Evaluation report for the research review of

Applied Physics

Bionanoscience Department
Radiation Technology and Science Department
Imaging Physics Department
Quantum Nanoscience Department

at Delft University of Technology

April 2023

meg@megvanbogaert.nl
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Preface

The committee would like to thank the Rector of the Delft University of Technology, the Dean of the Faculty of Applied Sciences, and the heads of the four assessed Physics departments, Bio Nanoscience, Radiation Science and Technology, Imaging Physics and Quantum Nanoscience, for placing their trust in us and assigning us the task to assess these four departments in the context of the SEP-protocol. The entire procedure was well-prepared, with excellent documentation and a carefully composed schedule for the site visit, and it was supported in a very professional way by the staff of the Delft University of Technology.

The assessment was conducted by a diverse committee, consisting of Prof. David Rueda, Prof. Roberta Ramponi, Prof. Dina Fattakhova-Rohlfing, Prof. Wim van der Zande, Prof. Johannes Fink, Twan Wilting MSc, Prof. Joost Frenken, and it was supported by dr. Meg van Bogaert, who organized the full procedure and had the role of committee secretary.

The assessment has paid due attention to all subjects in the Strategy Evaluation Protocol. Additional focus was requested by the Executive Board of the TU Delft for the role of the Casimir Research School in the training of PhD candidates in the Bionanoscience (BN) and QuantumNano (QN) departments, and the relation between the QuTech institute and TU Delft's physics departments, in particular QN. The explicit instruction to the committee by the Executive Board was to be critical and to provide concrete suggestions for the four departments to make improvements.

The site visit took place from Monday 16 January to Thursday 19 January 2023 and consisted of an intense programme, with inspirational lab tours, discussions with the Rector of the university, the Dean of the Faculty, the department heads, the staff at the four departments, a selection of PhD-candidates from the four departments, and a selection of assistant professors on a tenure track from the four departments.

The committee would like to express its gratitude and appreciation for the open atmosphere in which all interactions and discussions could be conducted. Not only the successes were enthusiastically reported, but also challenges and difficulties were brought to the table. This provided significant added value to our site visit.

Professor Joost Frenken
Chair research assessment committee
April 2023

Introduction

Scope of the assessment

In June 2021, the Executive Board of Delft University of Technology (TU Delft) commissioned a review of the research conducted in the Department of Bionanoscience (BN), the Department of Imaging Physics (ImPhys), the Department of Quantum Nanoscience (QN) and the Department of Radiation Science & Technology (RST) of the Faculty of Applied Sciences. The review is part of the regular six-year quality assurance cycle of the university and is intended to monitor and improve the quality of the research and fulfil the duty of accountability towards government and society. The quality assessment in this report is based on the assessment system in the Strategy Evaluation Protocol for Public Research Organizations 2021-2027 (SEP, appendix 1) drawn up by the Universities of the Netherlands, the Dutch Research Council (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW).

In accordance with the SEP for research reviews, the committee was requested to assess the departments within specified guidelines. It was asked to judge the performance of the four departments on the main assessment criteria specified in the SEP and to offer its written conclusions and recommendations based on considerations and arguments. The main SEP assessment categories are Research Quality, Societal Relevance and Viability. The committee was asked to include four specific topics in its review. These topics relate to how the departments and Faculty organise and perform the research, how they are composed in terms of leadership and personnel, and how the departments are run on a daily basis. The topics are Open Science, PhD Policy and Training (including the research school Casimir), Academic Culture and Human Resources Policy.

Finally, the Executive Board of TU Delft asked the committee to reflect on one additional question, namely to offer its observations and recommendations regarding the relationship between the physics departments (specifically Quantum Nanoscience) and the QuTech institute.

The review committee

The Executive Board of the TU Delft has appointed a review committee (hereafter: committee) of seven external peers, including a mid-career researcher and a PhD candidate. The committee consisted of:

- Prof. Joost Frenken (chair), University of Groningen, Groningen (NL);
- Prof. Dina Fattakhova-Rohlfing, Forschungszentrum Jülich, Germany;
- Prof. Johannes Fink, IST, Klosterneuburg, Austria;
- Prof. Roberta Ramponi, Politecnico di Milano, Italy;
- Prof. David Rueda, Imperial College London, UK;
- Twan Wilting MSc, Eindhoven University of Technology (NL);
- Prof. Wim van der Zande, ARCNL, Amsterdam (NL).

The TU Delft Executive Board appointed dr. Meg Van Bogaert as the secretary to the committee.

Members of the committee signed a declaration and disclosure form to the effect that they would judge without bias, personal preference, or personal interest. Their judgment is made without undue influence from the institution, the programmes, or other stakeholders. Any existing professional relationships between committee members and programmes under review were disclosed. The committee concluded that there was no risk in terms of bias or undue influence.

Information provided to the committee

The committee received detailed documentation consisting of the following parts:

- Self-evaluation report 2016-2021, including appendices;
- Strategy Evaluation Protocol 2021-2027;
- Terms of Reference for the research assessment Applied Physics TU Delft 2016-2021;

Procedures followed by the committee

The site visit of the departments took place from 16 to 19 January 2023 in Delft. Before the site visit, the committee members were asked to read the documentation and formulate preliminary findings and questions for the interviews. Several weeks before the site visit, the committee received a presentation with an introduction to the SEP, specifics about the Dutch research landscape and the working methods. In an online kick-off meeting, ten days prior to the site visit, the committee agreed upon procedural matters. On the evening of 16 January 2023, the committee discussed its preliminary findings and prepared the site visit.

During the site visit, the committee met with representatives of the University, Faculty and departments and discussed its findings of the four departments. To conclude the site visit, the committee presented the main preliminary conclusions to the Departments, Faculty, and University. The schedule for the site visit is included in appendix 2.

This report describes the findings, conclusions, and recommendations of the committee. The departments are assessed based on their own objectives and strategies as well as in relation to departments and institutes worldwide in similar disciplines and on similar topics. The texts for the assessment report were finalised through e-mail exchanges. The final version of the report was presented to the departments, Faculty Board, and Executive Board of the University for factual corrections and comments. The report was finalised on 25 April 2023.

Faculty of Applied Sciences

Introduction

In the following chapters of this assessment report, the committee provides detailed reviews and recommendations for each of the departments in this review. Next to the topics that are specific for the individual departments, the committee also recognized elements of a more generic nature. These elements are characteristic for the full physics part of the Faculty of Applied Sciences (hereafter referred to as "the Faculty") or, perhaps, for the entire Faculty or even on the scale of the university as a whole. In addition to these generic features, the simultaneous evaluation of four departments allowed the committee to also recognize important differences between the departments, where more uniformity might have been expected. The committee starts its report with some of these overarching observations.

Significant developments have taken place within the Faculty in the course of 2022 on several topics but were not fully covered in the self-evaluation report for the simple reason that the self-evaluations of the four departments were restricted to the six-year time interval up to and including 2021. Examples of these developments are the policies in the departments to control the average duration of PhD projects and the career trajectories at the departments for assistant professors on a tenure track. The committee recommends to the departments to include those elements in future self-evaluation reports even when they took place outside the period of evaluation.

Organisational structure

The research and education of the four departments that are being evaluated are embedded in the Faculty of Applied Sciences, one of the eight faculties of TU Delft. The research in the Faculty is fundamental and application-oriented in nature and is spread over a total of six departments. In addition to the departments in this evaluation, Imaging Physics (ImPhys), Quantum Nanoscience (QN), Bionanoscience (BN), and Radiation Science & Technology (RST), the Faculty includes two applied chemistry departments, namely Chemical Engineering (ChemE) and Biotechnology (BT). The Faculty also offers four bachelor programmes and five master programmes.

The Dean heads the Faculty and has overall responsibility for education, research, and management. The Head of Department is responsible for the distribution of resources (personnel and budget), for education, for the overall quality and quantity of the research and for the departmental budget. By the time of the site visit, all departments had adopted a flat organizational structure. This structure allows each PI, irrespective of whether they are an assistant professor, an associate professor or a full professor, to be fully responsible for their own research group. With this, the hierarchical system that characterized some departments before, with a single full professor managing a large research unit in which other research staff members played a secondary role, was abandoned. Generally, this change was experienced by all departments as a very positive development, typically leading to a structure without a formal organizational level between the Head of Department and the individual PIs. The committee applauds this development although it also warns the departments that the complete absence of delegation of tasks may make the managerial burden on the Head of Department too large. This can have consequences for the quality of the mentoring of individual PIs and the joint strategy of the department as a whole. One - partial - solution is using the 'dossier approach', referred to by the BN department. However, a more formal solution, for example by way of a representative system, might also provide a viable solution, combining the best of both worlds. In this representative system, each topical cluster within the department would be represented in the department's management team by one of its PIs. The representative would be taking over tasks from the Head of Department, without being in the role of the chair holder.

Communication between departments

There are several topics on which significant developments have taken place within the Faculty in the course of 2022. Formally, these developments fall outside the scope of this review, covering the period up to and including 2021. Nevertheless, some points of attention that the committee had recognized based on the self-evaluation documents, turned out to be ‘corrected’ by recent history. One example concerns recently implemented policies to acquire better control over the average duration of PhD projects. Another is that of the career trajectories at the departments for assistant professors on a tenure track.

On many occasions, the committee recognized a best practice within one department that deserves to be considered for faculty-wide adoption. For example, the ‘dossier approach’, followed by the BN department. Topics that are regarded important for the department as a whole are defined as a ‘dossier’ and are made the responsibility of a small number of staff members. In this way, several important subjects are taken care of, with the great benefit that many of the department’s staff members are made co-responsible for that subject and thus share involvement in the organization and operation of the department.

The committee encountered inspiring best practices in the context of the PhD-in-4 theme and in the context of career tracks. Similarly, the subject of social safety is handled differently in the four departments for which the committee again recognized best practices. Financial management, for example methods to free up budget for start-up funds for new assistant professors, is handled differently by different departments and also on this point they may be able to benefit from each other’s policies. A final example concerns an imported best practice in the form of the use of templates and standard documents for innovation transfer activities, which one of the departments took over from a benchmark research institute.

Strategy and research quality

The committee starts by sharing its overall observation of the outstanding quality of the research performed at the four departments, each operating at the international forefront in its discipline. The committee was impressed by the energy, the high potential, and the vision that it has encountered. It concludes that at TU Delft, physics research is simply of world-class.

The Faculty receives an annual budget, predominantly fixed and for a minor part based on teaching output and research output. The Faculty divides all funding across the six departments in a similar way. This allows the departments to conduct a long-term strategy as the annual budget fluctuations are limited.

The chapters on the four departments will elaborate on each department's strategy. According to the committee, the four departments are very different in their orientation, working style and raison d’être, as is reflected in significant differences in the metrics by which the departments chose to be assessed on research quality and relevance to society. For example, specific for QN is its relation with QuTech and the future technology that is developed there, for ImPhys it is its orientation towards practical applications of its imaging technology in the medical field and industry. BN has its orientation towards biological and medical subjects and its relation to hospitals, and specific for RST is its expertise on and access to Delft’s radiation facility. These differences naturally result in different research traditions and strategies concerning e.g., scientific publications and career development. Interestingly, despite the outstanding quality of the research across the board, a general perception by the committee was that most departments seem to struggle with their identity and strategy. For each department, this struggle had a different character; from departments feeling uncertain as to whether their strategic choices are optimal, to departments not having internal consensus about the directions in which to proceed. The committee regards it as a healthy sign that strategies are continuously made subject of discussion and adaptation. However, this should not lead to a sense of insecurity and it should always lead to a well-defined result that is embraced and supported by all.

The present way – according to the SEP - of assessing research units has significantly widened the scope, it now explicitly enables each unit to provide its own, fitting presentation within its context. The committee noticed that some departments had not yet fully internalized this, which is reflected in the fact that some departments were being systematically too modest in the roles and impact of their research, which the committee regards as unjustified. A more balanced appreciation within and between departments, in which differences in roles are factored in, will benefit not only those departments but also the Faculty as a whole.

Collaborations and partnerships

From the documentation and the interviews, it became clear that all departments have numerous local, regional, national and international collaborations, networks and collaborative initiatives. For example, the Convergence with Erasmus University Rotterdam and Erasmus MC provides ample opportunities for collaborations in which researchers from multiple departments participate. However, the self-evaluation report gave the committee the impression that the four departments operate quite separately and in disconnect from each other. It seemed that the departments do not always make optimal use of each other's presence, facilities and expertise. In part, this impression was corrected by several appealing examples of collaboration provided during the presentations and the discussions with research staff during the site visit. The committee recommends to the departments to increase the visibility of joint activities and highlight those in future self-evaluation reports.

Nevertheless, despite existing interactions and collaborations between departments, the committee recognizes further opportunities where departments can benefit from each other. One specific example to mention in this respect is the Delft Electron Microscopy Initiative, DEMI. The committee is very positive about the fact that the fragmented, local electron-microscopy community at TU Delft has joined forces in DEMI. However, the impact of DEMI presently does not yet go significantly beyond the level of joint technical support and favourable service contracts for the collection of electron microscopes.

A second example concerns the different missions of the four departments.

The lack of visible collaborations is also reflected in the (lack of) knowledge of tenure trackers on the research that is performed in other departments within the Faculty. The committee would like to stimulate an increase in activities to introduce all tenure trackers from the start of their appointment to all PIs in the Faculty and their research (tools). Such an onboarding action can stimulate a sense of belonging, creates a form of convergence (or prevents divergence) in way of working between departments, and most importantly, may give rise to constructive collaborations with a long-time impact.

Infrastructure and (shared) facilities

The four departments are currently located in three buildings. Since 2016 the BN department is located with the Biotechnology (BT) and Chemical Engineering (CE) departments in one building near the Reactor Institute Delft, which houses the RST department. The departments of ImPhys and QN are currently located in the Applied Physics building, next to the Kavli Nanolab Delft cleanroom facility. In 2026 a new building, including cleanroom facilities, is planned next to the buildings in which BN and RST are housed. The labs that were presented to the committee as part of the four tours were all well-equipped and provided with very effective, not to say excellent infrastructure and facilities.

QuTech

The committee was requested by the Executive Board of TU Delft to offer its observations and recommendations regarding the relationship between the physics departments (specifically QN) and the QuTech institute. The committee had difficulties acquiring sufficient insight in the relationship between QuTech and the QN department, including its history, challenges and the policies connected to the joint operation. This made it difficult to pass a well-founded judgment on the interaction and relationship and provide in-depth advice. The degree of entanglement between QuTech and QN simply makes it indispensable to know the story from two sides to provide proper feedback, even if that feedback is supposed to restrict itself only to one of the two sides. In the chapter on the evaluation of QN, the committee will provide further findings concerning the relationship.

Societal relevance

The committee noted that none of the departments had a well-defined strategy and course of resulting action aimed at achieving societal relevance. Some departments presented products, the use of these products and other marks of recognition as criteria for their relevance beyond the purely scientific domain. The committee will, of course, reflect on the societal relevance of the departments within the perspective of these metrics. Nevertheless, it wishes to emphasize the importance of developing a genuine strategy on societal relevance.

Through their research, the four departments train people for essential positions in the high-tech industry, in the consulting business or elsewhere in society. Since this is largely inherent in any PhD training in physics, the committee does not regard this as a distinguishing factor in the context of societal relevance. The committee would like to suggest that the Casimir Research School could actually be used as a vehicle, for example for supplying networking possibilities, to prepare PhD candidates for their future careers, in addition to providing advanced, scientific courses. Concerning specific, disciplinary knowledge with potentially direct societal relevance, the committee would like to draw attention to the RST department which has the unique role to train specialists with radiation expertise at the MSc and PhD levels. The committee considers this as an important, societally relevant aspect of the RST department, particularly as the training activities may sometimes compete with the use of the radiation facility for research purposes.

All departments mention patents as one of the metrics relating to societal relevance. The BN department explicitly mentioned the strategy not to primarily focus on the number of patents but rather to select patents that allow the protection of potential start-up companies. It is unclear to the committee if the other departments share this strategy. The committee recommends striving for a single and transparent strategy and concludes that under the present conditions, it is not meaningful to assess the number of patents generated, the average being around a modest 0.1 patent/PI/year. If creating patents is regarded truly important, the Faculty or the departments should provide training on the concept, function and legal aspects of patents and on ways to consciously work on their ideation.

Another dimension of societal relevance is outreach, which can be stimulated by allowing and encouraging researchers to invest time in connecting to the general public or other educational systems. Outreach metrics were explicitly provided by BN, QN and ImPhys, but no strategies were specified. The committee recommends each department to formulate concrete outreach objectives and set up a corresponding action plan. A natural start for the action plan may be provided by the ambitions and interests of individual PIs and PhD candidates with an inclination for outreach. In the framework of such an approach, they should be properly recognized and acknowledged for their outreach efforts.

Human Resources policy

Within the Netherlands, universities are rapidly changing their policies concerning career tracks, often abandoning not only the term 'tenure track', but increasingly also abandoning the long-term temporary positions that are associated with it. The Faculty of Applied Sciences in Delft is also changing its policy, from a Tenure Track towards an Academic Career Track system. It was difficult for the committee to distil a well-defined policy on this topic. All departments have or are transforming to the beforementioned flat PI structure. This structure does provide all employees with a level playing field to excel. The committee was pleased to receive consistent messages from the President of the Executive Board of TU Delft, the Dean and the Heads of Department that neither salary costs nor the explicit availability of open positions serve as arguments in the decision to grant or deny tenure or promotion.

During the site visit, the committee met with and talked to assistant professors from the four departments, who were in different stages of their tenure track. Overall, the committee encountered assistant professors who were satisfied with their position and most were happy with their start-up packages. The committee did notice that there are major differences between the departments in the way the career track is implemented in practice (e.g., mentoring, starting package and teaching). The main recommendation by the committee is to minimize the unnecessary differences between the departments, some of which are significant.

Tenure and promotion criteria

Criteria for tenure (and promotion to associate professor) are available, and are communicated in general terms but might not be sufficiently specific. Candidates know the areas they have to perform in, but not all have a clear picture of what is expected to get tenure. All assistant professors the committee met with, agree that clear communication at the start is essential and in many cases, this communication could still improve. The committee is positive about the fact that explicit quantitative requirements are abandoned, while the performance spectrum of the candidate is assessed according to five different criteria. The candidates understand this system and most consider it to be a positive development that a more qualitative approach is in place.

The distribution of assistant professors, associate professors and full professors exhibit systematic differences between the four departments, both resulting from and leading to sustained differences in how and at what pace research staff members are traversing the ranks of TU Delft's career track system. This must affect the appeal of certain departments for attracting new tenure trackers. The committee recommends reducing the differences between departments as much as possible and striving for more uniformity, for example by recognizing and applying each other's best practices.

Start-up packages

The departments are successful in hiring new talent and are often internationally competitive by offering start-up packages that sometimes include multiple PhD candidates. This competitive position is particularly the case for the BN, QN and ImPhys departments. The structure at RST is different, possibly in part due to costly beam-line investments, connected to the research direction of a tenure tracker. In some cases, the RST department could not provide an additional start-up package to an assistant professor. The large differences in starting conditions for young PIs between departments within the same Faculty are considered unhealthy and the Faculty is called upon to even these out.

Mentoring

The policy at the Faculty level is to provide each new PI with a mentor during their tenure track. Major differences were observed between departments in the implementation of a mentoring system. Not all assistant professors the committee talked to were provided with a mentor. Some chose their mentor, while others were assigned a mentor and some did not have a mentor at all. In some cases, the mentor was from within the assistant professor's department, while for others the mentor was from a different department.

The committee stresses that the independence that comes with the new, flat PI structure, also goes at the expense of the natural mentorship that is intrinsic to a more hierarchical structure. It therefore necessitates a more conscious mentoring attitude within the departments, especially by the Heads of Department. Mentoring should be provided to all research staff, with an emphasis on those PIs who are still early in their careers, and require the most attention. The committee regards the mentoring of assistant professors as an essential ingredient for their career development.

Training, teaching and workload

The teaching load of researchers – in particular tenure trackers – differs between departments. Even more pronounced differences were reported between Dutch and international research staff. Dutch assistant professors often teach in the larger BSc courses due to their proficiency in the Dutch language, occasionally leading to a very high teaching load. Other assistant professors are assigned the task to develop a new course, which is valuable but also time-consuming.

All tenure trackers have to obtain the University Teaching Qualification (UTQ). This explicit attention to the teaching quality is welcomed by the committee, but several assistant professors indicated that not all UTQ-courses are sufficiently meaningful and that the guidance provided in the UTQ trajectory should be improved. For example, an obvious part of the trajectory should be that some lectures of each new PI should be attended by educational experts and/or experienced colleagues, who can provide detailed feedback. At present, this is not customary.

Several assistant professors mentioned that they would appreciate attending a leadership course, helping them to become genuine leader of their group, 'read' personalities and learn how to deal with personal issues and with the spectrum of personalities of group members and colleagues. The committee expresses its strong support for this element of professionalization of leadership.

A healthy working atmosphere is important in general, and it plays an essential role in keeping the workload within bounds. Especially the tenure trackers operate under the pressure to be successful on multiple fronts within a limited time frame. The committee encountered tenure trackers quoting average working weeks of 60 to 70 hours. As a generic workload, this is considered unhealthy. The committee recommends providing clarity about the expectations (see earlier discussion on promotion criteria) and probing of the workload and experienced pressure, especially of the young PIs, in progress meetings, informal meetings and as part of their mentoring process.

Open science at TU Delft level

TU Delft has an Open Science Programme with the aim to take open science to the next level and make it a default way of practising research and education. The programme tackles areas of scholarly engagement and proposes new approaches to the processes of research, education, and innovation, with a focus on transparency, integrity, and efficiency. The implementation of this programme is facilitated by faculty-appointed data stewards, to whom researchers can turn for advice and help to implement open science. The committee recognises the opportunities and importance of the "open era" school of thought and the open questions and challenges researchers face in shaping a new scientific practice.

Academic culture

With its core values: Diversity, Integrity, Respect, Engagement, Courage, and Trust (DIRECT), TU Delft strives to be not only a leading university but also a great place to work. The Integrity Office coordinates the TU Delft policies and activities on integrity. A dedicated policy advisor is involved in topics such as social safety, (un)desirable behaviour, wellbeing, and health. This policy advisor works closely with the Diversity & Inclusion Office on the topics of diversity and inclusivity. A dedicated policy advisor works on the portfolio Academic Integrity, including Research Integrity, Research Ethics, and Educational Integrity. A clear policy of research integrity was visible in all four departments, in particular with an emphasis on the checking of data and peer review (also within the departments).

The various departments are consciously active in strengthening the academic culture, for example by involving all groups of researchers in decision-making, awareness around PhD-in-4 and PhD expectations, acceptance of failure in ambitious, high-risk research, social safety, and open data. Culture shifts, cohesion and potential social safety issues are addressed, though need to be consolidated in the upcoming evaluation period. For example, during the discussions with PhD candidates and tenure trackers, the committee noticed that not all of the intentions, guidelines, reported supervision goals and culture changes have already found their way to each individual. The committee thinks that it is very important to continue communicating the goals, the culture, and the expectations for a PhD degree, for tenure, etc., in the departments to all PhD candidates and new PIs. This should, for example, include the natural attitude to accept the occasional failure of high-risk research. Success is simply not guaranteed and it is the attempt that should be appreciated. The mere absence of full clarity on these matters and of genuine, collective adoption of the corresponding policies contributes to a lack of perceived social safety among PhD candidates and new PIs and might generate unnecessary pressure and stress. This was recognized in all departments, albeit with significant differences.

Another relevant observation in the context of the academic culture concerns the mutual appreciation between the departments and the self-esteem that the departments appeared to have. As was already mentioned, the committee regards the research of each of the four departments outstanding. Important in this respect is that for each department, this success is benchmarked with respect to the department’s own mission, where the four missions are not the same. This difference between missions puts every aspect of their performance and output in a different light. For example, it makes the importance of a high-impact publication different in each department. Similarly, a collaboration with a private party is not equally important for each of the departments. Even though this variation in character is recognized explicitly in the new SEP, it is not yet fully recognized and internalized within the Faculty, which leads to tension between the departments. The committee advises the Faculty and the departments to explicitly embrace the enriching diversity in the missions of the departments and implement this attitude in their appreciation, self-esteem and policies.

Diversity

TU Delft aims to be as inclusive as possible. This includes socio-economic, cultural, or religious background, nationality, gender, sexual orientation, age, physical appearance, and ability, as well as roles and positions. A diversity policy at the TU Delft level was founded in 2021 with dedicated policy advisors. The Faculty of Applied Sciences has appointed a

Faculty Diversity and Inclusivity Officer.

In the self-evaluation report the departments reflect on aspects of diversity, talent selection, and career perspectives. Diversity is part of strategy discussions in all departments, and the outcome of these discussions does affect decisions in hiring processes.

Obtaining a gender balance is translated into practical procedures. Obtaining balance regarding social, ethnic, and other minorities appears to be more difficult. This is partly because of the serious root cause problem in primary and secondary education in the Netherlands, making it hard for department management to act.

Graduate School

Some of the committee's findings on the training and supervision of PhD candidates are provided in the chapters of the respective departments. In this chapter, the committee provides its findings on several general aspects concerning the PhD candidates.

The TU Delft Graduate School (GS) prepares and trains doctoral candidates to become highly qualified, autonomous, and leading researchers and skilled professionals. The Faculty Graduate School (FGS) coordinates the Faculty PhD policy, consisting of guidelines for the selection and interim evaluation of PhD candidates, support for promotors and the objectives and guidelines for research and discipline-specific courses. Courses on discipline-related knowledge, competences and skills are offered by the FGSs or Research Schools. For PhD candidates from BN and QN, the Casimir Research School provides additional, discipline-related knowledge courses, as does the Kavli Institute of Nanoscience Delft. Disciplinary courses are overall considered good and valuable (e.g., Casimir), but transferable skills courses by the university are being evaluated as less useful.

The PhD candidates and PIs that the committee spoke to during the site visit were very open and willing to share their honest opinions. These interactions, combined with the information from the self-evaluation report, allowed the committee to get a clear view of the PhD policy and training. In general, PhD candidates are proud to be doing their PhD at TU Delft, where they can deliver high-quality research and boost their future (academic) careers.

The FGS is increasingly taking action to make sure that PhD trajectories run smoothly and PhD candidates are being well supervised, trained and finish in time. This development is a good start and the committee is stimulating the FGS to continue strengthening the structure and supervision of PhD candidates. In this regard, the committee has some suggestions and considerations.

Firstly, the committee noticed major differences in efforts taken by different departments in providing information and implementing suggestions made by the (F)GS. Forms have to be filled out, but these sometimes seem to be ignored and/or not taken seriously by the supervisors. Also, the committee learned that not all PhD candidates and PIs seem to receive all information. For example, the mentoring plan is a very nice initiative but the information is distributed once by mail and is often not mentioned to PhD candidates by the PIs. Another example is the PhD-in-4 plan (see also the PhD duration paragraph) that is already being implemented while PIs are still uncertain about its effects in the upcoming year.

Second, providing each PhD candidate with a mentor is mandatory, according to TU Delft regulations, while the self-evaluation report states that it is optional. A mentoring system seems to be in place, but many PhD candidates do not have (regular) meetings with a mentor. On request, a mentor is provided but the committee thinks that this should be enforced for all PhD candidates and that they should have at least a yearly meeting with their mentor.

Thirdly, the committee agrees with the importance of strengthening and supporting PhD candidates via a (local) Council that is mentioned in the self-evaluation report. The collaboration between the Faculty PhD Council and Departmental PhD Councils was greatly reduced during Covid-19 and not actively picked up thereafter. Due to the voluntary nature of the PhD representatives in the Departmental PhD Councils, it can be hard for them to maintain a complete representation within the department. However, the committee believes that PhD representatives are crucial for the wellbeing of all PhD candidates and for supplying them with adequate and timely information. By providing support and – more importantly – recognition from PIs, the Departmental Councils can play an important role in the interaction between PhD candidates and the Faculty. A more (pro)active role by the GS, departments and Faculty PhD Council could be of help to the local (departmental) PhD Councils.

PhD supervision and training

Although PhD candidates are overall happy with the supervision they get, some critical remarks were also made. For example, supervisors focus predominantly on the project and research and less on the PhD candidate as a person. Also, while some PhD candidates have (bi)weekly meetings with their supervising PI (and are happy with that), others have less contact and would appreciate more frequent meetings. The latter group often was less clear on the expectations for a PhD, which should not be to deliver four published papers but to conduct and report high-quality research. Formally, each PhD candidate has two supervisors, although in daily practice they usually deal with only one of those. If the interaction and supervision proceed well, which is usually the case, there is no problem. However, PhD candidates are strongly depending on this single PI, making them vulnerable in case of issues or problems.

PhD candidates mentioned to the committee that there are differences between supervisors when it comes to being offered opportunities for training and following courses; some candidates are fully supported to take courses and training, while others are discouraged by the argument that it would take too much time. Some candidates mention that they are not given the time to attend Casimir courses, which the committee regards as a shame. Similarly, the committee learned about differences between supervisors in providing support and opportunities to attend international conferences.

The committee concludes that initiatives for good PhD supervision and training are available, but mechanisms should also be in place to monitor the effectiveness of the supervision and ensure that it is working out well for each PhD candidate, without depending primarily on the interaction with a single supervisor. The Graduate School and group leaders should take a more (pro)active role in this.

PhD duration

An important focus for the committee regarding PhD policy was the PhD duration. The committee was pleased to learn about the new PhD-in-4 policy of the Faculty of Applied Sciences, especially because it had recognized in the self-evaluation report that the average duration for three of the four departments was alarmingly long. The committee has seen a strong drive from many PIs to work towards the PhD-in-4 goal and believes that the ongoing efforts will shorten the PhD duration.

The committee found during its interaction with the departments and individual PIs and PhD candidates, that there are significant residual differences between the departments in how and how seriously the departments have internalized this new policy. The policy still lacks clarity for PIs and PhD candidates. Moreover, if the intention is to increase the awareness of the PIs on the importance of time management, it is the PhD candidate who can suffer the most when time runs out and the contract is terminated. To the committee it is unclear if this new plan sufficiently 'measures' and - if needed - improves the quality of the time management by the individual PIs. The plan could benefit from more training and guidance of PIs on these matters. As a consequence of the new policy, an accumulation of delayed PhD defences may have to be expected in 2023-2027, with a large proportion of candidates who simply have to defend, in order to not drop out of the system. The committee would like to emphasize that this should not influence the quality and logistics of the PhD theses and defences.

Genuine implementation of the PhD-in-4 policy will require a culture shift that is not yet completed in all departments and not yet embraced by all PIs. The committee recommends the Faculty, and even the university as a whole, to make sure that the new PhD-in-4 target receives more thrust and that best practices are shared wherever possible.

An important point for improvement on which PhD candidates were very clear and consistent, is that more, clear, and consistent communication on expectations is necessary. It has to be clear both to PhD candidates and to their supervisors what the (minimum) requirements are to graduate and these requirements should be enforced. The committee recommends consciously moving away from the culture, in which often the 'myth' is still adhered to that at least four publications would be required for a PhD, sometimes even with the implicit expectation that at least one of these should necessarily be in a high-impact journal. In this respect, some improvements are seen, but the committee notices that more uniformity and clarity is still needed on what is really required to finish a PhD.

Typically, PhD candidates are given much freedom to find their own research topic. Even though this is appealing, it also often leads to a slow start and to delays in the PhD program. In this respect, the Faculty and departments should consider conducting the review of the first stage of the PhD trajectory earlier. By introducing strict agreements and deadlines and by forcing the PhD candidates (and their supervisors) to choose a research topic at an earlier stage, more PhD trajectories will enjoy a smooth start. Also, supervisors are advised to prepare a 'plan B' together with the PhD candidate who encounters a significant problem that blocks, delays or slows down their project, so that the PhD candidate can switch to an alternative project, before losing too much time.

1. In conclusion, the committee is positive about the PhD-in-4 policy that has been introduced. However, for this policy to be successful, a culture shift is required that is not yet completed in all departments or embraced by al PIs. The committee believes that the Faculty should work on the following recommendations:
2. Clear communication on expectations is necessary, for example on the (minimum) requirements to graduate. The committee considers it very important that the Faculty actively commits itself to myth-busting that four publications would be necessary for a PhD.
3. Information should be provided both to PhD candidates and to their supervisors on what policies are in place and what procedures should be followed. Also, more active monitoring is required of the application of the forms that document these procedures. Promotors and supervisors should know their responsibilities and be held accountable if they do not adhere to agreed policies and guidelines.
4. It should be ensured that all PhD candidates are assigned a mentor and that they have contact with their mentor at regular intervals, at least annually.
5. The departmental PhD councils and the faculty PhD council should be encouraged and supported in strengthening the interaction between PhD candidates and the Faculty.

Casimir Research School

The committee was asked to provide its view on the usefulness of the Casimir Research School for Delft PhD candidates (and others) in physics, in particular for the BN and QN departments. Even though the committee received mixed signals on this topic, its general perception is that the Casimir Research School remains a meaningful addition to the Faculty's own Graduate School. The added value is not so much in bringing together the PhD-candidates from Delft and Leiden, but is to be found in the disciplinary courses that are offered in the context of the school and that are not provided in other schools.

Concerning disciplinary courses, the committee noticed a significant difference in appreciation between PhD candidates with a physics background and those with a biology background. The latter mentioned that the course programme tends to be one-sided and concentrates primarily on physics subjects, some of which would not fit the level of background knowledge and research interests of biologists and biophysicists. In that respect, the committee advises the Casimir Research School to pay due attention to its course programme from the perspective of biologists and biophysicists, a target group with a significant representation in both Delft and Leiden.

Bionanoscience (BN)

Introduction
Quantitative biology at the molecular and cellular scale is a fast-developing research field. Industries traditionally rooted in physics and engineering are shifting their attention to multidisciplinary approaches focussing on biology at the nanoscale, requiring interdisciplinary science and talent to be developed. These developments have led to the establishment of the highly interdisciplinary Department of Bionanoscience (BN) in 2010.

The department's mission is to address fundamental questions in biology by developing and using cutting-edge methods at the interface of nanoscience and physics. From single molecules to the full complexity of living cells and tissues, the department wants to understand how biological function arises and can be harnessed for technological and therapeutic gains. Through research and the training of multidisciplinary engineers and scientists, the department aims to accelerate the translation of fundamental science into societal impact.

Organization
Similar to the other departments in the Faculty of Applied Sciences, BN employs a flat PI model that offers independence and equal say to all PIs. To foster engagement and ownership among research staff and allow early career PIs to directly influence the strategic actions taken, BN uses a dossier structure. Each dossier includes five members (PIs and other stakeholders) on a specific topic, such as people & culture, funding &strategic positioning, infrastructure & safety, and education. The dossiers are responsible for developing strategic actions to implement the department's strategic aims.

One aspect that strikes the committee as particularly unique and exciting, compared to other Biophysical Departments around the world, is the flat and democratic structure. This enables the department to integrate and engage all its PIs, who take part in the decision-making process. The committee initially had some concerns that this structure would put too much administrative burden on the head of the department, but the introduction of the "dossier" structure should help alleviate this burden.

Strategy and research quality
During the period of evaluation, the department's strategy was a continuation of the previously existing strategy, based on the recommendation by the previous committee to follow through on the stated strategic aims. New strategic aims supplemented the existing aims, categorized in research quality, societal impact, academic culture, HR policy, PhD policy, and open science. These new, long-term strategic aims resulted from numerous discussions at faculty meetings and the annual strategy off-site days for PIs. The strategic aims concerning research quality at BN are 1) to perform outstanding research and maintain a leading position across the full breadth of the research spectrum, and 2) to create synergy between theory and experiments across the research spectrum.

The committee congratulates the BN department for its successful development in the past 12 years. BN is a strong scientifically oriented research department. It started with just two groups and developed and grew into a healthy and sustainable department with approximately 20 PI groups, some of which are at the leading edge of their fields. This is evidenced by the quantity and quality of the publications, as well as by the department's ability to attract funds nationally but also internationally (European Council and the Human Frontiers Science Programme). The research in the department is leading edge and is advancing the respective research fields. By aiming at increased common participation in collaborative grants, the department might further improve cohesion and capitalise on funding opportunities.

The committee commends the numerous internal collaborations that further the quality of the research. These interactions are not organized top-down, but rather encouraged by regularly bringing together the departmental research staff and stimulating fruitful discussions that might lead to collaborations.

Relevance to society
The department has formulated a strategy

towards societal impact, consisting of three aims: 1) establish a knowledge base that will enable innovations in health care and sustainable production of bio-based products and smart materials, 2) establish patents, start-ups and collaborations with industries and societal stakeholders to translate the knowledge base into societal impact and 3) meet societal needs for talent with excellent training in multidisciplinary sciences.

The department aims to increase its activity within the Convergence programme to create opportunities for medical impact with Erasmus University Rotterdam and Erasmus MC.

The committee has the impression that connecting research to health care could potentially increase the societal impact of studies by bridging the gap between fundamental insights and health application, while currently the direct societal impact appears to be limited. The committee recognizes the value of collaborations with hospitals and other stakeholders to move fundamental insights towards the (fundamentally oriented) health and biology communities. These collaborations will help translate research into useful technologies. Patents, start-ups, and the Fagenbank are also relevant aspects of the department concerning societal relevance.

Open Science
The BN department aims to make its science and education freely available to societal stakeholders, to communicate the results to the public and to increase the influence of science in politics and public administration. A data management plan is drawn up at the start of each PhD, and many PIs maintain open-source software, and datasets, and run Open Science projects such as the Fagenbank. For the upcoming evaluation period, BN aims at establishing a departmental policy for Open Science and making adherence part of the yearly R&O cycle.

It is clear from the self-evaluation report that the department is making great efforts to disseminate its findings in an open format. The department is doing extremely well in this respect and deserves a compliment. The committee encourages the department to continue in this direction.

Academic culture
In the period of this review, BN formulated three aims on academic culture, namely, to craft an open culture where all layers of the organisation feel included and can reach their full potential, to craft a shared intellectual environment that allows them to fully capitalise on the in-house synergy, and to maintain and develop international recognition.

The committee considers the academic culture to be good, typical of an internationally leading department like BN. There is a good frequency and mix of departmental colloquia with internal and external presentations. Social safety within the department is also being addressed proactively, after the identification of some internal issues by the head of the department. The committee was pleased to learn that these issues are proactively dealt with, and that research staff and PhD candidates will soon be required to take ‘active-by-stander’ courses.

Human Resources policy
The department aims at attracting and retaining a diverse set of top scientific talent and broadly develop the talent base. Furthermore, BN aims at hiring both PIs with a focus on research and PIs with a focus on educational leadership. To attract international talent at the tenure-track level, BN has chosen to invest heavily in talent through internationally competitive start-up packages. From the interview during the site visit, it became clear that the department has no formalized mentoring in place for new tenure trackers. While the department's openness provides support, such as in writing proposals, the committee believes that a mentor can reduce the threshold to discuss issues or serve as an incentive, for example, the moment to share a research proposal for feedback.

The department has achieved a good gender balance at the PI level, but at the PhD candidate and postdoc level, the balance appears to be lagging due to the skewed balance of undergraduate students. The department has assigned this issue to the personnel dossier holders and the committee encourages the introduction of a mentorship programme that focuses on preventing dropouts, especially of female researchers, between the PhD and postdoc levels. Female PIs can act as mentors and role models to stimulate women to continue with a postdoc.

Viability
In the self-evaluation report, BN describes that the strategic aims of the evaluation period remain in effect. In addition, several new aims are added for the upcoming period. These aims include funding opportunities, internal and external collaborations, inclusivity, integrity and psychological safety and mentoring structure for tenure trackers.

The committee does not have any particular concerns regarding the future viability of the BN department. Finances appear to be very healthy, with ample external and internal funding. Furthermore, a well-balanced department is being built with a good distribution of senior PIs (full professors) and junior groups (tenure trackers). The additional aims that are formulated for the upcoming evaluation period show that the department is well aware of the issues and challenges it has to deal with. The committee is confident that the department will take significant steps on these topics in the upcoming period, furthering the quality and impact of the department and its research.

PhD training and supervision
Similar to all departments, BN aims at decreasing the average PhD duration (time to defence) to 4.5 years without compromising on thesis quality. It furthermore aims to increase the career prospects of the PhD candidates within industry and academia.

Overall, the department is performing well in its training and supervision of PhD candidates, though there is some room for improvement. In particular, the PhD supervision and training record reveals two important aspects that need to be addressed: (i) the time to completion is too long and (ii) the “quitting” rate is too high. These are recurring and persisting issues that were already highlighted in the evaluation report six years ago. Based on discussions during the site visit, the committee concludes that actions regarding ‘PhD-in-4’ at BN are not yet embraced by all PIs.

Therefore, the committee recommends that a drastic cultural change is adopted, which is required within the department. This cultural change has to start at the senior level of the department (PIs). For example, the department could consider revisiting its recruiting strategies and mentoring schedule following recent successful models at other institutions, such as the one at the Crick Graduate School.

By combining physics and biology, the department has to take a dual training approach: training biologists to do physics and vice versa. This is not an easy challenge, particular to train biologists in physics. It might even be part of the high drop-out rates of PhD candidates. This factor should be part of the fact-finding questionnaire.

Regarding the Casimir research school, discussions with the PIs gave the impression that Casimir is less useful than it once was. However, discussions with the PhD candidates clearly showed that the courses provided by Casimir are generally well appreciated. The committee recommends that - to improve Casimir and maintain its purpose - the courses offered are expanded to fill emerging gaps/needs in the PhD curriculum (i.e., Physics for Biologists).

Conclusion and recommendations
In conclusion, a highly successful and internationally recognised department was built that is doing very well in many fronts such as research quality, organisation, and academic culture. Towards the future growth and improvement of the department, the committee highly recommends that it addresses two specific aspects:

1. Gender balance and diversity amongst the PhD candidate and postdoc population,
2. The PhD completion times and quitting rates.

The committee thinks that both of these issues could be addressed by adopting a new PhD recruiting strategy. To this aim, a comparative study that includes other leading research institutes in Europe may help identify effective and diverse recruiting approaches.

Imaging Physics (ImPhys)

Introduction
The Department of Imaging Physics (ImPhys) is a hub for physics-driven innovation of imaging technologies and instrumentation. ImPhys consists of approximately 18.7 FTE PIs organised in several areas of scientific expertise and orientation. The group of PIs jointly supervises 75.5 FTE of PhD candidates and 17 FTE postdocs. A group of 12.4 FTE permanent staff technicians and administrative staff supports the department's research activities.

Organization
The ImPhys department focuses on three application themes, each with a societal impact: life sciences, healthcare, and the high-tech industry. During the evaluation period, the governance of the department has been reorganised, making a transition to a flatter organisational structure with larger independence and better visibility of starting faculty. In 2019 the different sections were reshuffled to better reflect the strategic focus, the current four sections are Computational Imaging, Medical Imaging, Microscopy Instrumentation & Techniques and Optics. According to the committee, the ongoing reorganization process is creating some uncertainty within the department on its identity, but is pleased to also recognize that consensus is being progressively reached. Overall, there are several interconnections among the different areas where the PIs are working. Some attention is needed to make sure that the new organisation will give all PIs the opportunity to make themselves visible, while ensuring critical mass for each team.

Strategy and research quality
In the evaluation period, ImPhys worked on the consolidation, strengthening and renewal of its position as an internationally leading centre for research into imaging physics. Strategic aims were to enhance the development of personnel and organization, to increase impact on sciences, industry and society, and to improve the facilities and infrastructure.

The ImPhys department is performing very well in terms of research and fundraising, with a boost in 2022. The major focus is related to the development of advanced technology and methodology in the field of Imaging Physics, targeting two major application areas: Health/Life Science and High-Tech Industry. Both lead to important advances also in material characterization and material science that could be made more evident to the opinion of the committee.

A promising research line in integrated quantum optics is also present, with connection with the spin-off company Single Quantum. Although it seems somewhat aside the mainstream of the department, the committee thinks that it would be of advantage for ImPhys to strengthen its collaboration with the Department of Quantum Nanoscience.

The instrumentation of ImPhys is really state-of-the-art, with novel approaches emerging in several areas: optical imaging in the extreme UV, acoustic imaging and electron microscopy combined with optical imaging. Wider application areas are also emerging, for example in agrifood for food quality assessment and in cultural heritage.

Several interactions are present with other departments, in particular Bionanoscience. In these interactions, ImPhys is often acting as a crucial enabler both for developing new science and for applications. In this respect, more visibility would be deserved. Although the department is already performing well in terms of collaborations within the Faculty, there is space for further improvement. The DEMI initiative will strongly involve ImPhys and will provide an important opportunity in this respect.

Collaboration with the high-tech industry is based on a very healthy interaction, granting good freedom in R&D and the possibility to publish scientific results without too severe constraints related to IP protection. In general, the challenges that are faced in actively supporting high-tech industry stimulate new scientific knowledge while fostering real innovation.

Relevance to society
Societal impact is based on solid research and to maintain and further extend impact, the department aims at strengthening and adapting long-term ties with leading academic groups, industrial partners, and academic medical centres. The committee is positive about the societal impact of ImPhys. Being strongly focused on the development of advanced enabling technologies is making the R&D outcomes of the department relevant to society. At the same time, the committee believes that the success of the department could and should be made more visible than it is in the self-evaluation report. It would be important that researchers of the ImPhys department are promoted to be part of public and policy-making bodies, such as the KNAW, the Netherlands Academy of Technology and Innovation (AcTI) as well as the Academy of Engineering that is to be founded in 2023.

The department is very active in dissemination and outreach activities. Some books that are in use at Delft's BSc and MSc courses have been written by members of this department. Moreover, several activities and participation in several outreach events are reported, for example, the active engagement in discussions with representatives of industry and multiple appearances in the media.

ImPhys has a clear strategy for bringing forward applications and linking technical progress to spin-offs, products and other forms of practice. However, due to retirement, two pioneers in this valorisation dimension will be leaving. Nevertheless, there are still sufficiently many experts in the department to continue the entrepreneurial mentality. The committee recommends having strategic discussions on the division of research between fundamental research and technique/model developments and to extend this strategy to the hiring policy.

Open science
The department strives for more open science through open-access publications and making research data, scripts, and software publicly available via data repositories and software development platforms. Whenever it is possible, open access policy is pursued in publications. The department has increased in the evaluation period, from 44% to 75% open access publications. ImPhys aims at 90% in the next reporting period. The committee notices that concerning open access, the ImPhys department is behind on the other departments in this review. However, this is partly due to General Data Protection Regulations (GDPR) in publications on health applications.

Human Resources policy and academic culture
In the evaluation period, ImPhys worked on attracting top talent and initiating new research, leading to extensive rejuvenation of the research staff and research portfolio. Diversity and inclusiveness are important aspects and in the evaluation period, the focus lied on gender balance. This is reflected in the percentage of new hires, with 3 out of 7 new tenure trackers being female. This is a promising development although further steps are required. The consciousness of the need to use all opportunities (e.g., specific programs for recruitment of women) to reduce the gender gap, but also to support diversity at large, is present.

Section leaders are expected to act as *coaches* for younger PIs and for handling common operational issues. A daily board of the department was introduced and now includes a diverse selection of four PIs. A rotation scheme for these PIs was created to increase awareness and understanding of internal processes among all research staff. This led to greater involvement of – in particular – associate professors in the department organisation. Strategic issues are discussed in monthly faculty meetings in which all PIs participate.

Concerning talent management, the committee recognizes that there is serious room for improvement. In particular, career progression within the department tends to be slow, with PIs staying unnecessarily long in each career stage. This stands in contrast with the overall successful level of activity of the department.

Viability
Based on a SWOT analysis and ImPhys' own benchmarking, the department formulated a strategic focus for the coming years. The department's mission statement is sharpened to make the ultimate societal relevance explicit to

the outside world. ImPhys aims to span the full dynamical range from fundamental curiosity-driven research to application-driven technology development. To create impact, the department will team up with societal and academic partners. Furthermore, the department will focus on networks as drivers of future research.

According to the committee, there are no issues that restrain the viability of ImPhys. The strategy for the upcoming period is solid. Nevertheless, in the self-evaluation report, the lack of full consensus on the identity of the department is mentioned as a weakness. The committee noticed that the department explicitly has different application directions, making it difficult to identify the strengths of the individual groups. However, some common technological and scientific approaches underlie the different application directions. It is important to make these common and unifying aspects more evident. The committee points out that new emerging areas could be targeted (e.g., quantum imaging, aerospace), profiting from future recruitment to cover the three senior positions that will become available in 2023, while trying to keep good synergy among the different application directions.

PhD training and supervision
The department is satisfied with the quality of the theses that PhD candidates produce but does recognise that the average PhD duration is a major issue and a real challenge. At the time of the review, there was a strong push to keep the duration of PhD projects within four years. This topic has been discussed extensively at the yearly strategy retreat with the PhDs, to search for the main reason for the delays and for measures to improve. A document with measures promoting cultural change, strategies for selecting candidates and for monitoring of the PhD trajectory has been written and distributed. At present, the department is performing reasonably well. Unfortunately, not all PIs seem to share the push to meet the PhD-in-4 timeline. Shared rules and – in particular – enforcing these rules would be welcome to normalise the situation for all.

Conclusion and recommendations
In conclusion, the assessment of the Department of ImPhys is largely very positive. The members of the Department can be proud of what they are doing. Indeed, they play a very important role with strong impact both in science and industry. The committee provides several recommendations to further improve the overall performance of the department.

1. The collaboration with other departments could be strengthened, and – where existing - made more visible, if only to recognise all the merits and receive the deserved credits for the ImPhys contribution.
2. Researchers of the department should be stimulated and promoted to be part of public and policy-making bodies to increase the impact of the valuable experience and knowledge developed in the department.
3. In terms of talent management, taking into account the successful activities of the department, career opportunities should be fostered to reduce the time for progression on the academic career path.

Quantum Nanoscience (QN)

Introduction
The Department of Quantum Nanoscience (QN) aims to initiate avenues for quantum innovation in the broadest sense. The research is organized into three themes, with every PI contributing to at least one, and all themes utilising experiments and/or theory: quantum matter, quantum transduction and quantum sensing. In the period of this evaluation, the department has focused on strengthening its research profile, enabling, and encouraging spin-off activities and strengthening its internal culture. QN houses 21 PIs who supervise and monitor approximately 16 postdocs and 120 PhD candidates.

Organization
Similarly, to the other departments, QN is structured in a 'flat' organisation, with all PIs being positioned directly under the Head of Department and being responsible for their group. All PIs meet once per month to discuss both short-term practical matters and long-term strategic matters. The management team of the department includes – by rotation – three PIs (including one tenure-tracker). In terms of governance, the committee has the impression that the department is extremely well run, and the transition of the flat PI structure has been implemented well, i.e. without overlooking the need for providing mentoring and guidance for the tenure trackers.

Strategy and research quality
QN developed its current research themes through a bottom-up process after QuTech was established. The research themes allowed an enhanced focus on advancing the department's abilities to design and create novel quantum materials, sensors and transducers. Particular attention has been devoted to the electron microscopy research field. The committee believes that the research quality in the QN department is of outstanding quality with high visibility. Many of the PIs are considered to be leaders in their respective fields. In addition, new talent has been successfully hired. The department has a very productive range of publication frequencies per PI, with an impressive list of prestigious grants and prizes. The research in the department is furthermore supported by state-of-the-art cleanroom facilities.

The committee believes that the focus on fundamental aspects of nano and quantum science – for example in quantum matter and materials, sensing and interfaces between physical encodings – will play a tremendously important role to enable the success of more applied research in the years to come, including the efforts pursued at QuTech. In that sense, QuTech will benefit from the more foundational research of QN.

The committee furthermore thinks that the department managed the difficult transition from pre-QuTech to post-QuTech very well and QN is well positioned for the years to come, well beyond the hype cycle that more applied quantum technology research might face. The strategic research direction was obtained based on a broad consensus and is well aligned with and distinct from the goals of QuTech. In this context, the committee perceives the existence of QuTech as a unique opportunity to have and maintain critical mass and attract the best talent to Delft to attain a worldwide top position in certain areas. A more clear and easy-to-handle administrative structure for QuTech and its relationship with QN might be advisable if feasible.

Societal relevance
Initially, the focus and strength of the department have been in fundamentally oriented research. Since more recently, the department also aims at complementing the fundamental research with more technologically oriented research. By now, the department has shown that it delivers on its mission to serve as a breeding ground for new quantum science and technology applications. In the more distant past, this resulted in two "spin-off departments" (Bionanoscience and QuTech), which demonstrates the department's success to innovate. More recent examples are to be found in two successful spin-off companies.

QN mentions influencing policy, and contributing to policy discussions on quantum technology, as an objective. If the ambition reaches beyond informing the general public on the “potential of quantum computing” and goes towards influencing policy making, then the committee recommends developing a specific strategy around this and considering alignment with QuTech.

Open science
The QN department, in line with the TU Delft ambitions, aims at being a frontrunner towards open science. Many measures are in place, e.g., data stewards and champions, consulting and learning opportunities. Overall, approximately 80% of publications have been in journals with immediate or delayed open access. Of those, > 90% of publications share some data and or code). According to the committee the QN department has taken on a leading role in the field of open science.

Academic culture
In general, the committee was impressed with the transparent and open atmosphere and the success in hiring scientific excellence while also raising diversity. The promotion culture is healthy, which leads to a future-proof age distribution of PIs. Throughout the site visit the committee perceived a sense of being heard in the department, not only with strategic goals but also with cultural change or social safety issues, e.g., in open science and PhD supervision. Important culture shifts mostly have already happened in this department in ways that could serve as best practices for adoption by the other departments.

Human Resources policy
The department aimed at recruiting and developing high-calibre research staff, facilitating and supporting their scientific independence and increasing the diversity of the team of PIs. Six new PIs were hired, primarily aimed at the tenure-track level. The department can offer attractive start-up packages, although it is difficult to have these packages fully competitive at an international level. Furthermore, the timescale for getting labs ready for new groups is a problem not only for those waiting for the labs but it is also becoming a problem for attracting the best talent.

The focus on inclusivity, a supportive culture and awareness is present in this department. Concerning diversity, the department does well on the aspect of internationality, with over 50% non-Dutch PIs. When looking at gender diversity, the department did improve during the evaluation period, though further improvements are required. Specifically, the department has no female full professors yet.

Viability
The department faces the challenge of phasing out of the Nanofront grant but has a viable plan in place with the broad support of the faculty. In addition, since the report was completed, new strategic funding via Quantum Delta has been acquired already. For a successful continuation of the department, the committee has several suggestions. The first is to continue with the bottom-up approach of adapting the department’s own identity, focus and strategy in the light of the rapid developments in the field. In particular, the committee would advise making sure that the focus areas are not considered to be a limitation for curiosity-driven research, both for the existing faculty and for new hires.

Second, having a well-defined strategy and mission that is distinct from the quantum information research at QuTech will be helpful to collaborate more closely with QuTech at the level of individual researchers. The committee stimulates the QN department to keep its scientific position and mission distinct, yet open and to make sure that they remain complementary to those of QuTech. The committee furthermore suggests the department to strengthen and incentivize the collaborations between QN and QuTech, in order to tap the full potential of this collaboration, in particular on the level of individual groups. Joint seminars and summer schools might be required to maintain cohesion. This is not only relevant between the researchers within the department but also between QN and QuTech, in particular once the two move into two different buildings. The committee would also advise providing a level playing field in terms of funding, building infrastructure and availability of technical staff, to avoid unnecessary tensions and uncertainties.

PhD training and supervision
With a relatively close supervision style, the majority of PIs spend a significant timeshare on individual and group discussions with their PhDs.

The department adopts a strict extension policy in which an extension is only provided based on a dossier with detailed planning towards the finalisation of the thesis. The success rates of PhDs show impressive percentages of PhD candidates graduating within five years and less than 10% dropouts. It shows that the QN department has already taken major steps in changing the culture of stimulating and enabling PhD candidates to graduate in time and, otherwise, keeping them employed until they succeed.

Conclusion and recommendations
The QN department conveyed a unified, positive, and energetic spirit on all levels. The research quality is excellent and its strategic positioning as a breeding ground for new quantum science and technology applications is sound. The committee has the following recommendations:

1. The department should to adapt the specifics of the strategy in a bottom-up way to further sharpen the profile without imposing any limitations on curiosity-driven and interdisciplinary research.
2. Further strengthening the collaborations between QN and QuTech to tap into the full potential of this unique setup in Delft.
3. The committee encourages the department to take an active role in the further dissemination, both internally but also within the faculty and the university as a whole, of its important culture changes, e.g., PhD duration and open science, and of the strategies adopted to realize these changes.
4. The university needs to make sure that the infrastructure and laboratories (both the new and old buildings) are functional and available with the necessary technical support to stay competitive in particular for new hires. This is necessary to maintain the successful trajectory of QN in the future.

Radiation Science & Technology (RST)

Introduction

The Department of Radiation Science and Technology (RST) has unique expertise in using neutrons and ionising radiation in research and education. The department has access to the 2.3 MW nuclear research reactor that is currently also being equipped with a cold neutron source. The RST has been established to provide academic research and education in various disciplines using the nuclear reactor, beam-line instruments, irradiation facilities, imaging instruments and radiological laboratories. The department consists of 23 FTE of scientists, four affiliated professors, 13 FTE technicians, ten postdocs and about 55 PhD candidates.

Organization

The RST department was established in 2005 when the Interfaculty Reactor Institute (IRI) was divided into the Reactor Institute Delft (RID), responsible for the safe operation and valorisation of the TU Delft reactor, and the scientific department RST, responsible for the academic research and education. The separation of RST and RID allowed the RST department to be established as a scientific department of the Faculty of Applied Sciences. The committee appreciates the amount of work that has been done to address the issues identified in the previous SEP review.

RST has been organised into eight disciplinary groups of independently operating researchers (PIs). The committee noted that significant efforts have been made to change the organization structure from traditional hierarchical sections to a flat PI organization, which provides much greater flexibility in adapting research directions in dynamically changing fields and is beneficial for further development.

Strategy and research quality

In its research, the RST department focuses on Materials Science with an emphasis on energy conversion and storage and Health Technology for imaging, therapy, and food research. Two other fields are related to Nuclear Technology and Instrument Development. In addition, RST contributes strongly to the education of TU Delft students with backgrounds in physics, chemistry, biomedical, sustainable energy technology, and computational/AI sciences. RST's activities are centred around the research reactor at TU Delft (jointly with the RID) and the proton beam at HollandPTC. Following the recommendations of the last research review, RST has taken extensive measures to raise the profile of its research strategy.

The department strategy was streamlined to focus on the topics that would benefit most from the radiation infrastructure and give RST a leading edge. This combination bore fruit in an overall very high level of research in all areas where RST holds one of the world's leading positions, including material research with a very successful and rapidly growing battery platform; health science with a focus on the medical application of radionuclides and radiation for cancer diagnostics and therapy with a strong track of collaboration with industry and hospitals; and the development of new methods and tools in nuclear science.

Although the standing of the RST department is excellent in several research areas, the committee recognizes that the process of shaping the identity of RST and understanding its overall strategy is ongoing and that further steps can be taken to increase the visibility of the department and to excel in research. Strategy discussions, currently limited to individual research areas, should be expanded to the Department and Faculty levels to improve interaction among the various areas within RST and to strengthen collaboration with other Departments. Directing research toward greater emphasis on reactor capabilities or toward excellence in specific areas should be discussed to further shape the department's strategy. For broad areas such as battery research or therapy development, a different organizational structure with stronger links to other faculties could be considered as an option.

Relevance to society

The RST department is clearly and macroscopically focused on societally relevant studies that drive strategy development. The apparent fragmentation into small groups is the logical consequence of the fact that it serves health, reactor knowledge, and material research for sustainable energy conversion and storage.

The Health science division has a strong record of collaboration with hospitals and the medical industry (MILabs and Quirem) in the development of imaging platforms for new radiation therapies for cancer patients. Techniques developed by the Materials science division are being used by Physee and Pilkington to produce large luminescent solar concentrator windows, while the small modular reactor developed by the Nuclear research division is now being commercialized by an industrial consortium. Reactor facilities are used for non-invasive investigation of heritage objects and in the context of the food industry (collaboration with Campina).

In *Advice to policymakers*, RST has defined a desired output without further quantifying what this entails. In this regard, a shift from the current passive role to a more active stance is needed by discussing this aspect with all PIs and making it part of the strategy.

Open science
The department's strategy was to commit strongly to the principles of open science. One of the PIs was appointed to the Open Science Working Group. Another was appointed as a Data Champion at the Faculty level and assisted many colleagues in adopting FAIR data practices. To build momentum, the department regularly organises information sessions on open science, open source, and data sharing. In the committee's view, the department performs very well in publishing in open-access journals and sharing data through repositories. The share of peer-reviewed journal articles reached 90% in 2021.

Academic Culture and Human Resources Policy
To strengthen the academic culture, RST made efforts to improve the collaborative environment within the department, such as establishing a technician pool to stimulate information exchange between researchers and groups. Furthermore, large instruments used by multiple groups are now purchased and maintained jointly. Both PhD candidates and tenure track professors are assigned a mentor from another department, to provide early-career and mid-career researchers with an independent mentor with whom they can discuss issues such as integrity, workload, and safety.

The research staff has been rejuvenated with the hiring of six tenure-track assistant professors, two of which are female. This has improved the gender balance, but more efforts are required. To ensure that all PIs contribute to the department in their own way and to increase motivation, the strategy has been to allow PIs to develop their focal points, such as education, research, valorisation, or leadership. These focal points are included in the yearly appraisal meetings. The transition to a collaborative department with small disciplinary groups increases the visibility of individual PIs, fosters their creativity and constructive collaboration with other PIs, and creates a positive academic environment for cutting-edge research. However, the starting packages for tenure-track assistant professors appear to be rather modest compared to other departments, and in some cases, they are limited to access to expensive instrumentation. Possible measures to bring the starting packages in RST in line with other departments might include shared funds generated from project levies. Also, the typical times required for reaching the next in carrier steps are relatively long and should be harmonized with the career paths in other departments.

Viability
In general, the viability of the RST appears to be very good. The department has recognized the importance of neutrons and other radiation sources to socially and economically important areas such as battery research, medical therapy and diagnostics, and the food industry so that the use of the reactor is assured in a long term. The reactor and existing instruments have been upgraded, and new instruments have been developed and installed. The cold neutron source opens unique research opportunities that will undoubtedly promote academic and industrial cooperation worldwide and contribute to the valorisation of the reactor. However, the heavy dependence on instrument availability (outages due to maintenance and installation of the reactor

are not uncommon) make RST financially and scientifically vulnerable to some degree.

During the period of this evaluation, a misbalance between the lump sum funding of the department and the permanent personnel costs led to a financial problem. Despite successful efforts to secure external funding, which was greatly increased during the evaluation period, the department decided to reduce the number of core research staff, as part of its long-term strategy to limit the budget deficit. Joint financial strategy and planning at Faculty or even at the University level will be required to alleviate the financial pressure and contribute to the research excellence of this department. To mitigate the risks associated with instrument closure, further strengthening of theoretical and computational sciences in addition to experimental research would be beneficial.

PhD training and supervision

The committee is positive about the development of the RST PhD council which is being actively supported by the department. The Covid-19 period led to a decline in social cohesion among PhD candidates, which is currently being remedied. The connection between departmental and Faculty PhD councils is also being stimulated, which is a good development.

The department is aware of the long average duration of its PhD trajectories and the high dropout rate (11% of candidates do not obtain the degree) and has taken steps to improve the situation. These measures are in line with the Faculty-wide PhD-in-4 policy. The changes that are being implemented concern both the recruitment process, which involves several people including two supervisors, and the mentoring process. The department head holds regular meetings with the supervisor and the PhD candidate, after one year and after 2,5 years, in order to plan for the remaining time. Even though this demonstrates genuine commitment, the committee believes that the problem of the long duration of PhD projects is more persistent and requires – in addition to the measures already taken – a cultural change in the department, in particular at the PI level.

Conclusion and recommendations

The research reactor at TU Delft is undoubtedly an asset to the Faculty of Applied Sciences, and the committee appreciates the extensive work done by the RST department to make the most of the radiation infrastructure, exploiting it to give RST a leading edge. The organisation and strategic decisions implemented by the RST have been largely positive and have helped to raise the profile and the international recognition of the department. The committee recognizes the excellent level of research in a rapidly growing battery platform that has the potential to become a hub for battery research at the university level, as well as the development in health science with an impressive track of collaborations with industry and hospitals. The committee recommends:

1. Continuing the successful process of shaping RST's strategy by expanding the department's strategy discussions to the Faculty level, in order to strengthen collaborations with other departments and anchor the mission of the department more firmly into the overall strategy of the faculty and the university.
2. The committee recognizes that the heavy reliance of the RST department on reactor availability makes it financially and scientifically more vulnerable compared to other departments. In this context, the committee encourages more general strategic discussions about either directing the research toward a greater emphasis on reactor capabilities or moving toward excellence in specific areas, as well as developing a joint financial strategy at the Faculty and University level to reduce financial pressures and contribute to research excellence.

Appendices

Appendix 1: SEP 2021-2027

The committee was requested to assess the quality of research conducted by the Physics departments at Delft University of Technology as well as to offer recommendations to improve the quality of research and the strategy. The committee was requested to carry out the assessment according to the guidelines specified in the Strategy Evaluation Protocol. The evaluation included a backwards looking and a forward-looking component. Specifically, the committee was asked to judge the performance of the departments on the main assessment criteria and offer its written conclusions as well as recommendations based on considerations and arguments. The main SEP-criteria are:

1) Research Quality: the quality of the unit's research over the past six-year period is assessed in its international, national or – where appropriate – regional context. The assessment committee does so by assessing a research unit in light of its own aims and strategy. Central in this assessment are the contributions to the body of scientific knowledge. The assessment committee reflects on the quality and scientific relevance of the research. Moreover, the academic reputation and leadership within the field are assessed. The committee's assessment is grounded in a narrative argument and supported by evidence of the scientific achievements of the unit in the context of the national or international research field, as appropriate to the specific claims made in the narrative.
2) Societal Relevance: the societal relevance of the unit's research in terms of impact, public engagement and uptake of the unit's research is assessed in economic, social, cultural, educational or any other terms that may be relevant. Societal impact may often take longer to become apparent. Societal impact that became evident in the past six years may therefore well be due to research done by the unit long before. The assessment committee reflects on societal relevance by assessing a research unit's accomplishments in light of its own aims and strategy. The assessment committee also reflects, where applicable, on the teaching-research nexus. The assessment is grounded in a narrative argument that describes the key research findings and their implications, while it also includes evidence for the societal relevance in terms of impact and engagement of the research unit.
3) Viability of the Unit: the extent to which the research unit's goals for the coming six-year period remain scientifically and societally relevant is assessed. It is also assessed whether its aims and strategy as well as the foresight of its leadership and its overall management are optimal to attain these goals. Finally, it is assessed whether the plans and resources are adequate to implement this strategy. The assessment committee also reflects on the viability of the research unit in relation to the expected developments in the field and societal developments as well as on the wider institutional context of the research unit.

During the evaluation of these criteria, the assessment committee was asked to incorporate four specific aspects. These aspects were included, as they are becoming increasingly important in the current scientific context and help to shape the past as well as future quality of the research unit. These four aspects relate to how the unit organises and actually performs its research, how it is composed in terms of leadership and personnel, and how the unit is being run on a daily basis. These aspects are as follows:

4) Open Science: availability of research output, reuse of data, involvement of societal stakeholders.
5) PhD Policy and Training: supervision and instruction of PhD candidates.
6) Academic Culture: openness, (social) safety and inclusivity; and research integrity.
7) Human Resources Policy: diversity and talent management.

Appendix 2: Programme of the site visit Applied Physics at TU Delft

Monday 16 January 2023		
18.00	20.00	Preparatory meeting committee
Tuesday 17 January 2023		
8.30	9.30	Welcome by Rector, Dean and Heads of Department
9.30	12:30	Department of Bionanoscience (labtour(s) and interview)
12.30	13:20	Lunch and private committee meeting
13:20	13:40	Transfer and safety check
13:40	16:40	Department of Radiation Science & Technology (labtour(s) and interview)
16:40	17:00	Transfer and break
17:00	18:00	Drink and talks (carousel-style) with PhDs of all departments, Casimir research school is represented (12-16 people)
18:00	19:00	Private committee meeting
Wednesday 18 January 2023		
8:30	9:00	Check-in
9:00	12:00	Department of Imaging Physics (labtour(s) and interview)
12:00	13:00	Lunch and private committee meeting
13:00	13:15	Break
13:15	16:15	Department of QuantumNanoscience (labtour(s) and interview)
16.15	16:30	Break
16:30	17:30	Drinks and talks (carousel-style with Tenure Trackers of all departments (12-16 people)
17:30	18:30	Private committee meeting
Thursday 19 January 2023		
8:45	10:15	Private committee meeting
10:15	10:30	Margin/break
10.30	11:30	Final questions/preliminary feedback to management
11:30	12:00	Private committee meeting
12:00	12:50	Preliminary feedback session
12:50	13:30	Lunch and goodbye

Appendix 3: Quantitative data

Table 1: Research staff in FTE

Bionanoscience

	2016	2017	2018	2019	2020	2021
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	9,3	7,5	5,8	5,2	4	4,8
Associate professor	2,1	2,8	5,4	6,8	8	7,5
Full professor	3,8	3,4	3	3,3	4	4,5
Postdoc	25,8	17,8	25	34,8	32,7	28,6
PhD candidates	65,5	62,9	66,4	64,5	67,7	65,8
Researchers (other)	2,4	2,3	3,2	2,6	1	0,9
Total research staff	**108,9**	**96,7**	**108,8**	**117,2**	**117,4**	**112,1**
Support staff	18,4	21,1	23,3	25,1	28,3	27,5

Imaging Physics

	2016	2017	2018	2019	2020	2021
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	6	6,1	6	6,8	8	9,7
Associate professor	7,5	8	8,2	7,4	6,3	6,6
Full professor	3,3	3,9	4,2	4,9	4,4	4,1
Postdoc	8,1	6,9	12,1	13,5	16,1	17,1
PhD candidates	69,2	71,5	76,1	70,7	75,1	75,5
Researchers (other)	0,2	0,7	0	2,8	3,5	3
Total research staff	**94,3**	**97,1**	**106,6**	**106,1**	**113,4**	**116**
Support staff	11,3	11,4	11,6	11,5	11,7	12,4

Radiation Science & Technology

	2016	2017	2018	2019	2020	2021
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	11,6	9,5	9	9	7,8	8,2
Associate professor	5,5	7,2	7	6,2	7,7	8,8
Full professor	5,5	5,5	5,7	6,5	6,3	6,5
Postdoc	14,2	14,1	15,1	15,1	12,9	10,3
PhD candidates	53,1	49,6	48,4	49,5	50	54,5
Researchers (other)	0,1	0,3	1	0,7	0	0,2
Total research staff	**90**	**86,2**	**86,2**	**87**	**74,7**	**88,5**
Support staff	11,6	11,7	10,4	10,5	9,8	10,5

Quantum Nanoscience

	2016	2017	2018	2019	2020	2021
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	4,3	4,8	3	2,5	2,7	4,8
Associate professor	6,1	6,7	7,5	6	6	7
Full professor	7,7	7,2	8,6	9,5	9,5	10,7
Postdoc	21,4	23,6	24,5	21,2	181	15,8
PhD candidates	84,6	94,1	101,5	101,1	113,9	120,1
Researchers (other)	2,3	2,8	3,1	4,3	3,3	2,9
Total research staff	**126,4**	**139,2**	**148,2**	**144,6**	**153,4**	**161,3**
Support staff	14,6	15,5	16,3	16,2	15,3	16

Table 2: funding in k€

Bionanoscience

	2016	2017	2018	2019	2020	2021
	k€	**k€**	**k€**	**k€**	**k€**	**k€**
Direct funding	5.503	6.012	17.061	9.748	9.514	9.375
Research grants	6.853	3.873	1.339	2.699	2.132	2.678
Contract research	2.802	2.277	472	2.014	1.454	1.788
Other	29	42	74	75	321	196
Total funding	**15.187**	**12.204**	**18.946**	**14.536**	**13.421**	**14.037**

Imaging Physics

	2016	2017	2018	2019	2020	2021
	k€	**k€**	**k€**	**k€**	**k€**	**k€**
Direct funding	3.144	3.304	3.244	3.256	3.487	4.258
Research grants	783	993	1.437	2.078	2.772	3.055
Contract research	4.490	2.657	3.132	3.718	3.943	3.809
Other	85	83	129	83	163	125
Total funding	**8.501**	**7.037**	**7.942**	**9.134**	**10.365**	**11.247**

Radiation Science & Technology

	2016	2017	2018	2019	2020	2021
	k€	**k€**	**k€**	**k€**	**k€**	**k€**
Direct funding	3.305	3.201	3.135	3.275	3.426	3.621
Research grants	2.879	1.819	1.634	3.009	1.799	2.544
Contract research	3.5111	3.257	2.696	2.156	1.201	1.929
Other	97	89	13	396	237	461
Total funding	**9.792**	**8.366**	**7.478**	**8.836**	**6.663**	**8.555**

Quantum Nanoscience

	2016	2017	2018	2019	2020	2021
	k€	**k€**	**k€**	**k€**	**k€**	**k€**
Direct funding	5.409	5.287	5.299	5.357	6.482	6.309
Research grants	12	2.092	16.216	4.203	3.795	3.937
Contract research	72	6.936	5.915	5.000	2.830	2.871
Other	179	414	552	514	498	972
Total funding	**5.672**	**14.729**	**27.982**	**15.074**	**13.605**	**14.089**