

Evaluation of the Ph.D. study programs of the IME faculty, NTNU

0. Executive Summary

This section lists in concise form commendations and recommendations which are discussed in more detail later in the report.

0.1 Commendations

- *Quality Assurance* processes of annual monitoring and midterm review are examples of good practice and can be analysed and exploited to identify best practice and underpin 'lessons learned' for IME's PhD education.
- The interviewed *PhD Students* were excellent ambassadors for IME's PhD programmes with good knowledge, thoughtful reflection, enthusiastic communication, and honest assessment.

0.2 Key Recommendations

- *Recruitment* Develop a strategy for publicising Ph.D. positions; develop guidance for interviews that includes exploration of research aptitude and motivation as well as technical expertise and high grades.
- *Learning Goals and Courses* Review the learning goals to ensure the inclusion of competences for non-academic careers; review course portfolio to ensure appropriate coverage of relevant specialized courses, suitable broadening technical courses, and generic research skills courses.
- *Supervision and Co-Supervision* Develop guidance on good supervisory practice for Ph.D. supervisors and candidates; create guidelines on the expectations for the co-supervisor role.
- *Student Engagement and Social Environment* Create a research ethos/environment with opportunities/encouragement for students to contribute/participate in relevant seminars and social activities.
- *Mobility* Improve the take-up of Ph.D. research visits to foreign universities and labs, and reciprocal visits from leading research groups abroad.
- *Progress, Completion, and Termination* Introduce regular reflective reviews of progress towards an agreed proposed thesis completion date; review expectations in practice for contribution and publication necessary for Ph.D. standard; establish a formal review/termination process for enrolled students whose thesis submission is long overdue.
- *Quality Assurance* Undertake a more focused analysis of annual questionnaire data; communicate the analysis and findings more widely across departments and to supervisors; introduce a more robust assessment of the quality and impact of Ph.D. theses using publication metrics compared to benchmark departments/universities; implement a follow-up of alumni and use their feedback to improve the programmes.

- *Ensure sufficient time for research and supervision.* For PhD candidates to succeed it is vital that they have enough time for research, and also that supervisors have enough time to provide high quality supervision and to be active researchers in their own right. Formulate clear goals for both Ph.D. students and faculty members / supervisors to ensure that there is sufficient time for high quality supervision and research of both parties.

1. Background and Process

The Faculty of Informatics, Mathematics, and Electrical engineering (IME) at the Norwegian University of Science and Technology (Norges teknisk-naturvitenskapelige universitet - NTNU) wanted to have its Ph.D. study programs evaluated by an international expert committee. This is part of the quality assurance procedure of IME (and NTNU), stating that internal evaluations of each Ph.D. programme shall be done annually by the programme leader, while it is the Dean's responsibility that larger evaluations with input from external parties take place at least every five years. This latter requirement is fairly recent, so the undertaken evaluation is indeed the first of its kind at the NTNU.

The following committee was appointed to perform the evaluation:

- Professor Arne Svensson, Dept of Signals and Systems, Chalmers University of Technology, Sweden (leader)
- Professor Susan Craw, School of Computing Science and Digital Media, Robert Gordon University, Aberdeen, UK
- Professor Anja Feldmann, Department of Telecommunication Systems, TU Berlin, Germany
- Professor Joaquim Bruna Floris, Department of Mathematics, Universitat Autònoma de Barcelona, Spain
- Professor Rolf Johansson, Department of Automatic Control, Lund University, Sweden
- Associate Professor Henk Polinder, Department of Electrical Sustainable Energy, TU Delft, Netherlands

In addition, Prof. Guttorm Sindre, NTNU, was appointed as an internal academic secretary to help the committee both during its visit and in the subsequent reporting.

The mandate of the committee is described in a document from IME dated 2015-08-06 (4 pages), here repeating some essential excerpts:

- "assess the quality and relevance of the research education" (i.e., of IME's 6 Ph.D. study programs: Electric Power Engineering, Electronics and Telecommunication, Engineering Cybernetics, Information Technology, Mathematics, and Telematics)
- "ensure that the learning outcomes [...] are up to date and relevant, and that portfolios of courses in the programmes are sufficiently supportive for the Ph.D. candidates in order to achieve the learning outcome."
- "offer a critical assessment of the strengths and weaknesses of the Faculty's research education and to improve the knowledge base for strategic decision-making by the Faculty in matters that are relevant for the Ph.D. studies."

It must be noted that the committee's mandate was to evaluate the quality of the research *education*, not the quality of the research per se. Evaluations of the quality of research are already

performed in other contexts, for instance by the Norwegian Research Council, who does this per research group in various disciplines approximately every 10 years (last reports for mathematics and ICT published 2012). Hence, the committee has not been reading Ph.D. theses or articles published by IME's Ph.D. students, or made other kinds of inquiries into the quality of the Ph.D. candidates' work (e.g., bibliometric analysis of papers, where they are published or how much they are cited).

The committee was provided with a number of written documents in early 2016:

- 4 documents that applied to the whole of NTNU (regulations for Ph.D. studies, Ph.D. handbook, guidelines for the assessment of Ph.D. candidates, and the quality assurance system for educations)
- 5 documents from the IME faculty (a presentation of IME's Ph.D. programs and how they are organized, a document describing the annual reporting process from students, supervisors, and departments / programme leaders, another appendix giving the 2015 results from this reporting, a document describing the mandate for the committee, and a time schedule for the visit)
- 3 documents from each study program (or department, as there is one Ph.D. study program for each department at IME), giving that program's self-assessment, a description of the department's research profile, and explaining the procedures for receiving new Ph.D. students.

The committee made an intensive three-day visit to NTNU (5-7 April 2016), including the following sessions:

- a plenary session with presentation of IME (by the Vice-Dean for Research) and each of its Ph.D. study programs
- a presentation of the quality assurance procedures at the NTNU
- for each of the six departments / Ph.D. study programs:
 - an interview with the Head of Department and the Program Leadership
 - an interview with some Ph.D. students (typically 3-5)
 - an interview with some supervisors (typically 3-5)
- a wrap-up session where further questions could be asked to the Vice-Dean and administration, and where the committee presented some quick impressions

The report is based both on the written material provided and on notes and impressions from the interview sessions. The rest of the report is structured as follows: Section 2 describes the committee's view on the status (current quality) of IME's Ph.D. educations and makes a number of suggestions for improvement.

2. Status and Recommendations for Improvement

The impression of the committee is that IME's Ph.D. education is of very good quality, with programs that are generally well-managed, offering good learning and working conditions for the Ph.D. students, and with supervisors that are competent in their field of research to the level expected for being a Ph.D. supervisor (or beyond). Although the quality of the research output has not been studied by the committee, it is also the impression that this is of good international quality, and

sometimes even of excellent, world-leading quality. The competence that the students gain during their Ph.D. studies appear relevant both for academia and industry.

The fact that the faculty has chosen to be the first to undergo this kind of evaluation, is also a positive sign in itself, indicating a strong commitment to quality assurance and improvement. The leaders, supervisors, and students generally appeared well-reflected during the interviews.

Since a main purpose of the evaluation is to propose improvements, the remainder of the report will spend much more space on critical observations than acclaim. This should not be misinterpreted as an indication that the evaluated Ph.D. programs are poor. Rather it follows from the mandate itself that the feedback that the faculty will be most interested in, is constructive criticism and suggestions for improvement, not an appraisal of the current situation. *The general observation of status is that the 6 evaluated Ph.D. programs are of good quality both from a national and international perspective, and that the resulting research is generally of high quality, sometimes even of very high quality. The evaluation committee did not discover any serious quality problems with the Ph.D. programs, nor any serious deficiencies with their quality assurance systems.*

Still there are some weaknesses / issues that the faculty should have an ambition to improve upon. Various weaknesses that were observed can be grouped under the following items, to be discussed in more detail in subsections below:

- recruitment
- learning goals and courses
- supervision and co-supervision
- student engagement and social environment
- mobility
- progress, completion, and termination
- quality assurance

2.1 Recruitment

Although the situation varies between departments, a general impression is that recruitment is often a challenge. Some announced Ph.D. positions get few or no applicants, and in some cases with numerous applicants, it may still happen that few (if any) are found qualified. Some departments especially found it difficult to recruit own master-degree candidates into Ph.D. studies, thus an increasing share of Ph.D. students are from abroad. Part of the reason was thought to be the strong industry demand for candidates in those disciplines, many students signing contracts with future employers a year before delivering their Master theses.

While candidates from abroad is an enrichment, the departments felt that it might be problematic if the share of Norwegian Ph.D. students becomes too low. In addition to three years of funding for the Ph.D. study itself, many Ph.D. fellows are offered extra time – from three months to a full year – for teaching duty. Many undergraduate courses are taught in Norwegian, and the set of teaching tasks available without being fluent in a Scandinavian language is therefore quite limited. If most Ph.D. students are from non-Scandinavian countries, it will not be feasible to offer teaching duty to all Ph.D. candidates.

While recruitment might be a challenge also elsewhere, the committee's impression was that IME / NTNU had more struggles with recruitment than expected. Since the Ph.D. fellow salary in Norway is very high compared to most other countries in the world, open Ph.D. positions at IME should be more attractive to good applicants than they seem to be. Some interviews indicated that announcement of open positions was limited.

Another issue with recruitment is poor hiring decisions. Interviews with supervisors and program leaders indicated that some hired candidates were in retrospect found to be lacking the talent or motivation to pursue a Ph.D. Of course, it is impossible to completely avoid such mistakes, but the committee suspects that the problem could be reduced with better hiring procedures.

The committee has the following recommendations for recruitment:

- R1. Specifically, for recruiting own Master candidates, *involve them actively in research already early in their studies* – and make them aware of Ph.D. as a career opportunity in connection with this research involvement. If Master candidates tend to sign contracts with employers a year before graduating, their interest for research must be nurtured much earlier than the Master thesis.
- R2. For recruitment in general, develop a strategy for how to announce positions, and collect data on what announcements elicit qualified candidates (or not), so that the guidelines can be gradually refined. Note that this recommendation does not necessarily mean to spend a lot of money on advertising, it could equally well be about free mailing lists or utilizing the personal networks of professors. It is important that announcements be well targeted so that they elicit good applicants, rather than a large amount of non-qualified applicants which just increases the administrative burden.
- R3. *Develop a faculty-wide interview guide for issues that should be addressed in interviews.* The committee got the impression that some guidelines exist, but not very precise ones. Interviews are an important tool for assessing the research skills and motivation of applicants, as well as technical expertise. The interview guide should include issues to discuss with the candidate and advice on how to discuss them. Of course, other questions could be added beyond the guide (e.g., related to the specific project) but the faculty-wide guide should contain questions that all interviews should explore.
- R4. *Always aim for face-to-face interviews* with short-listed applicants (rather than, e.g., Skype), even for those living far away. (Faculty indicated that this was already a goal, but not necessarily applied consistently). Although there will be some travel costs, the cost of a poor hiring decision is much higher.
- R5. *Test the short-listed applicants' research skills in practice.* If possible, have short-listed applicants stay at the department for a longer time than just the interview – such as an internship lasting a couple of weeks or months – for instance as an unpaid guest researcher receiving compensation for travel and accommodation. During this time, the applicant can be involved in ongoing research work, which will give much better insight into the applicant's capabilities than just the written application and an interview. The committee realizes that this might not always be possible. Good applicants may have several offers for Ph.D. fellowships or other jobs at the same time, so a delay in hiring may simply mean that the best ones pick other job offers instead. If a prolonged testing period is not possible, at least strive for a test lasting for a day or a couple of hours, for instance in connection with the

interview, giving the candidate some task that will demonstrate relevant topical competence and research skills.

- R6. *If unfortunate hiring decisions occur in spite of the above, try to discover this as soon as possible to be able to act on it.* The committee was informed that Norwegian law includes rules about a 6-month trial period for new employees, but understood from interviews with leaders and program managers that it was very difficult to make use of this in practice. I.e., the faculty might be recommended to investigate whether the trial period is at all possible to use in this context – and if so, how?
- R7. *Have ambitions to increase the number of Ph.D. students.* In some of the departments, the average number of Ph.D. candidates per faculty member seemed to be low compared to the situation in similar departments elsewhere in Europe. Of course, the limiting factor here might not be recruitment as such, but also the ability to attract funding for Ph.D. fellows. Anyway, the committee feels that departments who are in the lower end of the spectrum here, should be more ambitious to increase their number of Ph.D. fellows.

2.2 Learning goals and courses

The written learning goals for the Ph.D. programs all appeared to be sensible and well formulated. Yet, the committee observes that there is perhaps a mismatch between these goals – which mainly seem to be focussed on a future academic career – and the reality that many Ph.D. graduates end up working outside academia (mainly in industry jobs, some also in public enterprises).

The Ph.D. studies include a course component of 30 ECTS (normally taken as 4 courses of 7,5 ECTS each). According to regulations, at least 3 of these courses must be Ph.D. level courses, one course may be on the Master level. The committee observed that almost all courses tend to be on research topics, i.e., with a quite specialized content. This is somewhat different from the practice of many Ph.D. programs elsewhere, which tends to have a more balanced offering with some specialized topic-based courses and some courses providing more generic research-related skills (e.g., research ethics, research methods, academic writing, presentation technique, innovation and entrepreneurship, etc.). The committee observed that there were mixed opinions about the course portfolio, both among students and teachers. Some were happy with the current practice; some would have liked an increased share of more generic courses. Especially among the students, some were also unhappy that they had not been able to find 4 on-topic courses directly supporting their thesis research. This might indicate a mismatch of expectations, i.e., students thinking that all courses should be directly relevant to the thesis, whereas study program designers might rather have intended that the course component should give a somewhat broader competence in the field, also mandated from the learning goals. Especially, students felt that it was unfair if other Ph.D. students had been able to find 4 relevant courses while they had not, thus feeling that they were "wasting time" taking a course which did not really support the progress of the thesis work. Another comment that came up in student interviews was that the restriction that 3 courses had to be Ph.D. level and maximum one could be Master level, was sometimes too limiting for students with an interdisciplinary thesis topic. Such students, typically having a good background in one of the two disciplines but less (or even nothing) in the other discipline, might be unable to follow Ph.D. level courses in the second discipline, and would be better served if allowed to take more Master level courses in that discipline, or in some cases even a Bachelor level course.

A final observation from questionnaires and interviews is that some students are dissatisfied with the quality of some of the courses. The specialized nature of some of the courses means that they are only taken by a couple of students each time, and then there might not be economic incentives for staff to put very much teaching effort into the course.

The committee has the following recommendations for learning goals and courses:

- R8. *Learning goals should be modified or added to, due to the fact that a majority of candidates are likely to end up in jobs outside academia.* While competence needed for an academic career must of course still be an important component of the Ph.D. learning goals, there should also be a stronger focus on competence for industry and public enterprises. IME should investigate with typical non-academic employers of its Ph.D. graduates what competence they expect from Ph.D. graduates, and especially what competence they expect from these beyond the competence implied by a similar Master degree, where taking a Ph.D. might thus give added value. The learning goals should then be modified to take this into account.
- R9. The course part of the Ph.D. programs should be reconsidered in accordance with revised learning goals, and in light of feedback on course quality. One possibility could be to include more generic courses, and give some guidelines on the mixture of generic skills courses, courses that broaden expertise, and specialized topic courses. Also, consider if the rule of at least 3 Ph.D. level courses should be relaxed, or if it is sufficient to do other adaptations (e.g., exceptions for students with interdisciplinary backgrounds or thesis topics). The departments which have a large portfolio of Ph.D. courses, each taken only by a couple of students per offering, would also be recommended to consider whether they could have somewhat fewer and broader Ph.D. courses, which would then be taken by more students per offering. This would make it easier to justify putting more effort into improving the courses, and could also contribute towards creating a community feeling among Ph.D. students.
- R10. The purpose of the course part should be communicated clearly to students. If students believe that courses should directly support the thesis work while program designers have instead included the courses due to the learning goals that demand a broader perspective, this is bound to create unnecessary dissatisfaction. Students may also be dissatisfied if they experience the course menu as unfair, giving perfect synergy for some thesis topics but not for others.

2.3 Supervision and co-supervision

The questionnaire data provided by the faculty indicated a lot of variation in how often Ph.D. students were engaging with their supervisors. Most of the students in the interview sessions were meeting their supervisors bi-weekly or weekly (and some even more frequently), but it is likely to assume that students selected for (or volunteering for) taking part in these interviews belong to the more active part of the spectrum, thus maybe not being representative for the average in this respect. Similarly, students in the interview sessions were mostly happy with the quality of supervision, while the questionnaire data gave a somewhat more varied picture here also. Even in the interviews, the committee got the impression that the usage of co-supervisors was very variable. For some students, the co-supervisors were involved as much as the main supervisor, but more often the involvement of the co-supervisor seemed to be quite limited, sometimes mostly filling a required

formal role rather than being actively contributing in the supervision. The committee has the following recommendations for supervision:

- R11. *Encourage more teachers to take courses in supervision.* The committee was told that there are annual courses on how to supervise Ph.D. candidates, but that fairly few faculty members have yet taken them. It could be considered whether it should be compulsory to take such a course before one is allowed to be supervisor for Ph.D. candidates – or within reasonable time of being hired.
- R12. *Provide clearer guidelines for what is seen as a normal frequency of supervision meetings* (or e.g. email interaction with comments on written material if meetings are impossible). Of course, such guidelines might not fit every situation – there may be times when a Ph.D. student needs more supervision, other times less, but they can still be useful in communicating to Ph.D. students as well as supervisors what is considered normal, recommended practice in terms of supervision during a Ph.D. project. There may be several causes for infrequent contact between candidate and supervisor. For instance, the supervisor may be too busy with other tasks so that meetings are seldom scheduled (and the candidate may have wanted more supervision but is afraid to disturb). In other cases, it might be the student who does not want to meet, for instance being embarrassed that little work has been done since the previous meeting. In any case, frequent supervision is important to discover problems early and keep the project on track. Frequent meetings, which can be kept short on occasions where there is not so much to discuss, are generally better than infrequent ones.
- R13. *In particular, provide clearer guidelines concerning expectations for the co-supervisor role.* It seemed that both students and employees sometimes considered it the rule rather than exception that co-supervisors were only marginally involved. It must be assumed that the requirement for co-supervisors is not only a formality, but the result of an assumption that there is an important purpose behind the co-supervisor role. The committee believes it can be useful for a student to have feedback on the work from multiple perspectives, even in cases where the co-supervisor has less competence than the main supervisor on the thesis topic. Again, there may be many reasons for little involvement, e.g., that both supervisors and students believe it is only a formal placeholder, or that the co-supervisor is busy or afraid to “intrude” into the main supervisor’s domain. More precise guidelines for co-supervision might mitigate such risks of little involvement.
- R14. *Consider providing better incentives for supervision and co-supervision, or at least for good supervision leading to the successful completion of candidates.*
- R15. *Formulate clearer goals for the faculty members / supervisors.* To be able to provide high quality supervision, professors must have the time necessary for frequent meetings as well as reading and commenting upon student drafts, as well as being active researchers in their own right. If they are overloaded with teaching and administrative burdens, supervision may suffer. The Dept. of Engineering Cybernetics, having had better throughput of Ph.D. candidates than many of the other departments, presented a comparatively low teaching load as one of their success factors (each employee lecturing one course per year, rather than one per semester). Clearer goals for a faculty member and supervisor may improve the situation. Metrics may depend on the rank of the faculty member and may include items

such as number of Ph.D. students supervised / co-supervised, number of conference / journal publications, amount of funding, courses taught, etc.

2.4 Student engagement and social environment

The data from questionnaire surveys (annual progress reports from Ph.D. students and supervisors) indicated quite a lot of variation concerning how often students were involved in seminars and scientific discussions with peers, presenting their work or attending such presentations by others – and also some substantial mismatch between student and supervisor perceptions about the frequency of such activities. Notably, the leaders of the Ph.D. programme in Engineering Cybernetics department, who have fewer long overdue Ph.D. candidates and better ratios for successful completions than the other programmes (perhaps with the exception of Mathematics) presented frequent seminars to engage students – and partly organized by the students themselves – as one of their success factors.

In some other departments students said in interviews that there were seminars, such as for instance guest lectures or trial presentations of papers before going to a conference, but that they had attended some that did not feel relevant to them and thus been discouraged from attending more often (e.g., because the topic was different from their own thesis work and the presentation so specialized that it was hard to follow). Since many Ph.D. students struggle with completing their theses in the nominal time, it is of course not a good idea to require students to attend presentations that are of little relevance to them. It might be that different departments will need different approaches to this, for instance depending on the scientific breadth of the department. Perhaps Engineering Cybernetics has an advantage that although the application areas of various theses may be different, all are essentially using the same underlying control theory, so a presentation on snake robotics will appear relevant to a candidate working on vessel navigation, and vice versa, while other departments might be broader so that different candidates not only have different application areas but also different underlying theories and research methods. Hence, in some cases department-wide seminars may be good, while others might do better with seminars associated with sections, research groups or project teams. Anyhow, the committee believes that frequent interaction with peers and with faculty beyond the supervision team can be very useful for Ph.D. students, both for direct utility (ideas and feedback on their own work) and for creating a feeling of community and avoiding isolation. The committee has the following recommendations in this respect:

- R16. Every department should make efforts to ensure that all Ph.D. students have a frequent offering of relevant seminars that they can attend, and that there is a positive pressure to participate and contribute, though the way to implement this may vary from department to department.
- R17. Every department should make efforts to ensure that there are sufficient social events including Ph.D. students, or specifically for Ph.D. students. The latter could best be organized by the Ph.D. students themselves, but still, the department should have some strategy in place to encourage this and make sure everybody is socially included.

2.5 Mobility

As far as the committee understood, it is a stated goal that a Ph.D. student at IME / NTNU should spend some time abroad (for instance 3-6 months) during the Ph.D. study. From questionnaire responses and interviews it appears that in practice, there is a lot of variation, some going abroad for

6 months or even more, some just having shorter stays at foreign universities or staying at the NTNU for the entire Ph.D. study (except maybe for quick conference trips), perhaps not even considering or getting encouraged by the supervisor to consider a stay abroad. There may be many good reasons for this variation. First, there may be different opinions about the need for a trip abroad, for instance that this would be highly useful for a student who has done all previous studies in Norway, while it is less necessary for a student who took the Bachelor in his/her home country, then a Master in another country, and then came to Norway to do a Ph.D. Candidates may also have limited ability or motivation for going abroad, for instance due to their family situation or spare time activities requiring a consistent presence in Trondheim. Sometimes the project context may be an obstacle (e.g., empirical work in collaboration with local companies), or there may be limited funds for long stays abroad. In other cases, the supervisor might be reluctant. If the candidate is perceived as weaker than average and lagging behind in progress, it might feel embarrassing to send such a candidate to top-flight international colleagues. There may also be a general anxiety – both from the candidate and supervisor – that a trip abroad will slow down the progress of the thesis work. In spite of such reservations, the committee believes that it can be useful for all candidates to be exposed to another research group and social environment at least for some time during their Ph.D. studies, to get fresh views and alternative perspectives on their thesis work. Also, IME should have ambitions to increase the number of incoming guest Ph.D. candidates from foreign universities, since mobility should go both ways. As the committee understood, this type of mobility tends to be even more limited. Again, this can be understandable, given the high living costs in Norway, but there should still be an ambition to improve the situation – visiting Ph.D. students and researchers will also be an enrichment for the research environment at IME. The committee has the following recommendations for mobility:

- R18. Make a clearer policy / expectation that the Ph.D. study should include a stay abroad, and with best practice guidelines on how to achieve this in practice without causing substantial delay in the Ph.D. project. This effort could for instance start with an investigation of current Ph.D. students' experiences with stays abroad, and try to systematize the most successful experiences into a set of best practice guidelines for such mobility.
- R19. Explore alternative arrangements for candidates for whom it is difficult to spend much time abroad (e.g., family situation). One interesting option could be a secondment in a local research-intensive company of relevance to the thesis, or in a research institute (e.g., SINTEF). The main purpose is to get new impulses for one's research and fresh feedback on the thesis work, and sometimes it might not be necessary to go abroad to achieve this.
- R20. Work harder to attract Ph.D. students from high-quality research groups abroad to spend similar time as guest students at IME. One possibility could be to try to accomplish this as an exchange with international partners that professors are already collaborating with, so one student goes abroad while another comes in, simply swapping desks for a while. If Norway's high cost level is an obstacle here, try to find some supplementary funding for the guest students, for instance including an amount for this already in project applications.

2.6 Progress, completion and termination

In addition to the ongoing assessment of progress that must be assumed to take place in regular supervision meetings, IME has some more formal means to assess supervision:

- an annual reporting form to be filled by students and supervisors independently, among other things containing opinions on learning, satisfaction and progress (e.g., whether it is on track).
- a midterm review (a practice for many years in some programmes, newly introduced in others) where the candidate presents status and plans ahead, and this is then discussed by the supervision team plus, e.g., a representative from the department's research committee

Moreover, the Heads of Department must provide estimates to the Faculty on how many Ph.D.'s are likely to complete in the next couple of years, as completed degrees are a component in the model for distribution of money from NTNU to its faculties (and subsequently from the faculty to its departments). The "reward" per completed Ph.D. will vary from year to year because it is a zero-sum game on the national level, but was estimated to be approximately half a million NOK per candidate, so there is a clear incentive for the departments to ensure good progress and successful graduation of as many Ph.D.'s as possible. In spite of this, the data provided to the committee indicate that the success ratio of IME's Ph.D. students has been quite variable. The green/red/blue graphs in the appendix, showing completions vs. unsuccessful terminations vs. candidates still enrolled, show a lot of variation between years and departments. Mathematics has the smallest red area, thus indicating the highest success ratio over time (approx. 80% on average), and Cybernetics have had a clearly positive trend, going from lower figures to above 80% in more recent years. For some of the other departments, figures seem to be lower, around 70% success on average.

Another notable phenomenon is that there are a substantial number of still enrolled students that are long overdue with their theses deliveries (i.e., students who were admitted 2009 or earlier, and who should thus have been finished 2013 or earlier unless they had leaves; this is indicated in the appendix bar chart showing the IME Ph.D. community by year of admission). Again, Mathematics (5 students long overdue) and Cybernetics (4) are the exceptions in the positive direction, while for some departments such long overdue students comprise almost 1/3 of the Ph.D. student community. As the committee understood from interviews, most of these long overdue candidates are in the situation that they have run out of funding and left the university to take other jobs (typically in industry), but with an ambition to finish the Ph.D. thesis in their spare time. However, many do not find enough time and make little progress, though remain enrolled as Ph.D. students for as long as possible. Interviews revealed that even in Cybernetics (the most successful department wrt completion ratios of Ph.D. students in recent years) it was quite common that Ph.D. fellows were not yet ready to deliver their theses by the time their funding was spent, typically needing 3-5 months more to finish. Indeed, the department stated as one of their success factors that supervisors often had available extra project funds that could be used in such situations, to give the candidates extra time to complete rather than taking a job in industry. In some other departments it seemed to be the rule rather than exception that candidates were spending more than the nominal time for the Ph.D. studies, but possibility for extended funding might be uncertain.

It is impossible for the committee to say why so many Ph.D. students are spending more than the nominal time, but the end of funding cannot come as a surprise, as the date when the Ph.D. fellow salary will stop is known already at the time of employment. Possibly there could be a mixture of reasons, varying from case to case:

- Unfortunate recruitments (as discussed before), candidates not really having the capacity or motivation to come up with a Ph.D. thesis in 3 years (or really 2.5, since half a year will be spent on coursework)
- Personal problems, such as disease or other life changes
- Insufficient supervision? E.g., being too infrequent, confusing, or not sufficiently focussed towards the goal of finishing in time? If both students and supervisors begin to see delays as the rule rather than the exception, this may lead to an evil circle: since previous students spent some years extra, the next ones might as well do so, too.
- Too much fumbling, not leading to a coherent thesis. Some students may take too long from the outset to decide on exact thesis topic and research approach. Others may too easily digress from their thesis topic, e.g., due to sudden excitement for various cutting edge technology. Some of those interviewed had the impression that Ph.D. students recruited into externally funded projects had a better success ratio than internally funded ones - partly for the reason that the externally funded were introduced to a well-defined project with a stricter path to follow.
- Candidates not working hard enough? Ph.D. studies at IME imply two roles at the same time, one role as a Ph.D. student and one role as a Ph.D. fellow (employee). If some mainly take the latter perspective, seeing it as a normal 40 hours per week job, this will be unlikely to achieve a Ph.D. in 3 calendar years (nor 4 with teaching duty). The fellowship is a funding opportunity for taking the Ph.D. education, but the Ph.D. candidate should expect to spend additional hours in the student role beyond what one gets paid for as employee.

An important contributor to delayed completion in some areas is too high expectations by both supervisors and students for the amount of contribution and publication in a Ph.D. thesis. The nominal time for a Ph.D. degree in Norway is just 3 years, while in some other countries it is more (e.g., 4 years in Sweden). Yet, some of the interviewees seemed to have quite high expectations, for instance concerning the number of articles in a paper collection thesis (e.g., 3-4 articles in good journals, or 5-7 papers in conferences seemed to be typical suggestions). This seems to go beyond the formal requirements stated in the regulations – "The thesis must contribute to the development of new scientific knowledge and must achieve a level meriting publication as part of the literature in its field" (Ph.D. Regulations for NTNU, section 10.1) – which could be taken to mean that the key contributions must be *publishable* in recognized international channels – but not necessarily having been published already in any specific number of articles. Especially in fields where journal publications are the norm, the long lead times of many journals may also be a delaying factor for completing a Ph.D. if it is demanded that the articles are accepted before the thesis can be delivered.

Ideally, Ph.D. students should finish within the nominal time, if not defending then at least delivering their thesis before their funding ends. The committee has the following recommendations concerning progress, completion and termination:

- R21. Make a more detailed investigation into why so many students do not finish on time.
- R22. If these investigations reveal, e.g., that students on external projects do better than those on internal funding, try to emulate the positive aspects of the external funding for the internal ones, too (e.g., well-defined project from the start, less fumbling, more targeted supervision, a bigger group of people to get feedback from?).

- R23. Establish a culture where the expectation both among supervisors and candidates is to finish on time, not being delayed. If there are research groups or supervisors whose candidates tend to deliver before the funding ends, learn from these to establish best practice guidelines.
- R24. Give more status to the midterm evaluation. Many interviewees were positive to midterm evaluations, yet felt that it was hard to take substantial action from them in cases where progress had been so poor that the evaluation should be failed. While it could be "easy" to terminate the candidate's right to study, it was perceived as much more difficult to terminate the Ph.D. fellow employment, so a termination would imply the same waste of money as just letting the candidate keep on trying. Exactly what could be done legally is hard for the committee to say, but at least the midterm evaluations should be given more status. There should be participants from outside the core supervision team to give an unbiased view on the progress, and the review should be planned for and announced well in advance (almost like a half-way defence) rather than the somewhat ad hoc approach that sometimes seemed to be the case now.
- R25. Include more check-points in addition to the midterm review. It is important to avoid excessive bureaucracy here, and these additional check-points should be much less formal than the midterm review. The annual survey already completed by Ph.D. students and supervisors could also contain a review element through short textual summaries by both student and supervisor on achievements (including any publications) and progress during the previous year, and if necessary justification and planning for any delays in the projected completion date. It would probably also make sense to have progress assessment meetings with the candidate and all supervisors (plus maybe the leader of the funding project, if this person is not among the supervisors) once per quarter or semester. These meetings do not have to be long, but should have a clear objective of assessing whether progress is according to schedule so that the thesis is likely to be delivered on time, rather than the more free-flowing discussion of research ideas that might be found in a normal supervision meeting. Such a periodical review would ensure a more frequent involvement of co-supervisors than what tends to be the case today (see previously discussed R13), and encourage a persistent focus on progress and timely delivery of the thesis.
- R26. If it is found that a major reason for failure to deliver on time is too high expectations for the theses compared to the 3 years of nominal time, adjust the expectations (or alternatively: lobby for an extension of the nominal time to 4 years). Plans to complete the thesis should be initiated well before funding ends. Given a periodical review (cf. R25 above), the plan to complete the thesis in time should be the key discussion point 6 months before the funding will end. If the problem is that the candidate is too ambitious and wants to go beyond the time (e.g., to get more articles than necessary) the supervisors should convince the candidate that the research is achieved and there is enough material for a defensible thesis. It will still be possible to write more articles after delivering the thesis, especially if continuing as a postdoc.
- R27. The practice of offering 3-4 months of extra funding to have candidates finish their thesis before taking jobs in industry (reported as quite successful by the Cybernetics department) could be analyzed for adoption by other departments as well. However, this tactic must be used with caution. First of all, one must be very certain that the candidate is close enough to finishing that the extra funding will be sufficient. Both candidate and

supervisor may have a tendency to be over-optimistic and underestimate the work remaining to finish a thesis. Second, some months of extra funding can in some cases appear as a reward for being late. Thirdly, if extensions become the norm then the problem may simply be delayed, and further extra funding will be necessary.

R28. Consider being stricter about granting extensions for students that are already long overdue, perhaps terminating such candidates sooner than what seems to have been the case previously. The large number of long-overdue students in some departments does not look good, though it is hard to say to what extent this is a result of previous problems or if it reflects more persistent challenges with getting the candidates successfully through. Of course, if a student goes on for a long time and then finally delivers and defends the thesis, this is positive both for the candidate (getting a Ph.D.) and the faculty (getting the monetary reward for the completion). But if it becomes obvious that the goal of finishing is just an unrealistic dream, or to avoid the embarrassment of termination, it is probably better to terminate sooner to give closure to the process and avoid wasting administrative resources to have the student still enrolled. Hence – except for cases where the delay corresponds to granted leaves – a student who goes substantially overdue should satisfy some clear criteria to be allowed to remain enrolled, for instance showing commitment through regular interaction with the supervisor, visible progress, and submitting to periodical reviews. If the student has gone two years overdue, one possible arrangement could be that there must be a new review similar to the midterm review to assess whether the project should be continued or not.

2.7 Quality assurance

The quality assurance is done in accordance with NTNU's QA system, and generally seems well organized. As mentioned before the faculty runs annual surveys with Ph.D. students and supervisors. The form addresses many important issues about progress, frequency and quality of supervision, international networking, learning outcomes, etc. However, for some questions – where the answer from student and supervisor should ideally have been the same – there were notable, systematic discrepancies, indicating that the data gained from these questionnaires may not be entirely reliable or that there are differences in perceptions of students and supervisors. Also, the response rate is not 100%, which it should be if the Faculty considers this form an important instrument for quality assurance. Moreover, the analysis of data could be more detailed. For instance, long overdue students (cf. R28) who have long ago left campus are likely to answer quite differently to some questions than the students who are still pursuing their Ph.D. full time.

Departmental and Faculty-wide annual research reports contain summaries of the data collected from student and supervisor questionnaires. Individual departmental reports included discussions, priorities and plans related to these summaries, but there was no evidence in the paperwork or from interviews that there was any Faculty-wide discussion or reflection of shared issues and differences between departments. Communication of these reports did not seem to extend beyond the research leadership of each department and the supervisors that were interviewed did not appear to be aware of the collation or presentation of the questionnaire data. The panel had discovered interesting facts and differences from these reports that underpinned the discussions and interviews during the visit. Wider communication and discussion of these analyses across the Faculty and within departments could encourage sharing of best practice and assist tackling common challenges.

As for the quality of the theses themselves, this is assessed relative to international standards by a rubric in the assessment form for the Ph.D. defense where the foreign opponent(s) state whether they would consider the thesis to be among the top 25%, middle 50% or bottom 25% of accepted theses at their home institution. This is a rather blunt instrument and cannot be very reliable, as there will be a variety in research backgrounds. There might also be biases in both directions: some opponents may be unfair in the negative direction; other opponents may inflate the grading. Moreover, the comparison that the opponents are asked to make in this situation is not easy, due to different contexts and conditions for the thesis work. For instance, a Ph.D. study in Sweden has a nominal time of 4 years, while it is 3 in Norway.

The committee has the following improvement suggestions for QA:

- R29. Strive to get the response rate up to 100%. For supervisors and employed Ph.D. fellows, it should be a job obligation to respond, with sanctions in place for non-submission. For overdue Ph.D. students who are no longer employed, it should be an obligation for continuing enrolment in the Ph.D. programme.
- R30. Make more detailed analyses of the data, for instance separating students in normal progress from long overdue ones, externally funded from internally funded, etc., to see if this can give a deeper understanding of the situation. Wider communication and discussion of these analyses within and across departments could give valuable insights on the different environments, challenges and achievements in the various departments in IME, and perhaps more widely throughout NTNU.
- R31. If it is felt important to compare the quality of theses to an international level, try to find some supplementary ways to do this in addition to the fairly shallow data that is currently distilled from the defense forms. Such comparisons are notoriously difficult, but one option might be to benchmark the theses from each Ph.D. programme against the theses from some departments in other countries who are known to be well respected in that discipline. One possible comparison could then be the impact factor of journals / conferences that the Ph.D. candidates published in during their thesis work, or the number of citations that these papers have gained afterwards.
- R32. Keep better track of alumni, in terms of what jobs they get later, and for what employers. The committee got the impression that the faculty or departments do not have any systematic approach to this now, and to the extent that the career status of alumni is known, this is more coincidental knowledge by individual supervisors. The later career of alumni will of course depend on many other factors than just the quality of the Ph.D. education. Nevertheless, a more systematic gathering of qualitative and quantitative data on how Ph.D. alumni retrospectively consider the career value of their education could give deeper insights about strengths of the education. Also, a well-established alumni network, which can nowadays be effectively maintained through social media, can be an asset in its own respect, for instance to establish research collaborations.