 years).

3.5.2 Research integrity policy

Research integrity corresponds to the use of honest and verifiable methods in proposing, performing, and evaluating research, reporting research results with particular attention to adherence to rules, regulations, guidelines, including giving appropriate credit to prior work where it is due, and following commonly accepted professional codes or norms.

CWI scientists' work is undeniably of high quality and, as always, this goes hand in hand with high integrity in the way they conduct research as well. This permeates the entire at-mosphere in CWI, so when younger researchers join the institute, they are immediately immersed in its ways.

Dedicated training courses for PhD students are open to a larger audience and have been designed exactly to cover all research integrity aspects. The existence of these courses is one more element that shows the high level of seriousness that CWI puts on the relevant issues. Finally, particularly on reproducibility, CWI wants to take a leadership position, e.g., by having groups of researchers that focus on the issue at the research level as well, at-tempting to identify optimal ways for storage and invocation of software, preservation for depth of time, etc.

Closely related to research integrity is the open access policy on publications and data that result from (publicly funded) research. National and European policies mandate open access, but CWI has adopted this policy very swiftly and thoroughly, as a matter of principle. Not only does it provide an open access institutional repository for depositing such research re-sults, but it also enforces people to comply with the open access policy by making their promotions be based on what exists in the repository alone and nowhere else. It is no wonder then that 100% of all CWI publications in the recent years are offered in open access. Re-garding software, CWI management always encourages its researchers to release their software in open source, which also helps transparency, reproducibility, etc. Rightly so, how-ever, it does not mandate this, as sometimes focusing on the software IP may be beneficial to the Institute.

3.5.3 Diversity

The Institute is highly multi-national, with research staff from over 30 nationalities according to the self-evaluation report. This was evident also in the interviews, and it was clear that the foreign researchers at all levels were highly satisfied with the Institute. With regards to gender, it is evident that the management team is striving to reduce the gap between the number of women and men. In the management team itself, two of the five members are women. At the top level of seniority of scientists, 10% are women, doubling the number corresponding to the beginning of the period and matching the "Talent to the top" target. The percentages at the sub-top are presently below the target of 25% but are expected to reach this goal in a couple of years due to the recent hiring of two strong women tenure-trackers (one via a WISE grant). At the post-doc level, the percentage fluctuates over the years, and the average over the last three years approximately matches the target of 20%. For PhD students, there is actually a decline in the last two years. The management team explained that fluctuations are expected due to the small numbers (of female students in the undergraduate level), and that the percentage bounced back to 20% in 2017, but still it is far below the target of 35%. In our interviews with the PhD students, we asked the women how they felt about this gap, and they did not seem worried. Furthermore, several of the female researchers at various levels reported that they participated in outreach activities for attracting women.

The impression of the Committee is that there is certainly a strong awareness to the issue of diversity, and that measures are being taken to reduce the gender gap – especially in the hiring process for tenure-track positions, which is indeed most important. The policy remains that at the end of the process the best candidate receives the offer, regardless of gender, as we would hope and expect from such a top-level institute.

Notwithstanding the mixed success thus far in reducing the gender gap, the clear impression of the Committee is that the Institute's management and staff have a healthy attitude towards all matters of diversity, and that the Institute is an equally welcoming and pleasant environment for one and all.

3.6 Supplementary questions by the NWO Executive Board

3.6.1 Generic questions

NWO formulated three additional questions in the Terms of Reference SEP-evaluation.

1. *What is the Institute's added value in the national context and its international position.*

The CWI is unique in bringing together researchers from mathematics and computer science, and creating an excellent research environment that fosters cross-fertilizations between these disciplines. The Institute is as such unique, and not comparable to any other institution in the national context. The Institute is at the forefront of cutting-edge research and has a clear international leading position, exemplified by the history of trailblazing work (CWI connects Europe to Internet, CWI introduces the now remarkably widespread Python software, CWI establishes innovative approaches in quantum cryptography, CWI breaks the SHA-1 internet security standard, among others). A particular aspect of this added value is also the breadth and depth of fundamental research carried out at the CWI.

Due to its unique constellation, CWI is also best placed to take up a natural leading role in important developments and platforms in The Netherlands (and beyond, on European level),

such as the Data Science Platform dealing with large amounts of data in its various aspects (storage, exploration, data analytics, etcetera)..

Given the fast digital evolution, a unique institute as the CWI is destined to become even more important.

> 2. *How does the Institute stimulate and facilitate knowledge utilization in open access?*

The Institute has a very clear policy towards Open Access. For example, only publications that are taken up in the open repository of the Institute are counted for official matters (such as applications for promotion). Concerning software development there is no general policy, also because of the various stages in the development of software (from exploratory stages to sharing software utilization with industrial partners). Nevertheless, the prevailing attitude encourages producing software in an open source environment.

> 3. *How does the Institute's structure, size and financial policy contribute to its mission?*

The CWI is a very agile organization, due to its (reasonable) size and its managerial leadership. The financial policy is tailored to the vision and strategy of the Institute; witness of which are profiles of the recently hired tenure-track researchers, and the installation/reformatting of new groups. As such the Institute is ideally placed to carrying out its mission of conducting high-quality fundamental research in mathematics and computing science with a high relevance to society, with its in particular fast digitalization evolution.

3.6.2 Institute specific questions

NWO also formulated a specific topic:

> *The impact factor of a journal is not a good metric for the impact of a scientific publication, especially during a movement to open access. What other metric(s) can we use to measure the impact of a scientific publication?*

This is indeed an important question in the rapidly changing scientific environment with open access and renewed emphasis on exchange of knowledge. Given the diversity of the scientific output, CWI's contributions to research should be measured on various levels: (i) scientific publications; (ii) output in terms of software development; (iii) impact on fundamental and applied research; (iv) impact on economy and society (see Table 10 in Annex 3).

It is obvious that measuring the impact of this variety of research output of the Institute needs multiple measures. Some examples of possible measures, all related to appreciation by peers, are:

- The impact of a scientific publication can be measured via citations (but this is on the long-run), number of downloads and citations provided at the journal site, plenary and keynote lectures on its results at international conferences, and best paper or presentation awards, among others.
- The impact of software, can be measured by, among others, the number of downloads of the software, the number of times that sources of software serve as a basis input for further software development (worldwide), and invitations at international conferences (with peer-review system) focusing on software development.
- The impact of fundamental and applied research can also be measured indirectly by the international visibility of the members of the Institute, their networks of collaborators, their networks of industrial partners, and their successes in attracting external funding (on national, European and international level). Also a careful

follow-up on the career paths of former PhD students and postdoctoral researchers (in particular their appearance in leading positions in academia, industry or governmental organizations, on national and international level) is a useful performance metric.

- The impact on economy and society, can be measured via joint publications of members of the Institute and members from industry or governmental institutions, via involvement of members in advisory boards, via the impact of outreach activities, etcetera.

4 Conclusions and recommendations

4.1 Conclusions

Based on the self-evaluation report written by the Institute, the additional information provided, and the extensive site visit that took place on October 19 and 20, 2017, the Committee reached to the following conclusions.

- Research conducted at the CWI is of excellent quality, and is highly influential worldwide. The Institute with its members has a clear international leadership in their core research areas, and is comparable to the best in the world. Recently actions have been taken to increase success in ERC grants applications.

- The CWI is unique in the Netherlands due to the proximity and day-to-day interactions between mathematics and computer science. This enables CWI to take a leading role at national, European and even global level in future developments in cutting-edge emerging areas, such as data science and quantum computing.

- Research carried out at CWI is highly relevant to society, and makes an outstanding contribution to the society (on short, middle or longer terms). Increasing the efficiency of activities for a better visibility of the research results and output such as software, coupled with outreach activities, would even further increase the impact (societal, economical, etcetera) of the Institute's high-quality research work. With the recent (2017) establishment (or revitalizing) of the valorization team and communication management team, CWI has clearly taken the right path for improving this visibility.

- The viability of the Institute is/should be ensured given the following: (i) the continued basic financial support from NWO for carrying out top-quality fundamental research; (ii) increased basic funding by NWO to allow the CWI to achieve a strong and timely response to the huge challenges ahead in the rapidly evolving digitalized society; (iii) the established opportunities for valorizing the research output and capitalizing on successes to attract external funds; (iv) the governance skills of the management and the international leadership position, and (v) the specific role in exploiting synergy between mathematics and computer science disciplines.

- The Institute offers a unique and truly excellent research environment to highly-talented young researchers, who are particularly attracted to it because of this unique environment. In addition CWI maintains good practices in advising these promising researchers (PhDs and postdocs) to get the best out of their capacities towards leadership positions in their future professional lives.

- The Institute has a very clear policy towards Open Access, and specific processes to make its researchers aware of matters of scientific integrity and ethics.

- The Institute hosts a group of researchers that is very diverse in terms of nationalities and cultural background. The Institute has a sensible attitude and awareness towards other aspects of diversity.

4.2 Recommendations

During the site visit, the evaluation committee also noticed certain points which deserve some attention to further consolidate and enforce the leading position of the Institute. These are reflected in the following recommendations, either general in nature, or related to specific evaluation criteria/aspects.

Research quality

No specific recommendation with respect to this criterion.

Relevance to society

- The CWI, together with other NWO-institutions, would benefit greatly from an NWO-i platform organization providing support such as legal advice and patenting by highly qualified business personnel.
- We encourage CWI to continue on the path of establishing dynamic outreach activities and good visibility efforts for their research impact. The valorization team and communication team should continue to work together to improve outreach and visibility.

Viability

- Increased NWO basic funding would allow CWI to consolidate their leading role in a rapidly changing technological landscape with its important research challenges.

PhD programmes

- CWI may consider offering standardly to each PhD student the choice between an academic training (typically teaching one semester), an industrial training (typically working one semester in industry), or a research management experience (for instance participation in conference organisation).

Research integrity

- CWI should consider taking advantage of the Netherlands Research Integrity Network (NRIN) and apply for reproducibility grants (of significant pieces of research work) when the opportunity arises. This will help the Institute to establish itself as a leader on this field.
- CWI should take measures towards eventually offering all the data that it produces during research efforts in an Open Access framework, taking the lead in this important aspect of research integrity.

Diversity

- The institute is encouraged to continue with its current policy on diversity but also to seek ways to expand outreach to members of minority-presented groups. Examples of additional ways (with respect to the group of females) include organized visits of female Masters students to the institute, and talks by (influential) women scientists at various stages of their careers.
- The Institute is further encouraged to give female researchers a chance to lead groups, and to further grow into leadership roles at higher levels.

General recommendations

- The Institute may want to intensify its efforts towards encouraging and supporting junior researchers (PhD, postdoc, tenure trackers) in applying for national and international grants, informing about career opportunities and guiding them towards these opportunities.
- Given the size of the Institute, and the flat model of the organization, passage of information between the various layers (management, scientists, staff, and others, may seem to happen automatically, but might not. Awareness of good and efficient communications between the different layers is a point of attention.

Annex 1. Curricula Vitae of Evaluation Committee Members

Chair

Prof. Dr. Irène Gijbels

Irène Gijbels is Full Professor in Statistics, Mathematics Department, KU Leuven, Belgium. She holds a Ph.D. degree in sciences from the Limburgs Universitair Centrum (state commission); was a Visiting Professor at the University of North Carolina, Chapel Hill, USA (Fullbright-Hays scholarship), a Senior Research Assistant at the National Science Foundation, and Professor at the Université catholique de Louvain, Louvain-la-Neuve, Belgium. Since 2004 she is affiliated at the KU Leuven where she runs a research group in mathematical statistics. Her research focusses on statistical inference for semi- and non-parametric methods. She is past Editor of Journal of Nonparametric Statistics and serves/served on the Editorial Boards on several major international scientific journals. She serves/served on various national/international scientific boards/committees: committees of the Institute of Mathematical Statistics, NWO committees (Vici and Spinoza); the Scientific Council of the Fondation Mathématique Jacques Hadamard (France), and Flemish and Walloon Science Foundation committees, among others.

She is past-chair of the Leuven Statistics Research Center and currently chairs the center's research commission. She is a Fellow of the Institute of Mathematical Statistics and of the American Statistical Association, and an elected member of the International Statistical Institute. She is a member of the Belgian Royal Academy of Sciences.

Members

Ing. F.M. (Fred) Boekhorst

Before retirement (1/2/2017), Fred Boekhorst served as Senior Vice President of Philips Research, responsible for the world-wide innovation program for Personal Health as well as the world-wide innovation program for Intellectual Property and Standards. Throughout the years, Mr. Boekhorst has held numerous management positions in R&D, spanning the entire innovation chain from early research until market introductions of new products. He acquired international experience at Philips through postings in New York and Shanghai.

Next to his role at Philips, he served in many committees that foster cooperation in between knowledge institutes and Industry.

Currently, he is Board member of EIT Digital as well as chairman of the EIT Digital co-location in the Netherlands, in that role responsible for overseeing the Strategy and execution of the overall EIT Digital program Europe-wide.

Prof. Y. (Yannis) Ioannidis

Yannis Ioannidis (PhD, UC Berkeley – MSc, Harvard University – Diploma, National Technical University of Athens) is the President and General Director of the "Athena" Research and Innovation Center in Athens, Greece, as well as a Professor at the Department of Informatics and Telecommunications of the University of Athens. His research interests include Database and Information Systems, Data and Text Analytics, Personalization and Social Networks, Data Science, and Data Infrastructures and Digital Repositories, topics on which he has published over 150 articles in leading journals and conferences and also holds three patents. His work is often motivated by data management problems that arise in industrial environments or in the context of other scientific fields (Life Sciences, Cultural Heritage, Biodiversity, Physical Sciences). He is an ACM and IEEE Fellow, a member of Academia Europaea, and a recipient of several research and teaching awards. He has also served as the Chair of ACM SIGMOD. He is the Greek delegate to the European Strategy Forum on Research Infrastructures (ESFRI), a member of the ESFRI Executive Board, and the ESFRI representative to the e-Infrastructures Reflection Group (e-IRG).

Prof. H. (Hélène) Kirchner

Hélène Kirchner obtained her PhD in Computer Science in 1982 and her Habilitation (These d'Etat) in 1985. She entered CNRS in 1982 and became Research Director in 1995. After leading the Protheo project from 1997 to 2000, she took the Direction of the joint laboratory LORIA and of the INRIA Lorraine research center(2001-2007). From 2007 to 2010, she was on secondment at INRIA as Deputy Scientific Director. From September 2010 to 2015, she was Inria Scientific Director of the International Affairs Department. In 2012, she was selected as Grand Professor in the TU Dresden Cluster of Excellence CfAED - Center for Advancing Electronics Dresden.

Currently she is Scientific Affairs Officer at Direction of European and International Partnerships of Inria. She is also Board member of Hceres, the French authority in charge of evaluation of research and higher education.

Her research is concerned with the design and development of safe software: formal specifications, logic and automated deduction, program verification, with a special emphasis on deduction and computation by rewriting and strategies. Since 2005, she applies these techniques to the design and verification of security policies, bio-chemical processes and social networks.

Prof. K. (Klara) Nahrstedt

Klara Nahrstedt is the Ralph and Catherine Fisher Full Professor in Computer Science Department, and the Director of Coordinated Science Laboratory at University of Illinois, Urbana-Champaign. She is the recipient of the Early NSF Career Award in 1996, the Junior Xerox Award in 1998, IEEE Communication Society Leonard Abraham Award for Research Achievements in 2000, the University Scholar Award in 2008, the Humboldt Research Award in 2009, IEEE Computer Society Technical Achievement Award in 2012, and ACM SIG Multimedia Outstanding Technical Achievement Award in 2014. She was the editor-in-chief of the ACM/Springer Multimedia Systems Journal (2000-2007) and associate editor of various other journals. She was elected to serve as the chair of the ACM SIG Multimedia (2007-2013), and selected as a member of the Computing Research Associations' Computing Community Consortium (CCC) (2014-2017).

Klara Nahrstedt received her Diploma in Mathematics with specialization in Numerical Analysis from Humboldt University, Berlin, in 1985. She was a research scientist in the Institute for Informatik in Berlin until 1990. In 1995 she received her PhD from the University of Pennsylvania in the Department of Computer and Information Science. She is the ACM Fellow, IEEE Fellow, and the Member of Leopoldina German National Academy of Sciences.

Prof. dr. A.C. (Andrew) Yao

Andrew Chi-Chih Yao is a Chinese computer scientist and winner of the 2000 A.M. Turing Award, the highest honour in computer science, for his "fundamental contributions to the theory of computation, including the complexity-based theory of pseudorandom number generation, cryptography, and communication complexity." In addition to the fields cited above in the Turing Award, which have important applications in distributed computing, Yao contributed fundamental research in the analysis of algorithms, algorithmic game theory, and quantum computing.

Yao received a bachelor's degree (1967) in physics from the National Taiwan University, a doctorate (1972) in physics from Harvard University, and a doctorate (1975) in computer science from the University of Illinois.

Yao was elected to the U.S. National Academy of Sciences (1998), the American Academy of Arts and Sciences (2000), Academia Sinica (2000), and the Chinese Academy of Sciences (2004). In addition to the Turing Award, Yao received the SIAM George Pólya Prize (1987), the ACM Donald E. Knuth Prize (1996), and honorary doctoral degrees from the University of Waterloo, University of Macau among others.

Yao is currently Dean of Institute for Interdisciplinary Information Sciences at Tsinghua University, and is also a Distinguished Professor-at-Large at the Chinese University of Hong Kong.

Prof. I. (Irad) Yavneh

Irad Yavneh received his B.Sc. degree (Summa Cum Laude) in Aeronautical Engineering from the Technion in 1984, and his Ph.D. degree in Applied Mathematics from the Weizmann Institute of Science in 1991. He is a Professor at the Faculty of Computer Science, Technion, and is serving as Dean of the Faculty since 2013. His research interests include multiscale computational techniques, scientific computing and computational physics, image processing and analysis, and geophysical fluid dynamics. He currently serves on the editorial boards of SIAM Journal on Scientific Computing and of Numerical Linear Algebra and Applications, and on the program committees of the Copper Mountain Conferences on Multigrid Methods and on Iterative Methods.

Annex 2. Programme of the Site Visit 18-20 October 2017

18 October - day before the site visit

Committee arrives in the Netherlands, at Hampshire Amsterdam Manor Hotel.

- Committee meeting at 15:00 – 18:00. Topics: formal installation of the Committee by a member of the NWO Executive Board; presentation about NWO, the NWO 'transition' and the governance; short presentations about the Dutch science system, and about key notions in the Standard Evaluation Protocol.
- Dinner and private Committee kick off meeting: to discuss the assessment procedure, the Terms of Reference, and the procedure of writing the assessment report; to share information about the disciplinary expertise represented in the Committee; to discuss findings based on the material received prior to the site visit such as the self-assessment report; to prepare for tasks during the site visit.

19 October - 1st day site visit

08:30 – 09:00	Transport from the hotel to the institute
09:00 – 09:20	Welcome at the institute by Peter van Laarhoven en Jos Baeten
09:20 – 10:00	Interview with the directorate (Jos Baeten, Dick Broekhuis) and representatives of the board of the institute (Peter van Laarhoven, Anton Franken)
10:00 – 10:25	Scientific presentation 1*: *Computational Science,* Ute Ebert & Daan Crommelin
10:25 – 10:40	*Coffee break*
10:40 – 11:10	Tour of the premises (including FleXray Lab, Joost Batenburg)
11:10 – 11:35	Scientific presentation 2: *Data Science & Technology,* Martin Kersten & Peter Boncz
11:35 – 12:00	Scientific presentation 3: *Software*, Paul Klint & Jurgen Vinju
12:00 – 12:25	Scientific presentation 4: *Networks,* Lex Schrijver & Bert Zwart
12:25 – 13:25	*Lunch*
13:25 – 13:50	Scientific presentation 5: *Quantum Computing,* Harry Buhrman & Stacey Jeffery
13:50 – 14:15	Scientific presentation 6: *Crypto and Blockchain,* Ronald Cramer & Marc Stevens [Committee moves to next, larger, room]
14:15 – 14:40	Interview session with 14 PhD students
14:40 - 15:05	Interview session with 11 postdocs
15:05 – 16:00	Interview session with 14 tenured and non-tenured scientific staff
16:00 – 16:15	*Coffee break*
16:15 – 17:00	Interview session with the management team (Jos Baeten, Dick Broekhuis, Han La Poutré, Monique Laurent, Lynda Hardman)
17:00 – 17:10	Interview with Paul Vitányi, CWI Fellow
17:10 – 17:40	Transport from CWI to hotel
18:30	Transport (or walk) to dinner location
19:00 –	Closed session Committee
	*During the 'scientific presentations' Jos Baeten will be present as well.

20 October - 2nd day site visit

07:30 – 08:30   Closed breakfast session with Committee

08:30 - 09:00   Transport from the hotel to the institute; photo moment

09:00 – 10:00   Interview session with management and support staff (focus on institute's diversity, integrity policy, Open Access policy, PhD programme) (Angelique Schilder, Lieke Schultze, Ans Hekkenberg, Dick Broekhuis, Jos Baeten)

10:00 – 10:15   Coffee break

10:15 – 11:00   Interview session with the Valorization Team (Rob van der Mei, Peter Boncz, Eric Pauwels, Karin Blankers, Dick Broekhuis, Jos Baeten)

11:00 – 11:30   Closed session Committee

11:30 – 12:30   Interview with directorate and management, additional questions (Han La Poutré, Monique Laurent, Lynda Hardman, Jos Baeten, Dick Broekhuis)

12:30 – 13:15   Lunch (perhaps with directorate and management team)

13:15 – 16:45   Closed session Committee, to discuss the findings and related arguments, to arrive at a provisional judgement with respect to the three evaluation criteria (research quality, relevance to society, viability), and also to reflect on three other important aspects (PhD programmes, research integrity, diversity), as well as to provide recommendations for improvement if applicable. Tea and snacks provided at around 15:30)

16:45 – 17:00   Provisional evaluation outcomes shared and explained to director, management team, chairman of the institute's Board, and a representative of the NWO Executive Board.

17:00 – 17:15   Short presentation of the provisional evaluation outcomes to the CWI community, and end of the site visit.

17:15   In an informal setting, CWI offers drinks to the Committee and the institute community.

Annex 3. Quantitative data composition and financing

Table 1. Funding, absolute (k€) and relative (%) numbers, 2011-2016

CWI	Year 5 (2011)	Year 4 (2012)	Year 3 (2013)	Year 2 (2014)	Year 1 (2015)	Current (2016)
Funding (k€):						
Direct funding[6]	10,814 *60%*	10,764 *59%*	10,474 *59%*	10,212 *60%*	10,250 *60%*	11,063 *60%*
Research grants[7]	3,510 *19%*	3,609 *20%*	3,616 *20%*	3,080 *18%*	3,981 *23%*	3,956 *21%*
Contract research[8]	3,217 *18%*	3,545 *19%*	3,294 *19%*	3,609 *21%*	2,752 *16%*	3,426 *18%*
Other	562 *3%*	476 *3%*	291 *2%*	108 *1%*	172 *1%*	117 *1%*
Total funding	**18,103**	**18,394**	**17,675**	**17,009**	**17,155**	**18,562**
Expenditure (k€):						
Personnel costs	14,460 *83%*	14,508 *81%*	14,127 *85%*	13,463 *85%*	14,004 *86%*	15,307 *85%*
Other costs	2,945 *17%*	3,319 *19%*	2,480 *15%*	2,360 *15%*	2,215 *14%*	2,679 *15%*
Total expenditure	**17,405**	**17,827**	**16,535**	**15,823**	**16,219**	**17,986**

Table 2. Funding (FTE), absolute (k€) and relative (%) numbers, per type of funding, 2011-2016

CWI	Year 5 (2011)	Year 4 (2012)	Year 3 (2013)	Year 2 (2014)	Year 1 (2015)	Current (2016)
Direct funding	57.3 *42%*	52.7 *36%*	57.3 *38%*	53.8 *37%*	51.8 *34%*	51.9 *32%*
Research grants	58.9 *43%*	67.5 *46%*	67.4 *45%*	60.4 *41%*	64.4 *43%*	73.9 *46%*
Contract research	21.4 *15%*	25.9 *18%*	26.1 *17%*	31.5 *22%*	33.8 *23%*	35.7 *22%*
Other	n/a	n/a	n/a	n/a	n/a	n/a
Total funding	**137.60**	**146.10**	**150.80**	**145.70**	**150.00**	**161.50**

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[6] Direct funding (basic funding / lump sum budget).

[7] Research grants obtained in national scientific competition.

[8] Research contracts for specific research projects obtained from external organizations, such as industry, government ministries and the European Commission. Please note that in section 3b, 'contract work' is defined in a less encompassing way (i.e. only project funded by industry, excluding PPPs).

Table 3. Overview research staff, by type, 2011-2016

CWI (in fte)	Year 5 (2011)	Year 4 (2012)	Year 3 (2013)	Year 2 (2014)	Year 1 (2015)	Current (2016)
Scientific staff	48.0	47.5	47.3	48.1	49.3	48.9
Postdocs	30.6	23.3	24.7	19.7	22.2	32.3
Scientific programmers	7.6	8.6	9.8	10.9	12.4	12.6
PhD students	51.4	66.8	69.2	67.2	66.1	67.8
Total research staff	**137.6**	**146.2**	**151.0**	**145.9**	**150.0**	**161,6**
Support staff	43.4	41.6	38.2	37.2	36.7	36.7
Visiting fellows	5.5	6.0	6.7	6.4	6.2	6.4
Total staff	**186.5**	**193.8**	**195.9**	**189.5**	**192.9**	**204.7**

Table 4. Overview research output, by type of publication, 2011-2016

CWI	Year 5 (2011)	Year 4 (2012)	Year 3 (2013)	Year 2 (2014)	Year 1 (2015)	Current (2016)
Research quality						
Refereed articles	161	159	127	121	153	167
Non-refereed articles	3	3	1	0	3	0
Books	3	6	0	2	3	3
Book chapters	17	16	9	11	8	17
PhD theses	11	7	9	15	13	13
Conference papers	151	159	140	125	138	100
Relevance to society						
Professional publications	11	16	9	13	6	26
Publications aimed at the general public	0	0	2	1	0	0
Standards	4	4	5	12	22	17
Other	250	272	285	323	259	319
Total publications	**597**	**629**	**574**	**609**	**582**	**645**

Table 5. Overview NWO VI/TOP and ERC grants received (selection), 2011-2016

CWI (in fte)	Year 5 (2011)	Year 4 (2012)	Year 3 (2013)	Year 2 (2014)	Year 1 (2015)	Current (2016)
VENI	1	2		5	2	2
VIDI		1	1			
VICI	1				1	1
TOP M1			2			1
ERC StG	1					
ERC CoG			1			
ERC AdG				1		

Table 6. CWI Research staff with top h-indices, ranked according to (decreasing) h-indices (columns 1 and 4). Columns 3 and 6 provide the ratio h-index/scientific age (with scientific age = number of years since PhD). Anonymized table.

CWI Research Staff general scientific age-range of cohort: 17-40			Up-and-coming CWI researchers top h-indices since 2012 scientific age-range of cohort: 13-31		
rank	h-index	ratio h-index/scientific age[9]	rank	h-index	ratio h-index/scientific age
1	57	1.43	1.5	29	2.71
2	54	1.38	1.5	29	1.82
3	47	1.12	3	27	1.48
5	46	1.48	4	25	2.8
5	46	1.28	5	24	1.56
5	46	1.21	7.5	23	1.93
7	42	1.56	7.5	23	1.93
8.5	40	1.82	7.5	23	1.52
8.5	40	2.35	7.5	23	1.7
10	39	1.7	10	21	1.85

Table 7. Top 20 CWI researchers with the highest h-index/scientific age ratio, and ranked according to this ratio. Scientific age-range of cohort: 4-17. Anonymized table.

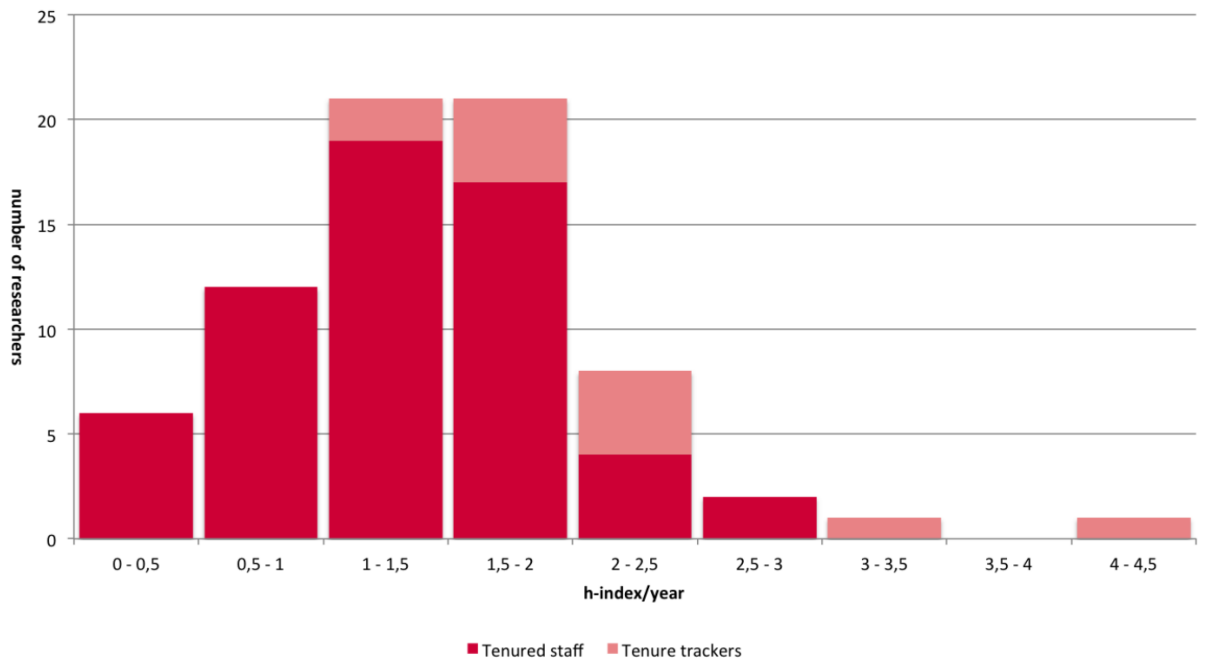| rank	h-index	ratio h-index/scientific age
1	25	4.17
2	13	3.25
3	28	2.80
4	38	2.71
5	10	2.50
6	40	2.35
7	21	2.33
8.5	9	2.25
8.5	18	2.25
10	20	2.22
11	28	2.15
12	33	2.06
14.5	22	2.00
14.5	30	2.00
14.5	10	2.00
14.5	8	2.00
17.5	29	1.93
17.5	27	1.93
19.5	28	1.87
19.5	28	1.87

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[9] Scientific age = number of years since PhD.

Figure 4. Distribution of ratio h-index/scientific age of all CWI-researchers

Table 8. A sample of top researchers (non-CWI) in the Netherlands in our field, i.e. Royal Academy Members, ranked according to the ratio h-index/scientific age. Scientific age-range of cohort: 19-45. Anonymized table.

Researcher	h-index	ratio h-index/scientific age
Researcher 1	135	5.63
Researcher 2	68	3.58
Researcher 3	65	2.83
Researcher 4	67	2.48
Researcher 5	35	1.84
Researcher 6	45	1.73
Researcher 7	75	1.67
Researcher 8	38	1.23
Researcher 9	49	1.23
Researcher 10	34	1.10
Researcher 11	33	0.79
Researcher 12	34	0.76

Table 9. Members of the Young Academy and Winners of the Dutch ICT prize (non-CWI), ranked according to the ratio h-index/scientific age. Scientific age-range of cohort: 4-15. Anonymized table.

Member Young Academy or ICT Prize winner	h-index	ratio h-index/scientific age
Researcher 1	35	5.00
Researcher 2	23	4.60
Researcher 3	16	4.00
Researcher 4	42	3.82
Researcher 5	22	2.20
Researcher 6	27	2.08
Researcher 7	21	1.91
Researcher 8	24	1.60

Table 10. overview of output indicators relevant to CWI: research quality and relevance to society

RESEARCH QUALITY	RELEVANCE TO SOCIETY
Demonstrable products	
Research products for peers	*Research products for societal target groups*
888 refereed research articles	81 professional publications
17 books	65 national newspaper features
78 book chapters	15 national TV appearances
68 PhD theses	33 national radio appearances
813 conference papers	at least 5 features in prominent international media, e.g. the New York Times and WIRED
19 software tools	233 press releases
64 web and multimedia standards	at least 2 national and 1 European policy reports
	45 software tools
	2 exhibitions
	1 popular history of science book
	3 industry outreach events
	6 Open Science Days
	6 lectures at the 'Universiteit van Nederland' (over 103,000 views)
	over 70 lectures for a broad audience
	more than 10 lectures for professional audiences
Demonstrable use of products	
Use of research products by peers	*Use of research products by societal target groups*
15 publications with citation count >100	271 co-publications with non-academic partners
Software products (selection):	25 strategic cooperations in PPPs
MonetDB: 500,000 downloads	35 strategic cooperations through contract work
Rascal: estimated user base of 1,000	3 spin-off companies
Counter-Cryptanalysis: over 6,000 downloads	
Demonstrable marks of recognition	
Marks of recognition from peers	*Marks of recognition by societal target groups*
over 80 science awards/scholarly prizes	around 10 public prizes
over 600 lectures	12 PhD students funded by industrial partners
12 NWO Veni grants	4 M€ funding by industry for PPPs (started in 2014) and other contracts
2 NWO Vidi grants	membership of 1 ethical committee (information sciences)
3 NWO Vici grants	
1 ERC Consolidator Grant	
1 ERC Advanced Grant	
24 European FP7 projects	
5 European Horizon2020 projects	
3 tenure track positions through the Dutch Mathematics clusters	
3 NWO Top Module 1 Grants	
1 WISE tenure track position	

Table 11. Number and success rates of PhD candidates

Enrolment (base year: 2016)			Success rates, graduated ...					
Starting year	Enrolment (male/female)		Total (M+F)	<= Y4	<=Y5	<=Y6	<=Y7	Not yet finished	Discon-tinued
T-8	9	5	14	7 50.0%	2 14.3%	0 0.0%	1 7.1%	3 21.5%	1 7.1%
T-7	14	5	19	11 57.9%	3 15.8%	1 5.2%	0 0.0%	3 15.8%	1 5.3%
T-6	15	2	17	8 47.0%	3 17.6%	2 11.8%		2 11.8%	2 11.8%
T-5	16	5	21	7 33.3%	6 28.6%			6 28.6%	2 9.5%
T-4	14	8	22	7 31.8%				10 45.5%	5 22.7%
Total	**68**	**25**	**93**	**40** **43.0%**	**14** **15.1%**	**3** **3.2%**	**1** **1.1%**	**24** **25.8%**	**11** **11.8%**
				58 **62.4%**					

The finishing date used in this evaluation is the date of the student's PhD defences, which is often several months after the actual completion of the thesis.

Please note, of the ten PhD students who started in 2012 (T-4) who have not yet finished their doctorate degree, six will almost certainly finish their degree in 2017.

Table 12. Overview of Public-Private Partnerships, 2011-2016

Research group	Industry partner	Period	Description
N&O/ST	Rovecom/ Lanting Reizen	2015 - 2017	Route planning and scheduling
ST/N&O	CTVrede	2016 - 2019	Optimization container planning
ST	Trinité automation	2014 - 2017	Traffic flow optimization
ST/SWAT	ING	2014 - 2018	Software quality analysis(performance and robustness)
ST	Gemeente Amsterdam	2016	City logistics and Mobility
ST/IAS	Engie (former Cofely)	2016 - 2017	Modelling and optimizing production processes (smart industry)
ST/DA	BZK	2016 - 2020	Big data analytics
SC	KEMA	2015	Intelligent Energy Networks
SC	Exxon Mobile	2014 - 2016	3D imaging nanomaterials
FM	SDL Fredhopper	2014 - 2016	Monitoring techniques for cloud applications
DIS	Xinhuanet	2015 -2016	User experience lab; sensor technology
DIS	ByBorre	2016	Wearable sensors for data driven experience
DA	AAA	2016 - 2020	Real time financial data analytics
CR	NXP	2016 - 2017	Future cryptographic standards
MD	ABB	2016 -2017	Multiscale modelling of discharge growth
LS	SysBioSym	2016 -2017	Multiscale biosystems modelling

List of CWI's spin-offs (as of 1 October 2017)

Throughout the years, CWI has spun off the following start-up companies and initiatives. The next table only contains the companies that are still existing. Next to the logo, the founding year and the area of business has been provided. Furthermore, it is mentioned from what area of work in the institute the company has been incubated. Spin-offs that were launched in the evaluation period, are highlighted.

swat•engineering Software engineering, 2017, existing (SWAT group)	seita energy flexibility Energy consultancy, 2016, existing (IAS group)	Stokhos emergency mathematics Emergency math, 2015, existing (ST group)	monetdb solutions Database consultancy, 2013, existing (DA group)	spinque Knowledge retrieval, 2010, existing (IA group)
monetdb Open source DB, 2008, existing (DA group))	SAFIRO Software design, 2007, existing (N&O group)	personal space technologies 3D environments, 2005, existing (CI group)	adaptive planet Software composition, 2002, existing (FM group)	SIG Software consulting, 2000, existing (SWAT group)
SIDN .nl top level domain, 1996, existing (IT depart- ment)	Can Math software vendor, 1995, existing (IT department	NLnet Internetprovider, 1989, existing (IT department)	sara Dutch supercomputer, 1971, existing (IT depart- ment)	

Annex 4. Explanation of the SEP-categories

The committee assesses the institute on the three assessment criteria: research quality, relevance to society and viability. These criteria are assessed both in qualitative terms (with arguments) and quantitative terms (in one of the four categories, see the table below).

Table 13. Meaning of categories in SEP 2015-2021

Category	Meaning	Research quality	Relevance to society	Viability
1	World leading / excellent	The institute has been shown to be one of the few most influential research groups in the world in its particular field.	The institute makes an outstanding contribution to society.	The institute is excellently equipped for the future.
2	Very good	The institute conducts very good, internationally recognised research.	The institute makes a very good contribution to society.	The institute is very well equipped for the future.
3	Good	The institute conducts good research.	The institute makes a good contribution to society.	The institute makes responsible strategic decisions and is therefore well equipped for the future.
4	Unsatisfactory	The institute does not achieve satisfactory results in its field.	The institute does not make a satisfactory contribution to society	The institute is not adequately equipped for the future.

In addition to the three criteria, every assessment also considers at least three further aspects: PhD programmes, research integrity, and diversity. These aspects are only assessed in qualitative terms.

Annex 5. Terms of Reference

The board of The Netherlands Organisation for Scientific Research (NWO) hereby issues the following Terms of Reference to the assessment committee of CWI, chaired by Prof.dr. Irène Gijbels.

Topic	Description
Title	External evaluation of CWI of the period 2011 – 2016
Why	NWO organizes periodic evaluations of each research institute within the organisation every six years. This is part of the standing agreement with the Ministry of Education, Culture and Science. Together with the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Association of Universities in the Netherlands (VSNU), NWO has stated to conduct these evaluations according to the Standard Evaluation Protocol (SEP). The goal of the periodic assessments is primarily to identify the quality of the research and the societal relevance and secondly to - partly on the basis of the assessment results - determine the mission and the basic funding for the next six years (2018-2023).
What	The assessment committee evaluates the quality and the relevance to society of the research conducted by the institute, as well as its strategic targets and the extent to which it is equipped to achieve them. The committee does this by judging the institute's performance on the three SEP assessment criteria, taking into account current international trends and developments in science and society in the analysis. Each criterion should receive a ranking in one of the four categories in accordance with the SEP guidelines. The committee also ensures that the qualitative assessment (text) and the quantitative assessment correspond. Furthermore, the committee should give recommendations for improvement. **The three SEP assessment criteria are**: - **Research quality** - **Relevance to society** - **Viability.** The assessment committee also gives a qualitative evaluation on three **additional aspects**: - **PhD programmes** - **Research Integrity** - **Diversity** Further information about the criteria and additional aspects can be found in chapter 2 of the Standard Evaluation Protocol (SEP). **In addition to the topics above NWO has formulated three questions**: 5. What is the institute's added value in the national context and its international position? 6. How does the institute stimulate and facilitate knowledge utilization and open access? 7. How does the institute's structure, size and financial policy contribute to its mission? **For this particular institute NWO has also formulated the following specific topic**:

	- The impact factor of a journal is not a good metric for the impact of a scientific publication, especially not during a movement to open access. What other metric(s) can we use to measure the impact of a scientific publication?
For whom	- The researchers themselves in order to establish where they stand, how they can improve and what the research should aim for. - The management of the institute who wishes to track the impact of their policy. - The board of NWO who decides on the accountability of the institute and the support for the institute. - Other stakeholders from, for example, the society and private sector. - The Ministry of Education, Culture and Science has requested a portfolio analysis of all the research institutes of NWO and the Royal Netherlands Academy of Arts and Sciences in 2018. The results of the SEP-evaluations will act as input for this portfolio analysis.
Who	The independent assessment committee consists of 4-7 renowned international experts within the realm of the institute. Each committee member signs a statement of impartiality and confidentiality.
How	The assessment committee will be supported by a liaison officer from NWO and an independent secretary. The necessary documentation to conduct the assessment will be made available to the committee one or two months before the site visit. This documentation includes at least a self-evaluation by the institute, a strategy document of the institute and the conclusions and recommendations from the previous assessment. If feasible the institute may provide a bibliometric analysis or a different study of its own choice to support the self-evaluation. The assessment committee will be invited to the institute for a site visit of two days during which the institute will present itself in short lectures and interviews by the committee. The assessment committee will deliver a draft evaluation report to the NWO board no later than eight weeks after the site visit and a final version no later than 12 weeks after the site visit. Finally, the NWO board will publish the assessment report on the website accompanied by a public statement.
When	The site visit will take place in September or October 2017. NWO distributes the necessary information and documents to the committee 1 or 2 months in advance of the site visit. For further information on the general time schedule please refer to the attached Standard Evaluation Protocol.
Contact	Robbin te Velde, MA (Dialogic) and Margreet Bouma, MA (NWO)

Necessary documents that will be made available to the assessment committee:

- Self-evaluation 2011-2016 including
- Strategy document 2018-2022 (N.B.: in the CWI Self-evaluation report)
- Further description of what the committee needs to know about the scope/context, assessment questions, method, time schedule, final report
- Programme of the site visit
- Standard Evaluation Protocol (SEP)
- Conclusions and recommendations from previous evaluation
- Response NWO to the previous evaluation report
- <optional> Bibliometric analysis (N.B.: CWI decided not to have such analysis.)