Evaluation 2011-2016

AMOLF

Physics of Functional Complex Matter

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NWO Netherlands Organisation for Scientific Research
dialogic innovatie • interactie
Birch

Content

1 Introduction

1.1 Scope and context of this review

This evaluation concerns the research carried out at the NWO Institute AMOLF since 2011. 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, AMOLF submitted a self-assessment document covering the period 2011-2016 and a strategic plan for 2017-2022. This report was approved by the NWO Executive Board on the 5th of July 2017. The self-assessment report and addendum included a SWOT analysis and a full set of statistics at institute level concerning input (finances, funding and staff) and output (refereed articles, books, PhD theses, conference papers, publications aimed at the general public, and other output) for the six years prior to the evaluation. A number of tables were included about research staff, main categories of research output, funding, and PhD candidates (see SEP appendix D, D3). The self-assessment report therefore offered a concise picture of the institute 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, the programme coordinators, other levels of staff, and a tour of the laboratories and facilities.

1.2 The Evaluation Committee

The Evaluation Committee was appointed on 18 October 2017 by the NWO Executive Board. Its members were:

Prof. Søren Keiding	Aarhus University, Denmark (chair)
Prof. Ted Sargent	University of Toronto, Canada
Prof. Romain Quidant	Institute for Photonic Sciences (ICFO), Barcelona, Spain
Prof. Heinrich Jaeger	University of Chicago, USA
Prof. Martin Howard	John Innes Centre, Norwich, UK
Prof. Berenike Maier	University of Cologne, Germany
Prof. Aart Kleijn	Center of Interface Dynamics for Sustainability, China

A short curriculum vitae of each of the members is included in Annex 1. The Committee was supported by NWO (Peter Spijker) and Birch Consultants (Maaike Romijn).

Before the site visit all members of the Committee signed the NWO Code of Conduct, 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. The Committee concluded in the meeting on 18 October 2017 that the Committee had no conflicts of interest.

1.3 Data supplied to the Committee

Four weeks prior to the site visit the Committee received the self-assessment report of AMOLF together with the AMOLF Strategic Plan 2017-2022, 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.

During the site visit the Committee received further documentation about the professorship affiliations of the current group leaders at Dutch universities and the organisational embedding of research themes and subthemes as specified in the self-assessment and strategic plan.

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 AMOLF self-assessment report and the other documentation provided by NWO, the institute, and the interviews.

The interviews took place during the site visit from 19 October 2017 till 20 October 2017. The programme of the visit is included in Annex 2.

The Committee was installed on 18 October 2017 by prof. Stan Gielen, President of the NWO Executive Board. Prof. Stan Gielen gave a short presentation on (the transition of) NWO and the governance structure of the NWO research institutes. Maaike Romijn gave a brief overview of the Dutch science policy and the organisation of scientific research in the Netherlands. Afterwards the committee met in closed session to finalise the division of tasks and the agenda for the site visit on day two and three.

The Committee agreed on procedural matters and aspects of the assessment as described in the following paragraphs.

The interviews with the AMOLF Management Team, Institute Advisory Committee, stakeholders, group leaders, PhD students, postdocs and support staff took place during the site visit on 19 and 20 October 2017. The entire Committee conducted all interviews.

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

At the end of the site visit, the chair reported the committees' main conclusions and recommendations to the AMOLF director, management team, group leaders, heads of support and a member of the NWO Executive Board (prof. Niek Lopes Cardozo).

On 10 January 2018 a draft version of this report was sent to the AMOLF 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 their 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 assessment was given in qualitative form, accompanied by a quantitative figure. The scale is as follows: 1. World leading/excellent; 2. Very good; 3. Good; 4. Unsatisfactory (see Annex 3).

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 (instead of using the four-category scale).

In addition to the topics above NWO formulated three supplementary questions for all NWO institutes:

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

2 Institutional framework of AMOLF

2.1 Mission

The mission statement of AMOLF is: *To initiate and perform leading fundamental research on the physics of complex forms of matter, and to create new functional materials, in partnership with academia and industry.*

2.2 Research

The strategy of AMOLF for the period 2011-2016, was to organise its research into two themes of research: Nanophotonics and Biophysics. The Biophysics theme was to be organised in two programmes: Systems Biophysics and Molecular Biophysics.

During the last strategic period, the focus of the Nanophotonics theme shifted from spatio-temporal control of light at extreme scales to hybrid nanophotonics. In 2012, AMOLF started a focus group "Light Management in Photovoltaics" within the Nanophotonics theme, on the enhancement of photovoltaic efficiencies through the simultaneous control of light and charges in nanostructured materials. This theme combines the strength of AMOLF in nanophotonics with new expertise in the chemistry and physics of organic and inorganic nanomaterials. The focus group has quickly grown with the hiring of three tenure-track group leaders and has now matured to the full research theme Nanophotovoltaics.

Within the Biophysics theme, the Molecular Biophysics programme came to an end in 2015. The Systems Biophysics programme of AMOLF has increasingly shifted its focus from the understanding of the molecular basis of cellular functions to the reconstruction of cellular functions from molecular components, and the physics of multicellular systems. As a consequence, the Systems Biophysics programme has now developed into the research theme Living Matter.

A fourth research theme, *Designer Matter*, focusing on the physics and design of smart materials possessing emergent properties that derive from their architecture, started in 2014 with a group working on mechanical metamaterials. Since then this theme has expanded with two tenure-track hires and now encompasses soft robotics and hierarchical self-assembly as well.

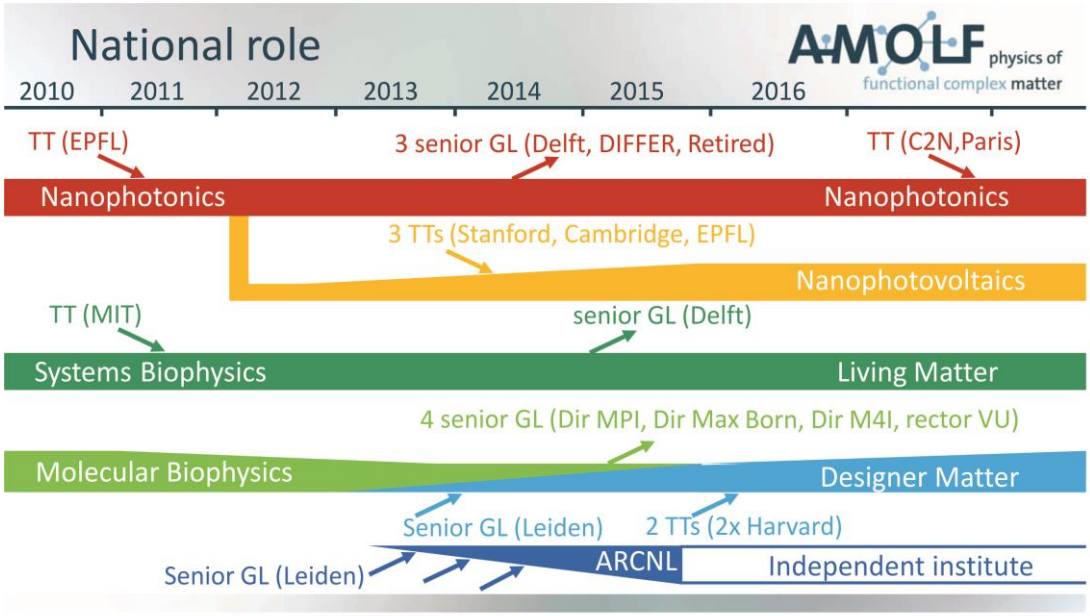

Figure 1. Evolution of the research themes of AMOLF over the last 7 years, also indicating the group leaders leaving and starting (TT=tenure-track group leader, GL = group leader).

2.3 Organisational structure

AMOLF has a flat organisation with short communication lines. The institute has 17 research groups with 5-10 scientists (PhD students, postdocs, undergraduate students and guests) per group. Each group is led by a group leader, who has overall responsibility for the functioning of his/her group and reports to the director. The research groups are currently organised within four research themes described above. The technical and general support divisions of the institute (which also support ARCNL) are organised in small groups that are managed by the institute manager, who also reports to the director.

The director receives external advice from the Institute Advisory Committee (IAC). The IAC comprises seven leading persons from academic institutions and industry. The IAC advises the director of AMOLF on strategy and long-term policy. The IAC also advises on intended tenure decisions of scientific group leaders.

The Advanced Research Center for Nanolithography (ARCNL) was initiated in 2013 as a public private collaboration between AMOLF and ASML with participation of the Amsterdam universities and the city of Amsterdam. ARCNL is a joint industrial-academic collaboration focusing on the fundamental physics underlying extreme ultraviolet (EUV) lithography. In 2015, it became an independent research institute outside AMOLF. ARCNL is reviewed separately and not part of the AMOLF SEP evaluation

2.4 Financial matters

The NWO mission budget of around M€8 a year (direct funding) covers most of the salaries of scientific group leaders, group working budgets, start-up packages of new tenure-track group leaders, and most of the indirect and overhead costs, i.e. the technical and administrative support, the acquisition and maintenance of part of the technical and scientific infrastructure, and the exploitation of the building. The running and investments costs of

nearly all research projects and approximately 90% of the junior scientists (PhD students and postdocs) are paid from external grants obtained in competition. The share of this external funding obtained in competition has been quite steady at approximately 50% of the total funding.

The total budget of AMOLF was M€ 18.455 in 2016. In 2016, the mission budget was M€ 7.911, research funding obtained from NWO and FOM M€ 4.999, research funding obtained from other sources (e.g. EU grants such as ERC and FET Open, companies, universities, government ministries) M€ 4.312 and other income M€ 1.233.

Over the last strategic period, the share of external funding granted by the foundation for Fundamental Research on Matter (FOM) declined from 48% to 33%, largely reflecting the increasing constraints in national funding schemes. Also the funding by government ministries showed a decrease from 12% to 4%, as the NanoNextNL programme, funded by the ministry of Economic Affairs, came to an end in 2016. Over the years, the share of funding granted by the EU, mainly consisting of ERC grants, notably increased from 9% to 31%.

2.5 Staff

AMOLF employs a scientific staff of about 110 FTE. Over the last five years, the total number of employees at AMOLF increased, mainly due to an increase in undergraduate students and in support staff (related to the support of ARCNL). The number of research groups remained steady at 16-18. Each of these research groups is composed of PhD students, post docs, undergraduate students, guests, and one leading staff member (typically 5-10 group members). In 2016 the scientific groups were led by 9 group leaders with a permanent position and 8 tenure track group leaders who are appointed at AMOLF. After four years, tenure-track group leaders are evaluated and can be offered tenure.

The support staff consists of technical and general support staff. The technical staff is comprised of technicians who are embedded in the research groups, and in the divisions for mechanical engineering, precision manufacturing, electronic engineering, software engineering and the staff of the AMOLF NanoLab cleanroom. The total technical support staff is nearly 36 FTE. Administrative support and general facility management is provided by another 29 FTE. The total number of technical staff has remained steady over the past few years. Since 2014, AMOLF has also provided the administrative and technical support for the neighboring institute ARCNL. ARCNL involves an additional 16,2FTE support staff at AMOLF, which is fully integrated in the AMOLF staff but dedicated to ARCNL.

3 Assessment of AMOLF

3.1 Strategy and targets AMOLF

As already explained in Section 2.2, AMOLF shifted its research themes from two in 2011 (Nanophotonics and Biophysics) to four in the new upcoming strategic period (Nanophotonics, Nanophotovoltaics, Designer Matter and Living Matter). Nanophotonics was continued in the same set-up, Nanophotovoltaics was already added after the SEP evaluation in 2011 and Systems Biophysics was converted into Living Matter. In 2014 Designer Matter was created.

This flexibility in focus and research themes was partly caused by the changes in personnel and mobility of PIs. This mobility of personnel created opportunities for new themes and hiring new talent. When AMOLF detects a very promising and innovative new theme for research, the institute has the flexibility to foster this new theme at high pace. This agility/ ability to respond in refocusing research programmes is seen as a major strength of the institute. The Committee strongly endorses this flexibility in themes and research lines that enables AMOLF to play a leading role in innovating the Dutch research and fostering the talent needed to develop promising research into future solid Dutch research themes.

For the period 2017-2022, AMOLF's research programme aims at four intertwined research themes: Nanophotonics, Nanophotovoltaics, Designer Matter and Living Matter. These themes are connected by the central aims of understanding how function emerges in complex matter and of leveraging this understanding to create completely new forms of adaptive and responsive (smart) materials. The interaction between research groups studying natural and man-made systems should lead to strong cross-fertilisation effects. The research ambitions are supported by the following strategic actions:

- Expand the new research theme Designer Matter;
- Invest significantly in the innovation of scientific instrumentation, in particular in the equipment of the AMOLF NanoLab cleanroom;
- Introduce a data management policy to make its research data accessible to the outside world;
- Increase the proportion of female scientific group leaders to 25% in 2022
- Strengthen the coordinating role in national and international research programmes

The Committee fully acknowledges the need to stay flexible and to keep focus on development of advanced scientific instrumentation, as this is key to performing cutting edge physics research. Gender balance was and still is an important issue for AMOLF and science in general. The strategy of AMOLF to strengthen its national and international coordinating role is strongly endorsed by the Committee as well. A leading institute such as AMOLF should play a key role in creating support at the level of government, society and industry on the scientific topic of materials. AMOLF should be able to unify the Dutch scientific community, which is needed to have a good dialogue with government and industry and safeguard political support and funding for this important line of research.

The track record of AMOLF proves that its research groups are very successful in obtaining funding for research. The Dutch funding landscape is changing drastically with the new NWO(I) organisation, new government and new research agenda's such as the Dutch National Research Agenda. Dutch funding has decreased in the past few years, whereas European funding increased and is getting more important. It could be therefore beneficial to have a clear strategy for funding. Funding for technical infrastructure (both equipment

and personnel) is reliant on core funding. AMOLF does request extra budget in its new strategy.

3.2 Research quality

Research themes

As mentioned before, during this strategic period, AMOLF initiated two new research themes, namely Nanophotovoltaics and Designer Matter. Each of these new themes capitalizes on the expertise developed over the past years, and incorporates other scientific disciplines. Both new themes have reached nowadays a critical mass with the hiring of several young tenure track group leaders. The committee was genuinely impressed by the speed and agility by which two new research directions were brought to the same level of scientific quality and output as the existing activities in Nanophotonics and Living Matter.

A remarkable strength of the current overarching research scheme at AMOLF is to cover a broad scientific spectrum directed towards complex matter, while maintaining strong synergies between the four underlying research themes. The committee was deeply impressed by the institute´s efforts to create an interdisciplinary intellectual environment and to stimulate interactions between the different groups and themes. The fact that 50% of the new tenure track group leaders are not Dutch is a strong testimony to the scientific strength and reputation of AMOLF. The committee also noted genuinely deep interactions between Living Matter and Designer Matter and between Nanophotonics and Living Matter.

Scientific output

The scientific output during the period 2011-2016 is more than 120 articles published every year of which over 25% were published in high impact international journals including high ranking journals with an impact factor >8 including Science, Nature and other Nature family journals. The bibliometric performance of AMOLF in terms of citations is at par with the very best departments/faculties/institutes at the best universities in the world and 8 ERC and a significant number of NWO grants were awarded to AMOLF group leaders. The Committee assesses the scientific output from the AMOLF institute as truly outstanding.

Talent

The key feature of AMOLF is the team of talented independent group leaders. AMOLF has a steady team of around 16-18 group leaders, who each work with around 5-10 PhD’s and Postdocs. Most of them are researchers in early to mid-career. Talents are carefully recruited from all over the world and given the opportunity to fully develop their potential in a world leading and very stimulating environment. Once the group leaders enter a certain level of seniority and the group grows over more than 10 researchers, group leaders are often offered prestigious positions at international or national research institutions and universities. This turnover allows AMOLF to start new themes and continue to attract top talent in the physics of functional complex matter.

Strategy 2017-2022

For the next strategic period 2017-2022, the objective is to further strengthen the four intertwined research themes, where future directions are clearly defined for each. These directions are ambitious and have the potential for important scientific outcomes that will keep AMOLF at the international scientific forefront.

Technical / scientific infrastructures

Important assets of the AMOLF environment are the clean room and technical departments, which offer researchers and their partners in science and industry state of the art equipment and support to be able to develop new research infrastructure. Substantial efforts have already been made to renew / upgrade the scientific infrastructure, in particular the nanolab and precision manufacturing workshop. It is planned, within the forthcoming strategic period, to further modernise the clean room, as well as acquire or develop novel cutting-edge equipment (e.g. time-resolved cathodoluminescence) that will give AMOLF further unique capabilities. This unique infrastructure is a key ingredient in the outstanding agility and competitiveness of the institute.

The committee assesses the research quality of AMOLF as world leading/ excellent (1)

3.3 Relevance to society

The Committee and the industrial partners underline the importance of the fundamental research done by AMOLF, given that less and less of it is done by industry. This puts AMOLF in a position of increasing importance, where collaboration with industry provides the partners with access to state-of-the-art fundamental research. Also the flexibility and agility of AMOLF to start and grow new research themes is very attractive to industry to start collaborations. In all these interactions AMOLF is very professional and realistic towards industry about what they can and cannot do.

The committee identified four broad areas of relevance to society in AMOLF's contributions and in its strategic plan:

1. **Contributions to the Dutch economy via entrepreneurship and spinouts.** AMOLF's contributions have produced significant industrial impact, including in the form of start-ups. Both ARCNL and DELMIC are exemplary in this respect. The formation of DELMIC, the AMOLF-Delft spinout focussed around the further development and deployment of the cathodoluminescence microscope, illustrates the power of deep science plus profound expertise in scientific instrumentation to create jobs and revenues. Specifically, DELMIC employed during its R&D phase 16 people. Now that it is in its sales and revenue generation phase, it currently employs 10 people. It has sold about twenty systems. It has raised multiple millions of euro from a mix of private and public sources in support of its entrepreneurial mission.

2. **Engagement of industry partners and building bridges between basic science and industry technology roadmap development.** With regard to major industry partner engagement, the impact on Dutch companies has been impressive, in the form of partnerships with Philips, Philips Lighting, FEI, Shell, ASML, Unilever, and also with SMEs. Especially ARCNL, as a partnership with ASML, is an extraordinary accomplishment. Winning that bid through a very competitive process and developing this public private partnership into a very successful and sustainable institute is an absolute showcase for science in the Netherlands. Next to the successful creation of ARCNL, the committee was profoundly impressed by the industry partners' perspective that AMOLF must focus on making strides in basic physics research since industry partners have deemphasised this in their own organisations; AMOLF's role is all the more critical in light of industry's shift away from basic work, and industry partners fully recognise this, and it attracts them to sustained engagement with AMOLF. Obtaining patents is not a major goal for AMOLF, but the institute participates in filing them together with industry.

AMOLF participates in discussions on research policy nationwide. For instance, the institute was one of the key contributors to the national report on the future for materials research in the Netherlands: Dutch Materials. Furthermore, members of the institute participate in several strategic committees related to physics research in the Netherlands and supports the younger group leaders to participate as well in such committees.

3. **Training of highly qualified personnel, such as via doctoral students and post-doctoral fellows.** AMOLF provides truly outstanding training of high-qualified personnel. AMOLF masters, doctoral, and post-doctoral trainees consistently go on to take up positions at leading global companies, universities, and government labs; with an appropriate blend of Dutch and international impact. On average AMOLF produces 15 PhD's each year and 2-3 highly qualified group leaders that are trained to become the future leading scientists in their field. More recent examples of the "AMOLF diaspora" (past group leaders and PhD students who are now faculty members at leading schools) include Mark Brongersma (Stanford), Mischa Bonn (Director at the Max Planck Institute for Polymer Research, Mainz, Germany), Willem Vos (Twente), Laurens Siebbeles (Delft), Kobus Kuipers (Delft), Marileen Dogterom (Delft) and Ron Heeren (Maastricht).

4. **Public engagement around science, innovating creative initiatives that engage the wider public.** AMOLF has a very high reputation for broader public outreach. This includes both engagement with the public via media (a remarkable fraction of their scientific publications receive appreciable public interest), and also highly innovative strategies such as the theatre show Voor niets gaat de zon op by Albert Polman. AMOLF is clearly connected with wider contemporary interest in the Science, Technology, Engineering and Mathematics (STEM) fields, finding linkages among creative contributions in science, engineering, mathematics, and the arts. As a result, though primarily a scientific institution, AMOLF's impact is being felt in social and cultural formats as well as within their principal fields of expertise.

The committee assesses the societal relevance of AMOLF as world leading/ excellent (1)

3.4 Viability

In order to facilitate the assessment of the viability the committee focusses on three separate parts that all contribute to the institute's viability: talent management and recruitment strategy, the management of the institute, and its funding position.

Talent

- AMOLF has a very strong and successful recruitment strategy. AMOLF scouts and screens candidates extensively and is able to attract very promising excellent scientists on a regular basis. To set-up new innovative research themes or strengthen its group leaders, AMOLF offers an attractive startup package. In addition, a good mentoring system is in place for these scientists. A continuous influx of young people, both at the MSc, PhD or postdoctoral level and at the tenure track level, ensures that the institute remains vibrant and rejuvenates all the time. This influx causes a rethinking and readjustment of the scientific themes. It allows the institute to take up novel scientific directions in a fast and flexible manner;
- Cooperation and interaction between all members of the staff is a key feature of the institute. This might be called the 'magic of AMOLF'. This is driven by not only the size of the individual research groups (up to approximately 10 persons, no permanent scientific

staff besides tenured or tenure track group leader), or the size of the institute (~200 persons), but also by the separate dedicated building and by their working atmosphere as well. This 'magic of AMOLF' is crucial to the future success.

Management

- The management structure of the institute is quite flat. This prevents hierarchical structures to get in the way of the cutting-edge science AMOLF wants to perform and encourages collaboration;
- Administration overhead within the institute is kept at a minimum. An example of this is that there is no internal accounting for the facilities each of the groups can use: it is based on a fair-use policy. The flat organisation makes this possible, as people are in close contact at all times.

Funding

- In a funding landscape that is shifting from national to European (notably ERC) and is simultaneously becoming increasingly competitive, the Institute has managed to attract very significant funding to operate the research groups. The institute provides solid support to its researchers in preparing grant applications and the process of writing, rebuttal and interview. The committee has no doubt that the high success rate in obtaining external research funds will be sustained, but the committee is also aware of the challenges faced by the increasing amount of time spent on securing funding.
- The internal/external balance in funding is 50%-50% at AMOLF. This is regarded as a feasible and sustainable balance in the coming years;
- AMOLF requests an increase of 740 k€ to its annual mission budget. This budget increase is required to keep the scientific infrastructure state-of-the-art and to fulfill AMOLFs regional function within the Amsterdam Science Park as a central facility for nanofabrication and characterisation (300 k€). Additional budget is requested to pay for the costs of the new data management policy (100 k€), to enable the accelerated increase of the proportion of female scientific group leaders to 25% in 2022 (130 k€), and to cover the costs of guest positions and collaborative projects with university groups (210 k€). The Committee strongly endorses this request for additional funding for AMOLF to remain an excellent forerunner in science and society.

Infrastructure

The excellent support groups of the institute in the areas of design, mechanical (micro) Fabrication, IT, software development, electronics and an efficient administration are instrumental to the fast operation of AMOLF. The hosting of the technical and administrative support for ARCNL has enlarged and strengthened the AMOLF support divisions.

The committee assesses the viability of AMOLF as world leading/ excellent (1)

3.5 Considerations regarding organisation, management policies and staffing

3.5.1 PhD programmes

AMOLF offers a structured four-year PhD programme. Within this programme, the PhD students have formal interviews with their supervisor each year. During these meetings, the progress and future directions are discussed helping the students to structure and plan their PhD work. These meetings are in addition to the scientific meetings with their supervisors

that take place typically at a weekly or bi-weekly schedule. In addition, the students are required to write detailed reports about their research results and the acquisition of new skills. Moreover, they have to provide a detailed plan for the following year. After one year, the students have an interview with the department head, their theme leader, and an oral presentation to their group. After 2.5 years, the PhD students have to submit a preliminary outline of their PhD thesis with the aim of finding out which additional steps are required to finish the thesis. They also have an interview with an MT member which is not topical but more on the entire process of obtaining a PhD in four years. Based on discussions with the group leaders (supervisors), the director of AMOLF, and PhD students, we conclude that the system helps the PhD students to streamline their PhD work. Small extensions of the four-year contract are possible in exceptional cases. This measure is considered important to enable the candidates to finish their PhD theses despite unexpected obstacles.

The institute has installed measures to help the PhD students transitioning from their PhD thesis work into positions within or outside of academia. To this end, 6 months before their contract ends, the supervisor discusses future career options with the PhD candidates and encourages them to apply for jobs. The Committee finds this measure very promising to help the students think about future plans.

AMOLF offers a highly interactive and stimulating working atmosphere for young researchers. For example, weekly seminars are organised where PhD students present their progress. Sharing offices between groups is likely to stimulate cross-disciplinary discussions. Moreover, they are encouraged to attend summer schools and scientific meetings. Within the NWO Institute Organisation, PhD students have the ability to receive soft skills training and are encouraged to do so.

AMOLF has set up a highly attractive structured PhD programme with the aim of guiding their candidates towards a PhD degree within four years. The quality of the PhD's at AMOLF is extremely high. With their very successful PhD programme, AMOLF enables the PhD's to contribute significantly to the vibrant culture of excellence at AMOLF. Every day, they are the very valuable linking pins between all groups and research themes.

3.5.2 Research integrity policy

Entering Master and PhD students are provided with written information about how to conduct research. AMOLF furthermore organises symposia about research ethics (roughly every two years). In addition, a new course on research integrity is currently being developed. The Committee was particularly impressed that AMOLF publications undergo an internal peer review by (non-coauthor) group leaders. The committee was also impressed with the degree of active mentoring of PhD students being outstanding (see PhD programmes). The prevailing research culture and manner of interaction among all institute members is open and transparent.

Over the last 6 years there have been two violations of research integrity. The Committee asked more about these incidents, and concluded that they were identified and dealt with appropriately and satisfactorily. They illustrate that the policy and its implementation work effectively.

Data management is increasingly an item of attention worldwide. AMOLF has been taking on a leading role in the Netherlands by proactively developing a data management plan that has the potential of becoming a model for the country.

Overall, the Committee determined that AMOLF pays close, and very appropriate, attention to the many aspects of research integrity. The policy currently in place is functioning well.

3.5.3 Diversity

AMOLF promotes an inclusive culture and family-friendly environment. The Committee was impressed by the commitment to these goals by the management team. At present among the PhDs/postdocs about 30% are female. This figure is roughly in line with equivalent cohorts at Dutch universities (where about 40% are female in physical studies, with 23% female in technical studies). However, currently only 2/17 (12%) of group leaders are female. This figure is volatile due to the small numbers involved (for example, during 2011-2013, the percentage was 17%), but nevertheless the current situation is not ideal.

The Committee realises that the issue of gender diversity is a difficult topic that cannot be solved by AMOLF in isolation. Nevertheless, AMOLF aims to expand the percentage of female group leaders to 25% by 2022. To realise this goal, AMOLF expects 2-3 of the approximately 5 new hires will be female (with one female hire expected imminently). The Committee fully supports this objective and hopes that an even higher percentage of future hires will be female to prepare for possible poaching of women group leaders by other institutes or universities. AMOLF actively scouts for talented women researchers, who will be encouraged to apply personally. AMOLF also participates in NWO's Women in Science Excel (WISE) scheme. WISE provides talented women scientists with opportunities to develop their own research group at an NWO institute. AMOLF anticipates that 1-2 of the new group leader hires will be via WISE. In its future budgeting AMOLF is requesting 130k€ per annum to have flexibility to hire excellent female tenure-track group leaders before a vacancy opens. The Committee fully supports this extra expenditure, which further underlines the seriousness with which the institute takes the issue of diversity. We also encourage AMOLF to try to influence NWO and other Dutch institutes/universities into taking more coordinated action to solve the "two-body" problem (two partners both in science having difficulty obtaining positions in the same geographical area), which can strongly restrict female (or male) hiring.

AMOLF also intends to set-up mentoring for female postdoc/PhD scientists, though it would be helpful if AMOLF could articulate in more detail precisely what form this mentoring will take. The Committee also encourages AMOLF to enhance female participation at all levels, including technical support as well as senior leadership roles. The committee also strongly supports a role for female role models, highlighted by AMOLF's intention to invite a representative number of women for colloquia and by employing around 50% female speakers at summer schools.

With respect to diversity in nationality, before 2011, a high proportion of tenure-track group leaders were Dutch and sometimes former AMOLF PhD students. This situation has now been successfully diversified: 50% of recent tenure-track hires have been non-Dutch and 9/11 newly hired group leaders graduated from institutes other than AMOLF. Group leaders now comprise 5 nationalities, while the postdocs/PhD students originate from a very diverse 24 nationalities. The Committee does, however, note that diversity should mean more than just gender and nationality diversity. We therefore encourage AMOLF to in the future monitor, for example, ethnic minority representation as far as is possible consistent within legal restrictions.

AMOLF is very much aware of the diversity issue and has an appropriate strategy to address this matter.

3.6 Supplementary questions by the NWO Executive Board

3.6.1 Generic questions

In addition to the three main and three additional criteria assessed in the evaluation, the NWO board has formulated three additional questions to be addressed by the assessment committee as well.

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

AMOLF is a national initiator and incubator for innovation in complex and functional matter physics research. The organisational strategy and the carefully built up research culture can be regarded, both nationally and internationally, as a role model. AMOLF has a distinct added value to the Dutch scientific landscape, especially to the Dutch universities. Where universities focus on individual research groups around professors and long-term strategy, AMOLF is much more flexible. AMOLF has proven to be very sustainable in strategy, size, budget and level of excellence of both scientific and technical staff. In addition they are also very flexible when it comes to initiate (in very short time) new promising and innovative research themes and attract the most talented researchers from around the world. The unique mobility of the research staff guarantees the opportunity to hire new talent group leaders and thereby the ability to kick-start new research activities. It also provides (inter)national research institutions and industry with a sustainable flow of talent at the highest level.

This enables AMOLF as well to coordinate large national research programmes, and to be the national representative body in relevant disciplines for the government, funding agencies and industry.

2. How does the institute stimulate and facilitate knowledge utilisation and open access?

AMOLF researchers collaborate with industry on a very regular basis and are flexible to develop their fundamental research along with the company strategy or find new partners once a company is not interested anymore in a research theme. The size of AMOLF provides industry with an extensive multidisciplinary body of knowledge, instead of only single researchers and topics.

Open Access is a distinct policy priority. AMOLF is frontrunner when it comes to data management strategy, including open access, and has implemented it already in their working flows and culture. The transparent culture, in which extensive internal peer review plays an important role, also strongly contributes to open access.

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

Again, the structure and size are key to the outstanding research, training, and impact of AMOLF. It is crucial to maintain the current size of the institute and its research groups. The size guarantees flexibility and is key to what the Committee came to refer as the magic of AMOLF – This magic is key to the world leading excellence and innovation of AMOLF. AMOLF has also been financially stable for many years, because the institute obtained an increasing amount of European funding, whereas funding from NWO calls decreased. AMOLFs financial policy is solid, but is also very dependent on future NWO funding. With all developments and changes within NWO this certainly is an important point of concern for the committee. A

particular challenge is to maintain the ability to provide an attractive start-up package when new group leaders are hired to the institute.

Conclusions and recommendations

3.7 Conclusions

AMOLF has made an outstanding scientific impact and has established and maintained a worldwide reputation as one of the leading research institutions in the fundamental investigations of matter. In this way AMOLF has built an international reputation not only for itself, but also it has contributed to the elevation of the quality and profile of Dutch science. AMOLF is a jewel for fundamental research in the Netherlands.

The creation of ARCNL illustrates in one example AMOLF's significant impact on Dutch science, in that the new lab was a product of an AMOLF-ASML partnership, and builds on (and customises to the field of next-generation lithography science and technology) the AMOLF model.

The committee very highly valued the following key aspects, which it feels provide the basis for AMOLF's success:

- Modest size of groups and staff in total which enables AMOLF to safeguard an organisational culture of close interaction and collaboration, fostering personal development, multidisciplinary cross-overs and scientific excellence;
- Strong emphasis on sustainable talent development- from recruitment to mobility;
- Flexibility in focus and themes to act on promising novel research opportunities and provide a sustainable model for innovation in the Dutch field of material science;
- Excellent technical infrastructure (including equipment and personnel).

Together, these aspects might be thought of as the AMOLF model of institutes for basic research and could bring important added value also to bigger research institutions such as universities.

AMOLF has a clear sustainable strategy building on existing scientific strength but also a strategy allowing for new group leaders being hired and the growth of entirely new research themes

3.8 Recommendations

Based on the evaluation of the institute and the above assessments, the committee has a few specific recommendations for the near future.

The committee strongly recommends that AMOLF should:

- Maintain and extend the strong links between the four research themes;
- Explore further opportunities for start-ups. Especially in the domain of physics instrumentation, opportunities will arise;
- Safeguard the AMOLF model and maintain the limit on the size of the research groups;
- Monitor diversity in all aspects and maintain manegerial focus on gender policies and hidden biases.

The committee strongly recommends that NWO should:

- Safeguard the consistency in AMOLF's overall budget. AMOLF is world leading because of its consistent ability to foster cutting edge research. Large fluctuations in

annual NWO support together with an increasing dependency on (short term) European funding streams will make AMOLF vulnerable. AMOLF requests an increase of 740 k€ to its annual mission budget. This budget increase is required to keep the scientific infrastructure state-of-the-art and to fulfill AMOLFs regional function within the Amsterdam Science Park as a central facility for nanofabrication and characterisation (300 k€). Additional budget is requested to pay for the costs of the new data management policy (100 k€), to enable the accelerated increase of the proportion of female scientific group leaders to 25% in 2022 (130 k€), and to cover the costs of guest positions and collaborative projects with university groups (210 k€). The Committee strongly endorses this request for additional funding for AMOLF to remain an excellent forerunner in science and society;

- Provide additional, targeted support for policy-driven and administrative aspects that are becoming increasingly important, such as support for large-scale data management, tech transfer, IP, and patents. In addition, create support mechanisms among all NWO institutes to help influence EU science policy and identify favorable EU programmes.

Annex 1. Curricula Vitae of Evaluation Committee Members

Prof. Dr. Søren Keiding (chair) is Professor in the Chemistry Department of Aarhus University, Denmark. His main research focuses are on non-linear spectroscopy, microwaves and THz spectrology, optic tweezers and nanotechnology. Since 2012, Keiding is a honorary member of the Huejunta, Institute of Physics and has been a long-standing Fellow of the Danish Natural Science Academy and of the Academy of Technical Science. Keiding does research in the field of chemical reactions and processes on the molecular level, using femtosecond laser techniques and measuring optical forces in fluids. Keiding is a pioneer in the field of THz spectroscopy in fluids. Also, he is active in developing new sources and techniques for the Chemical field, like interferometric CARS microscopy.

Prof. Dr. E.H. (Ted) Sargent is Canada Research Chair in Nanotechnology and Professor of Electrical and Computer Engineering at University of Toronto, Canada, where Sargent is Vice Dean for Research at the faculty of Applied Science and Engineering. He is known for his multidisciplinary type of research, in which he connects physics, chemistry and photonics for the development of bottom-up and top-down nanophotonic materials and devices for optic information technology, light sources, sensing and solar energy. Furthermore, he is the founder of two companies: Xagenic and Invisage Technologies. He is Fellow of the Royal Society of Canada; Fellow of AAAS and IEEE, was awarded numerous prizes and authored the popular-scientific book 'The Dance of the Molecules: How Nanotechnology is Changing Our Lives'.

Prof. Dr. Romain Quidant is ICREA Research Professor at ICFO, the Institute for Photonic Sciences in Barcelona, Spain. At the same institute, he is Group Leader of the "Plasmon Nano-Optics" Group. His research focuses on capturing light in nanoscale structures for optic addressing molecules, optic forces on the nanoscale and the usage of light, heat and optic forces for biomedical applications. Quidant received four ERC grants and many prices for his work, most recently the European Fresnel Prizes (Applied Physics) awarded by the European Physics Society for his outstanding contribution to Optics. Furthermore, he is Associate Editor of ACS Photonics (American Chemical Society) and leads four tech-transfer initiatives in the field of biotechnology and ICT.

Prof. Dr. Heinrich Jaeger is a Professor Experimental Psychics at University of Chicago, USA. He researches irreversible processes and how they can be used to design smart materials. Jaeger is one of the founding fathers in the field of granular materials and has a long track record in self-assembly of nanoparticles. More recently, his focused has shifted on soft robots and the rational design of materials. From 2007-2010 he was a director of the James Franck Institute at the University of Chicago. He is on the editorial board of Physical Review Applied; Granular Matter and has recently won the Faculty Award for Excellence in Graduate Teaching and Mentoring. He is a Fellow of the American Physical Society.

Prof. Dr. Martin Howard is an Honorary Professor, associated with the University of East Anglia and a pioneer in the usage of non-equilibrium static physics for biological research questions in the field of pattern forming of protein in cells, regulation of cell division and growth. Since 2007, Howard chairs the research group 'Computational and Systems Biology' at the John Innes Centre in Norwich, the United Kingdom. Recently, he has been studying the mechanic basis of the epigenetic memory. His group works closely together with experimental groups mathematical models of biological systems to get a fundamental understanding of biological and physical mechanisms at a systemic level. In 2014, Howard received the Institute of Physics Tom Duke Lecture Prize.

Prof. Dr. Berenike Maier is a Professor in biophysics and chair of the Biophysics research group at the Institute for Theoretical Physics of Köln University in Germany. In this research group, she studies the physics of bacterial systems. At a single-molecule level, she studies the mechanical interactions of bacteria, with special attention for the bacterial molecular motors that are associated with motility. Moreover, she studies horizontal gene transfer and its evolutionary significance. Her work combines physics, biology and biochemistry, with the use of nanotechnology, image analysis and molecular biology. From 2004 to 2011, she was professor of 'Single Molecule Biophysics' at the Institute for Molecular Cell Biology at Westfälische Wilhelms Universität, Münster.

Prof. Dr. Aart Kleijn is a Director at the Center of Interface Dynamics for Sustainability, Chengdu Development Center for Science and Technology at the China Academy of Engineering Physics. Here, his main research focuses on surface chemistry, molecular physics, materials and catalysis. Kleijn served on many boards and committees nationally and internationally and organized and co-organized many international conferences regarding chemistry and physics. Interestingly, he was a member of the scientific staff of the FOM Institute for Atomic and Molecular Physics (AMOLF) in Amsterdam until 1999 and worked as a Professor of Physics at the University of Amsterdam and as a Professor of Chemistry in Leiden.

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

Wednesday 18 October

Committee arrives in the Netherlands, transport to location

16:00 – 16:05 Opening (president of the Executive Board of NWO, prof. Stan Gielen)

16:05 – 16:10 Short introduction (all committee members)

16:10 – 16:15 Formal start of the committee by the president of the Executive Board of NWO

16:15 – 16:20 Call to Order (chairman of the committee, prof. Søren Keiding)

16:20 – 16:50 Interview with the president of the Executive Board of NWO

17:00 – 17:15 Presentation on the Dutch Science Landscape (Maaike Romijn, secretary)

17:15 – 17:30 Introduction to the Standard Evaluation Protocol (Maaike Romijn, secretary)

17:30 – 18:30 Closed committee meeting (only committee members and secretaries)

18:30 – 21:00 Dinner and continuation of closed meeting

Thursday 19 October

08:30 – 09:00 Transport from the hotel to the institute

09:00 – 09:15 Welcome at the institute

09:15 – 09:30 Introduction to AMOLF

09:30 – 10:15 Interview with the directorate

10:15 – 11:00 Tour of the premises

11:00 – 11:15 *Coffee break*

11:15 – 12:15 Scientific presentations by *Designer Matter* department head and 2 group leaders

All group leaders from department present at presentations (5’ introduction head; 2 x 10' group leaders) and discussion (after each presentation, in total 35’)

12:15 – 13:15 *Lunch*, incl. interview session with the tenure track group leaders

13:15 – 14:15 Scientific presentations by *Living Matter* department head and 1 or 2 group leaders

All group leaders from department present at presentations (5’ introduction head; 2 x 10' group leaders) and discussion (after each presentation, in total 35’)

14:30 – 15:30 Scientific presentations by *Nanophotovoltaics* department head and 1 or 2 group leaders

All group leaders from department present at presentations (5’ introduction head; 2 x 10' group leaders) and discussion (after each presentation, in total 35’)

15:30 – 15:45 *Coffee break (with heads of the support division)*

15:45 – 16:45 Tour of the cleanroom and technical support divisions

16:45 – 17:45 Posters and interview session with PhD students and postdocs (2 of each department), with *drinks*

17:45 – 18:00 Transport from institute to restaurant

19:00 Dinner closed session committee, followed by transport to the hotel

Friday 20 October

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

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

09:00 – 10:00 Scientific presentations by *Nanophotonics* department head and 1 or 2 group leaders

All group leaders from department present at presentations (5’ introduction head; 2 x 10' group leaders) and discussion (after each presentation, in total 35’)

10:00 – 10:15 *Coffee break*

10:15 – 11:30 Interview with directorate and management team (focus on data management, institute’s diversity and integrity policy, also including Bela Mulder for integrity policy)

11:30 – 12:00 Interview session with Institute Advisory Committee chair and members

12:00 – 12:30 Interview with external stakeholders (focus on relevance to society)

12:30 – 13:30 *Lunch*

13:00 – 17:30 Closed session Committee to draft report (multiple rooms)

17:30 – 18:15 Closure with directorate, management team, group leaders, and heads of support division;

Committee shares preliminary conclusions

Annex 3. Explanation of the SEP-categories

Table 1. 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.

Annex 4. 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 AMOLF, chaired by Prof. dr. Søren Keiding.

Topic	Description
Title	External evaluation of AMOLF of the period 2011 – 2016
Why	NWO organises 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 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 quality and 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**: 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 utilisation and open access? 3. How does the institute's structure, size and financial policy contribute to its mission?
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 three 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	Maaike Romijn (Dialogic/Birch) and Peter Spijker (NWO)

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

- Self-evaluation 2011-2016
- Strategy document
- 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