The Research Council of Norway

Evaluation of Mathematics, ICT and Technology 2023-2024

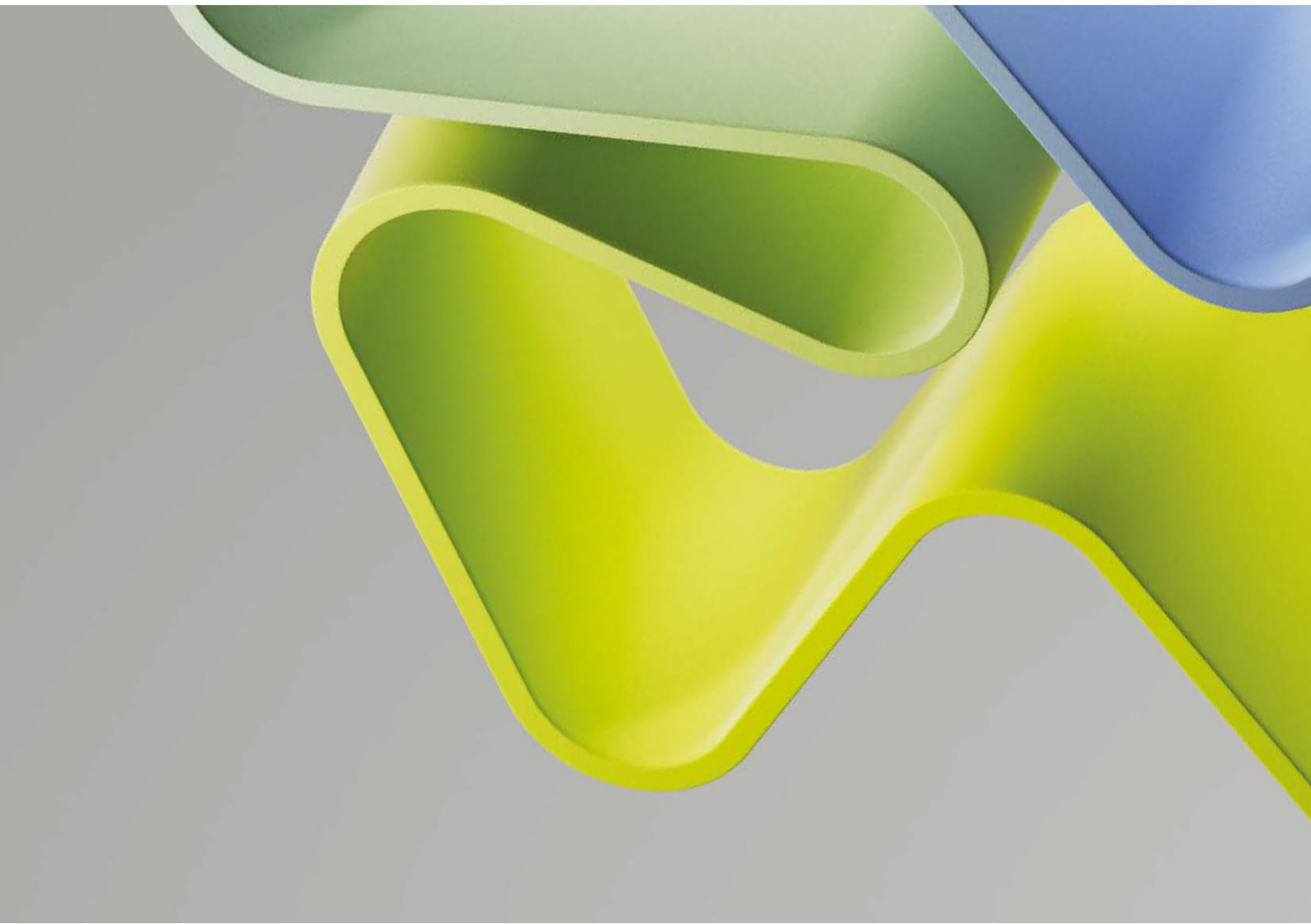
Evaluation Report for Administrative Unit

Administrative Unit: **Department of Engineering Cybernetics (DeptCybernetic)**

Institution: **Norwegian University of Science and Technology (NTNU)**

Evaluation Committee Higher Education Institutions 2

December 2024



Contents

Statement from Evaluation Committee Higher Education Institutions 2 3
Description of the Administrative Unit 4
Overall Assessment 6
Recommendations 6
1. Strategy, Resources, and Organisation of Research 7
1.1 Research Strategy 8
1.2 Organisation of Research 8
1.3 Research Funding 9
1.4 Research Infrastructures 10
1.5 National and international collaboration 10
1.6 Research staff 11
1.7 Open Science 11
2. Research production, quality and integrity 12
2.1 Research quality and integrity 13
3. Diversity and equality 14
4. Relevance to institutional and sectorial purposes 15
5. Relevance to society 15
5.1 Impact cases 15
Methods and limitations 17
List of administrative unit's research groups 18
Terms of Reference (ToR) for the administrative unit 19
Appendices 21

Statement from Evaluation Committee Higher Education Institutions 2

The members of this Evaluation Committee have evaluated the following administrative units at the higher education institutions within Mathematics, ICT, and Technology 2023-2024 and have submitted a report for each administrative unit:

- Department of Computer Technology and Computational Engineering (IDBI), UiT The Arctic University of Norway
- Department of Automation and Process Engineering (IAP), UiT The Arctic University of Norway
- Department of Electronic Systems (IES), Norwegian University of Science and Technology (NTNU)
- Department of ICT and Natural Sciences, Norwegian University of Science and Technology (NTNU)
- Department of Information Security and Communication Technology (IIK), Norwegian University of Science and Technology (NTNU)
- Department of Engineering Cybernetics (ITK), Norwegian University of Science and Technology (NTNU)
- Department of Information Systems (IIS), University of Agder (UiA)
- Department of Computer Science, Oslo Metropolitan University (OsloMet)
- Faculty of Science and Technology (REALTEK), Norwegian University of Life Sciences (NMBU)
- Department of Science and Industry Systems (IRI), University of South-Eastern Norway (USN)
- School of Economics, Innovation and Technology (SEIT), Kristiania University College

The conclusions and recommendations in this report are based on information from the administrative units (self-assessment), digital meetings with representatives from the administrative units, bibliometric analysis and personnel statistics from the Nordic Institute for Studies of Innovation, Research, and Education (NIFU) and Statistics Norway (SSB), and selected data from the National survey for academic staff in Norwegian higher education and the National student survey (NOKUT). The digital interviews took place in the autumn 2024.

The members of the Evaluation Committee are in collective agreement with the assessments, conclusions and recommendations presented in this report. None of the committee members has declared any conflict of interest.

The Evaluation Committee consisted of the following members:

Professor Jan Canbäck Ljungberg
University of Gothenburg

Professor Bo Wahlberg (Chair)
KTH

Professor Nancy Pouloudi
Athens Univ. of Economics and Business

Professor Alessandra Costanzo
University of Bologna

Professor Torsten Braun
Universität Bern

Professor Stefan Wermter
University of Hamburg

Description of the Administrative Unit

The Department of Engineering Cybernetics (ITK) is part of the Norwegian University of Science and Technology (NTNU). The permanent scientific staff by 31 October 2022 consisted of 15 full professors, 11 associate professors, five university lecturers and four permanent researchers. The temporary staff consisted of two professor IIs, four associate professor IIs, two university teacher IIs, 96 PhD students and 10 postdocs. Women make up 13% of permanent staff, none of the II positions and 15% of PhDs and postdocs.

ITK has three main fields of focus and research which are organised into separate research groups, i) Control and AI for cyber-physical systems, which studies aspects such as instrumentation and sensor systems and AI for decision-making, ii) Robotics and autonomous systems, looking at aspects such as sensor fusion and robot vision, and iii) Cybernetics in life sciences, which looks at areas like biomedical cybernetics and biogeochemical ocean modelling & data assimilation. The research groups are informal and inclusive, as the Department uses a matrix organisation with no barriers to cooperation between groups. Both education and research take place across all groups, with employees partly teaching fundamental MSc and BSc courses and partly teaching specialised courses at the MSc and PhD level within their own subdomain.

ITK's aim is to be an internationally leading academic group within engineering cybernetics. This includes contribution to maintaining and advancing the field, cooperation with leading user groups, national and international cooperation, industry collaboration, combination of theory and applications, maintaining in-house workshop and prototype labs, education, dissemination and innovation. ITK's focus spans from academic research to industrial applications.

Education and research comprise the main activities at ITK. With one 5-year and two 2-year MSc programs, one BSc program and a large PhD program, ITK plays a key role nationally for education in the field of cybernetics. At the MSc level, ITK educates >80% of candidates in the field nationally, and the share is even higher at the PhD level. ITK's MSc programs are highly regarded by industry and attract high-quality students. The 5-year program is one of NTNU's largest master programs within technology and has been featured among the top 10 programs at NTNU for the last 10 years, and among the top 10 in Norway for the last 3-4 years. Overall, the activities within education, knowledge exchange, researcher training and outreach are distributed among all faculty members, as these activities depend on each other. Outreach is closely tied to research projects or education activities, research projects build on the knowledge that is taught to students, and ITK's courses are research-based in the sense that they are based on the evolving state of the art.

At ITK, collaboration with other academic groups and/or industry is a crucial component in most of their research projects. Engineering cybernetics provides a toolbox applicable to the modelling, observation, estimation and control of a wide range of technical and natural systems. For this reason, collaboration on applied research with academic groups and industry within almost any field comes naturally. ITK researchers have extensive collaboration within maritime technology, ocean modelling and observation, autonomous ships and drones, robotics, process industry, oil and gas production, energy systems, space technology, defence, medical technology, fisheries and aquaculture. Over the last decade there has also been a close relationship between the group and NTNU's Technology Transfer Office that have strongly supported the researchers, provided professional services, and contributed to the necessary processes towards commercialisation. This has significantly reduced the workload on researchers that want to pursue commercialisation and

provides a smooth and predictable path forward. NTNU has also provided so-called Discovery grants where doctoral students, postdocs and researchers could get funding to extend their contracts to pursue the commercial potential of their innovation. NTNU's policies have given incentives for researchers through shares of license incomes and spinoff companies.

The most commonly used infrastructures by ITK researchers are related to autonomous vehicles for observation and/or intervention. Researchers at ITK are also frequent users of high-performance computing and storage infrastructures, which are provided at a national level by Sigma2, but also available through the IDUN cluster at NTNU.

The unit have identified opportunities to exploit the popularity of their focus areas, as well as the placement of cybernetics within megatrends such as robotics, AI, healthcare, ocean spaces and energy systems. There is high potential for innovation and commercialisation within these areas.

Overall Assessment

The Department of Engineering Cybernetics should develop a cohesive and collaborative forward looking research strategy for the whole department. The interview confirmed that such a research strategy is on its way, and in particular joint applications for national research centres.

The administrative has excellent research and educational resources, but the administrative support should be improved. A challenge for the organisation is its large size and in integrating more recent recruitments. The diversity and equality plans are very good, but the gender balance can be improved. ITK has expanded the number of faculty members in the recent years without substantial increase in base funding. External research funding to keep up with this increase is a main challenge in the near future.

The research production, quality and integrity are excellent with several outstanding examples. The department is internationally well recognised for its research with high impact societal applications. The research at ITK is highly relevant to institutional and sectoral purposes and of high relevance for society. The submitted case studies confirm this. The involvement in EU research can be improved.

The Terms of References request the assessment of the four aspects:

1. NTNU has a national role in developing the technological foundation for the future society.

2. ITK aim to have a good balance in their portfolio between basic research based on small, cutting-edge research groups, and innovation-oriented requiring labour-intensive activities.

3. ITK educates more than 80% of students nationally within Engineering Cybernetics at the MSc and PhD levels.

4. ITK's focus spans from academic research to industrial applications. Some researchers in the department are primarily dedicated to specific application domains of cybernetics.

The Evaluation Committee confirms that the strength of ITK is in addressing fundamental societal research challenges within basic science and engineering applications and has been very successful in achieving its objectives. Their track-record and societal impact is excellent. ITK has also an excellent balance between education and research, and the number of current and graduated PhD students is most impressive.

The Department of Engineering Cybernetics faces challenges such as high workloads due to a large student-to-professor ratio, the need for even stronger interdisciplinary collaboration while not losing quality in basic engineering science research and keeping up with rapidly evolving new technologies such as in AI. Addressing these areas could further strengthen its academic and research leadership.

The Terms of Reference for the administrative unit is attached to the report.

Recommendations

The main recommendations to the Department of Engineering Cybernetics from the Evaluation Committee on how to improve its performance and develop future research strategies to ensure high quality of research and research output relevant both to national and international development are:

1. **Develop a Collaborative Research Strategy**:
    - Finalise and implement a department-wide research strategy.

- Prioritise joint applications for national research centres.

2. **Administrative Support**:
   - Assign an administrative project manager/coordinator to each research group to reduce the workload of professors, allowing them to focus on teaching and research.
3. **Enhance Postdoc and PhD Engagement**:
   - Improve the involvement of postdocs and PhD students in departmental leadership.
   - Consider establishing a Postdoc and PhD Student Council, if not already in place.
4. **Reflect on Departmental Organisation**:
   - Reassess the organisational structure to better manage the large department size, given the challenge of coordinating over 40 faculty members.
5. **Revisit Hiring Policy**:
   - Align hiring practices with the availability of base funding to ensure sustainability, especially considering the volatility of external grant funding.
6. **Promote ERC and EU Grant Applications:**
   - Encourage the department's strongest faculty members to apply for ERC and EU grants to enhance international reputation and ambition levels.
7. **Focus on Applied Research**:
   - Continue prioritising applied research projects and centres.
   - Invest in the improvement of critical ITK infrastructures.
8. **Enhance Publication Quality**:
   - Aim to publish in higher-quality journals, especially in the field of applied engineering science.
9. **Improve Gender Balance**:
   - Establish metrics to track and improve gender balance across the department.
   - Consider creating faculty positions specifically for women and forming an internal diversity, inclusion, and gender balance group.

These recommendations aim to strengthen ITK's research capabilities, organisational effectiveness, and inclusivity while enhancing its international visibility and industry relevant research focus.

1. Strategy, Resources, and Organisation of Research

The self-assessment report confirms that the Department of Engineering Cybernetics has a well-defined research strategy and organisation aligned with NTNU's overall goals on enabling a smart, safe and sustainable future for people, organisations and society. The research focus of the unit also matches closely with the strategies of the Faculty of Information and Technology and Electrical Engineering, making strong contributions to key areas such as Autonomous Systems, Cybersecurity, Digital Electrical Energy and Digital Health.

ITK strives to be an internationally leading academic group within engineering cybernetics and prioritises research excellence in control and AI for cyber-physical systems, robotics and autonomous systems and cybernetics in life sciences. The research group reports confirm that its research is of high international quality, and the unit has several internationally highly recognised professors. It also has excellent industrial collaborations and is an important educational department.

The administrative unit has been expanded in the recent years, and it is a challenge for such a large unit to have a joint research strategy. The development of the department has been organic over many years with no mergers with former university college units nor with other departments at NTNU. The size of the ITK department from both a national and international perspective is quite large. The successful history and branding of engineering cybernetics would make it difficult to re-organise the department.

1.1 Research Strategy

The research strategy of the Department of Engineering Cybernetics fits well with national and international strategies. The department prioritises outstanding researchers and emphasises identifying and supporting emerging research talent. The strategy has been to be the core principal investigator in major Norwegian research centres, such as the recently closed Centre for Autonomous Marine Operations and Systems (AMOS). The interview of the leadership showed that there are many ongoing initiatives and applications for new research centres. ITK is the coordinator of the centre Autoship and partner in SFIs Digiwells, Harvest and SubPro.

ITK has, in total, increased the number of permanent academic staff with 18.5 person-years in the last ten years. The strategy for hiring new associate professors has mostly been successful, while it has been more difficult to integrate and support some of the new more experienced professors. The age distribution among academic staff is balanced, with healthy renewal of researchers in the unit. At the same time the department depends on a high degree on external funding and is sensitive to changes in Norwegian research strategies. However, five gift professorships at ITK have been funded by Norwegian companies, which shows a very strong industrial relevance and support. However, the independence of industrial funding and support should also be noticed for the future.

The research groups within the department follow different strategies in their research and innovation activities, somewhat varying in structure and organisation. However, all research groups connect with the NTNU's overall strategy and the Sustainable Development Goals (SDGs), engaging in both basic and applied engineering research.

The identified lack of adequate administrative support poses a potential risk to the department's future success. It seems to be a result of the centralisation of administrative staff and support at NTNU.

Recommendations to the administrative unit:

The Evaluation Committee recommends to ITK to develop a collaborative research strategy for the whole department. The interview confirmed that this is on its way, and in particular joint applications for national research centres.

The Evaluation Committee recommends that all research units should have an administrative project manager/coordinator to reduce the workload of the professors and allow them to focus on teaching and research.

1.2 Organisation of Research

The management team, led by the Head of Department and two deputies for Research and Education, has well-defined roles. The Deputy Head of Research oversees the graduate program in Engineering Cybernetics, while the Deputy Head of Education is also the head of the 5-year MSc program in Cybernetics and Robotics. The leadership team includes representatives from administrative and technical staff.

The organisation of the Department of Engineering Cybernetics is well-suited for its research and education activities and the department understands its role in the Norwegian research system. The professors are rather independent in their roles and are on similar levels within the department. The associate professors are also independent as research leaders, and benefit from their senior colleagues.

The research is organised into three informal and partly overlapping groups in terms of competences and profiles. One group is more focused on applications in life sciences. The structure fits well with similar intentional departments without hierarchies among the faculty members. At the same time, it is more difficult to implement changes on a department level, as mentioned by the head of the department during the interview.

The teaching load for professors and associate professors are quite low from an international standard, with one master's course per teacher and academic year. This means that most faculty members have one semester per year without teaching. There seems also to be a voluntary dimension in the teaching distribution. There is a strong interplay between research and teaching. From a funding point of view the general distribution for the faculty members are research (40%), teaching (40%) and administration (20%). These numbers seem more related to budgeting than to the actual workload.

The research career opportunities seem most adequate, both early career development and within the PhD and postdoctoral training. The social interaction within the department seems good.

There are plenty of opportunities for international traveling including international conferences and research stints abroad.

Recommendations to the administrative unit:

- The involvement of PhD students and postdocs in the leadership can be improved by for example starting a Postdoc and PhD student council. This may already be in place, but no information could be found in the self-assessment report. The number of PhD students is large (in the order of 100).
- The Evaluation Committee recommends that the department should reflect on how to organise its research given its very large size. Departments with over 40 faculty members can be difficult to coordinate and lead.

1.3 Research Funding

The self-assessment report states that the Department of Engineering Cybernetics receives 60% of its funding from the Ministry of Higher Education, and 40% from competitive sources such as national grants, industry projects and international grants.

External funding primarily comes from RCN grants (about 70%), with industry projects contributing 22%, EU grants 5%, and other international grants making up the remainder. The administrative unit has been very successful in applying for external grants. Approximately 69% of ITK's total budget is allocated to research. There are some 100% internally funded PhD students.

Recommendations to the administrative unit:

- The Evaluation Committee recommends that the administrative unit should re-consider its hiring policy in relation to the amount of base funding in times when external grants are sensitive to political decisions.

- The Evaluation Committee recommends that successful faculty members should be encouraged to also apply for ERC grants. This would strengthen the international reputation and visibility and increase the ambition level.

1.4 Research Infrastructures

The Department of Engineering Cybernetics is well-equipped with the necessary facilities for more applied research projects. The infrastructures most frequently used by ITK researchers are those related to autonomous vehicles for observation and intervention. It includes ocean drifters from Arctic ABC, autonomous underwater and surface vessels via AUR-Lab, and aerial drones from Seabee and ITK's UAV lab. Oceanographic data is collected through NorSoop's instrumentation on regular ships, supporting both data acquisition and research. Marine operations and autonomous ship research are facilitated by OceanLab, and ITK, in partnership with the Department of Electronic Systems, has developed the prototype autonomous ferry milliAmpere II through the Autoferry project. OceanLab also supports research on aquaculture technology, while PLANKTONLAB and RI Seaweed provide facilities for plankton and seaweed aquaculture research. ITK researchers frequently use high-performance computing and storage through national infrastructures like Sigma2 and NTNU's IDUN cluster.

Several ESA infrastructures are relevant to ITK research, including the Copernicus satellite remote sensing data. Key ESFRI infrastructures important to ITK research include Euro Argo ERIC and SIOS Svalbard for ocean modelling and observation, and the Finnish node of Euro-BioImaging ERIC for brain cybernetics research.

ITK also manages or co-manages several additional cutting-edge research infrastructures.

There is an NTNU Data Management Plan to fulfil the FAIR-principles.

<u>Recommendations</u> to administrative unit:

- The Evaluation Committee recommends focusing on applied research projects and centres and invest in the improvements and maintenance of the most important ITK infrastructures.

1.5 National and international collaboration

Collaboration with industry and national and international research institutions is essential for ensuring quality, relevance, and competitiveness in securing funding. NTNU has partnerships with major Norwegian companies, as well as public institutions, involving support for PhD students, professor positions, and joint research. NTNU also partners with SINTEF, Norway’s largest independent research institute, a key partner for both NTNU and the administrative unit.

International cooperation is a priority in NTNU’s 2022–2025 strategy, focusing on leveraging EU funding, forming strategic global partnerships, recruiting top researchers, and promoting student and staff mobility.

At the Department of Engineering Cybernetics, collaboration with academic groups and industry is vital to most research projects. Engineering cybernetics is applied across fields such as maritime technology, autonomous systems, energy, space technology, and medical technology. National and international networks are maintained by research groups and individual researchers, supported by mobility programs like PhD exchanges and research leave.

The NIFU report shows good relative citation indicators, with average mean normalised citation score of 119 for the period 2019-2021. Here is 100 is the world average. The trend the last ten years is, however, descending.

The NIFU bibliometric report also shows the share of publications with national and international co-authors as an indicator of collaboration. From 2013 to 2022, 17% of publications had co-authors from other Norwegian institutions, and 42% from international ones. There is a slight increase in national co-authors and a slight decrease in international ones, likely reflecting stronger collaborations with Norwegian industry and research organisations. The most frequent national partners in 2020-2022 include SINTEF, Equinor, FFI, DNV, and major universities. High-impact publications with international co-authors are indicators for true successful collaborations.

Recommendations to administrative unit:

The Evaluation Committee recommends further improving the quality of the chosen journals for more applied engineering projects.

1.6 Research staff

The Department of Engineering Cybernetics has a good recruitment policy and succession plan to promote future needs for researchers and meet the requirements for gender balance, age distribution and recruitment, proportion of professors/senior researchers etc. It is more difficult to realise the plans given the current constraints, and on gender balance that is a common challenge in the areas of the department. Women are still underrepresented, making up just 13% of permanent staff, none in in part-time II positions, and 15% of PhD students and postdocs.

The Personnel section of the NIFU report confirms the information in the self-assessment report. It also shows that ITK has rather middle-aged faculty members (average age around 50).

The distribution of research time among the staff, including criteria for research leave/sabbaticals, seems most adequate. This is confirmed by the self-assessment report.

Recommendations to the administrative unit:

The Evaluation Committee recommends that the department should put up metrics for gender balance and may initiate faculty positions only for women. It would also be good to set up an internal diversity, inclusion and gender balance group.

1.7 Open Science

Research results at the Department of Engineering Cybernetics are published according to NTNU's "Policy for Open Science," with data management plans supporting FAIR principles. Sensitive data in innovation projects are protected, ensuring compliance with GDPR and industry needs. ITK aims to release software as open-source whenever possible.

Open science is emphasised through training for PhD students and staff, with seminars and support from the NTNU University Library. NTNU also supports open access publishing by covering article processing charges through publisher agreements.

Currently, about two-thirds of ITK publications are open access, a figure that grew from 2013 to 2018 and has remained stable since, though further efforts are mentioned to increase it.

NTNU's open science policy mandates that research results and data should be made publicly available when legally and practically possible. However, open access may not always be appropriate due to issues like sensitive data, copyright restrictions, or commercial agreements while researchers must adhere to good scientific practices for documenting results and managing data. NTNU encourages sharing underlying data, methods, algorithms, and code where feasible.

The policy also requires all research projects to have a Data Management Plan (DMP), with resources available for support. While DMPs are not used in all projects, they are implemented in most and are standard for national infrastructure projects.

Several good examples of open science are reported in the self-assessment report.

Recommendations to the administrative unit:

- The Evaluation Committee recommends maintaining the current level and quality of work, as such consistent performance significantly contributes to overall success and progress.

2. Research production, quality and integrity

NTNU's code of ethics covers employee conduct, impartiality, confidentiality, and research ethics. The Research Integrity Committee handles misconduct cases and promotes ethical awareness through seminars. Research ethics is mandatory for PhD students, who complete courses on academic integrity, data handling, and provide an ethical reflection as part of their project plan.

The Department of Engineering Cybernetics is organised around three overall research focus areas. The descriptions of the subtopics are condensed from the self-assessment report.

1. **Robotics and Autonomous Systems:**

Autonomous Ferries: Aims to revolutionise the maritime industry by enhancing efficiency, reducing costs, and contributing to greener mobility.

Underwater Snake Robotics: Focuses on reducing subsea maintenance costs through innovative inspection and repair technologies.

Uncrewed Aerial Vehicles (UAVs): Supports the growing drone industry, with applications in delivery, agriculture, shipping, and emergency response. Research on UAV icing improves reliability in cold climates.

Small Satellites: Promotes advancements in space technology for communication and earth observation.

2. **Systems and Control Theory:**

Estimation and Control: Applied to pipelines, oil drilling, power systems, and chemical processes, with key advances in predictive control, Kalman filter estimation, and explainable AI for decision-making.

Model Predictive Control (MPC): Links MPC to Reinforcement Learning, reducing computational demands for power converters.

Instrumentation Systems: Improves safety-instrumented systems by enhancing automation and failure data reporting, aligning with Industry 4.0 standards.

Safety-Critical Systems: Develops new safety methods for complex systems, including digital twins for safety demonstrations.

Internet of Things (IoT): Focuses on real-time data from low-cost, low-maintenance nodes, with emphasis on energy management and tailored data quality.

Big Data & Digital Twins: **C**ombines physics-based and data-driven models for high-stakes applications and has advanced digital twin technology.

3. **Cybernetics in Life Sciences:**

Brain Cybernetics: Optimises EEG electrode selection using Genetic Algorithm Optimisation for Brain-Computer Interfaces.

Biomedical Cybernetics: Contribution to prosthetic control systems and patented diabetes treatment technologies.

Precision Fish Farming: Establish and advance precision aquaculture, now widely adopted by industry.

In summary, NTNU ITK's research spans advanced control strategies, optimisation, safety systems, and robotics, with most important industrial and life-science applications.

2.1 Research quality and integrity

Research group Robotics and Autonomous Systems – RAS overall assessment

The RAS research group at NTNU is among the leading labs in Europe in guidance, navigation, and control of autonomous robots, including marine- and aircraft. The RAS group is a formation of some of the most outstanding information- and communication technology (ICT) and Technology professors in Norway. The Autonomous Robots Lab has a new research direction led by an internationally recruited excellent younger professor. The Industrial Robotics Lab is the weakest lab in terms of academic and industrial impact, and the recommendation from the Expert Panel is to reconsider this research direction. There is also a similar research activity at the Department of Mechanical and Industrial Engineering, NTNU. The UAV Icing Lab seems well connected to the UAV Lab. The Small Satellite Lab. where students can do research in satellite engineering for environmental and disaster response monitoring, is an exciting new initiative. Their main challenge is strategy after the essential and significant AMOS Centre of Excellence. There are some new initiatives such as the CAROS (NTNU VISTA Centre for autonomous robotic operations subsea), SFI Autoship, and the involvement in the Ocean and Coast strategic area for NTNU. The scientific impact of the RAS group research and publication is outstanding. An ERC advanced grant, awards, keynotes, and many high-impact journal publications, with best paper awards, and important books confirm this. The group’s dependence on and sensitivity to the work of the three more established professors is high, and faculty renewal on a 10-to15-year horizon is a key challenge. The research group combines excellent scientific contributions with important engineering applications. The main reason is their strength in basic research in combination with the ability to move into exciting application fields together with collaborators. Their high external funding and many successful projects confirm this. To achieve societal impact, it is of utmost importance to focus on PhD education. The ratio of PhD students to supervisors at RAS is very good. The primary societal contribution of the research group is in educating students, imparting them with advanced robotics knowledge and lifelong skills. Additionally, the group promotes development through initiatives at the Autonomous Ferry Lab, the Underwater Lab, the Snake Robot Lab, the UAV Lab, and the Small Satellite Lab. These efforts not only advance technology but also stimulate economic growth, positioning Norway as a leader in the fields of robotics and autonomous systems. The RAS group was instrumental in initiating and running the very successful AMOS Centre of Excellence for the last ten years. They have excellent relations with the Norwegian industry, particularly in the maritime technology field. The organisational environment is very strong for supporting the production of excellent research. The research group mentions

some challenges with centralised administration. The quality of the research is world leading in terms of quality and is comparable to the best work internationally in the same area of research. The submitted examples of publications confirm that the work of the group meets the highest international standards in terms of originality, significance, and rigor. The group has an outstanding role in the research process from the formulation of overarching research goals and aims via research activities to the preparation of the publication. The group has contributed extensively to economic and societal development in Norway and internationally. The involvement of societal partners is outstanding – industrial partners have had an important role in all parts of the research process, from problem formulation to the publication and/or process or product innovation. The group should be highlighted in the evaluation's national assessment of the area.

Research group Control and AI for Cyber-Physical Systems overall assessment

The Control and AI for Cyber-Physical Systems group at the Department of Engineering Cybernetics at NTNU is among the leading research groups in the world related to model predictive control for applications in the process industries. The research group is logically divided into a process control group, an industrial computer and instrumentations systems group, and a big data cybernetics group. The research group could benefit even more from these competencies by putting even more emphasis on collaboration and overall industrial demonstration of complete process control systems based on model predictive control. Such collaboration could potentially have a very large impact on the digitalisation of the process industries. Also, the collaboration with other process control groups at NTNU should be strengthened. The quality and quantity of research publications in leading scientific journals are impressive and these publications have a significant influence on the direction of international research with model predictive control.

Research group Cybernetics in Life Sciences-Biocybernetics overall assessment

The Control and AI for Cyber-Physical Systems group at the Department of Engineering Cybernetics at NTNU is among the leading research groups in the world related to model predictive control for applications in the process industries. The research group is logically divided into a process control group, an industrial computer and instrumentations systems group, and a big data cybernetics group. The research group could benefit even more from these competencies by putting even more emphasis on collaboration and overall industrial demonstration of complete process control systems based on model predictive control. Such collaboration could potentially have a very large impact on the digitalisation of the process industries. Also, the collaboration with other process control groups at NTNU should be strengthened. The quality and quantity of research publications in leading scientific journals are impressive and these publications have a significant influence on the direction of international research with model predictive control.

3. Diversity and equality

Following NTNU's gender equality and diversity plan, the Department of Engineering Cybernetics is committed to promoting inclusion, tolerance, and a sense of belonging, helping NTNU grow as a diverse university. The plan addresses six main areas: achieving gender balance, enhancing diversity and inclusion, supporting international staff and students, addressing functional diversity, acknowledging gender identity and expression, and combating discrimination and harassment.

To support this, ITK utilises tools like the ARK Work Environment Survey, conducted every two years to assess workplace conditions, and a whistleblowing system that allows staff to confidentially report issues like harassment.

ITK has increased the proportion of female MSc students to 40%, thanks to long-term efforts like the Ada project, which encourages women to pursue technology careers. However, female representation among PhD students and postdocs remains low at 15% in 2022, showing fluctuations over recent years.

4. Relevance to institutional and sectorial purposes

The Department of Engineering Cybernetics leads nationally in cybernetics education, offering a 5-year program, two 2-year MSc programs, a BSc program, and a large PhD program. It educates over 80% of MSc and PhD candidates in the field, with its programs highly regarded by industry. The 5-year program is among NTNU's largest and consistently ranks in Norway's top 10 for admission standards.

Research is prioritised, with capped teaching duties allowing for high output. ITK’s publications have grown from 150 to 250 annually (2013-2022), with 66% now Open Access. In 2022, 36% of its journal papers appeared in top-tier journals.

ITK’s research spans control theory to applications like aquaculture and power systems. Strong industry ties have resulted in patents, technology licensing, and spinoffs. Public outreach includes over 100 talks, 40 interviews, and a published book.

5. Relevance to society

The Department of Engineering Cybernetics has a strong research portfolio aligned with the Long-Term Plan for Research and Higher Education, focusing on ocean autonomy, observation, and sustainable fisheries. Notable projects include AMOS, AutoFerry, and SFI AutoShip, producing over 140 PhDs and 1,900 publications. ITK also pioneered Precision Fish Farming, significantly influencing the aquaculture industry.

In health, ITK has made key contributions to prosthetics and diabetes treatment. In climate and energy, ITK's work optimises processes for sustainability, including wind energy and smart grids. ITK’s research enhances control systems for critical infrastructure, contributing to Industry 4.0 and developing reliable autonomous systems.

The department has also advanced civil protection through models for critical infrastructure and safety systems. In education, ITK's BSc, MSc, and PhD programs in cybernetics are highly sought after, producing over 80% of national candidates and enrolling over 100 PhD students. The PhD program is a key driver of ITK's research efforts.

5.1 Impact cases

Comments to impact case 1: Autonomous urban passenger ferries

In 2016, NTNU began research on autonomous passenger ferries for urban waterways, aiming to replace bridges and reduce road traffic with self-driving electric ferries. Over 300 researchers and students, along with industry and public sector partners, contributed to this effort. This led to the world's first full-scale trial of an autonomous ferry in Trondheim in 2022. In 2019, the spinoff company Zeabuz was founded. In 2023, Zeabuz and Torghatten launched the first commercial autonomous passenger ferry in Stockholm.

This case study shows how to successfully transfer research into innovative businesses. It also shows the importance of PhD education and let graduated PhD students take the lead in starting new companies. The industrial prospect of Zeabuz seems promising, but it is still too early to say.

Comments to impact case 2: Improved system training for myoelectric upper limb prosthesis control

Prior to this work, myoelectric control systems for upper limb prostheses using pattern recognition and machine learning worked well in labs but were unreliable in everyday use. In collaboration with a Canadian university around 2010, researchers identified the "limb position effect" as a key issue and proposed training control systems with the limb in various positions to improve reliability. These findings influenced how prostheses are now trained in clinics. Since 2020, users are advised to calibrate their systems in different positions, enhancing control reliability and personalisation. The WHO estimates 35–40 million people globally require prosthetic and orthotic services, though data on upper limb prosthesis users is limited.

Otto Bock, a leader in prosthetics, launched the MyoPlus system in 2020, which uses pattern recognition for myoelectric hands. The system requires training in multiple arm positions, echoing earlier research. Key training positions include elbow flexed, arm down, and arm extended, with further adjustments made for unrecognised movements.

This case shows that it takes time to move basic research results into high impact products, and the importance of having long-term goals.

Comments to impact case 3: Unlocking the potential of UAV operations in icing conditions

Unmanned Aerial Vehicles (UAVs) have diverse applications, but in-flight icing is a major safety issue, especially in cold climates like Norway. Leading research in this field led to the creation of UBIQ Aerospace in 2017, which commercialises ice protection systems for UAVs. This research expands UAV use in areas like medical logistics, search and rescue, and defence, while also contributing to greener aviation technologies, such as fully electric aircraft and eVTOL. UBIQ Aerospace, a spinoff from NTNU ITK, was founded in 2017 with three employees and has since grown into one of Norway's most successful deep-tech startups, now employing over 30 people. With significant private investments from 6AM, Lupa Systems, and Statkraft Ventures, UBIQ aims for continuous growth.

This case study shows how a successful PhD project is developed into a successful company. It also illustrates the importance of cold climate innovations.

Methods and limitations

Methods

The evaluation is based on documentary evidence and online interviews with the representatives of Administrative Unit.

The documentary inputs to the evaluation were:

- Evaluation Protocol that guided the process
- Terms of Reference
- Administrative Unit's self-assessment report
- Administrative Unit's impact cases
- Administrative Unit's research groups evaluation reports
- Bibliometric data
- Personnel and funding data
- Data from Norwegian student and teacher surveys (only for HEIs)

After the documentary review, the Committee held a meeting and discussed an initial assessment against the assessment criteria and defined questions for the interview with the Administrative Unit. The Committee shared the interview questions with the Administrative Unit two weeks before the interview.

Following the documentary review, the Committee interviewed the Administrative Unit in an hour-long virtual meeting to fact-check the Committee's understanding and refine perceptions. The Administrative Unit presented answers to the Committee's questions and addressed other follow-up questions.

After the online interview, the Committee attended the final meeting to review the initial assessment in light of the interview and make any final adjustments.

A one-page summary of the Administrative Unit was developed based on the information from the self-assessment, the research groups' evaluation reports, and the interview. The Administrative Unit had the opportunity to fact-check this summary. The Administrative Unit approved the summary without adjustments.

Limitations

The Committee judged the information received through documentary inputs and the interview with the Administrative Unit sufficient to complete the evaluation.

List of administrative unit's research groups

Institution	Administrative Unit	Research Groups
Norwegian University of Science and Technology	Department of Engineering Cybernetics	Robotics and Autonomous Systems - RAS
		Control and AI for Cyper-Physical Systems
		Cybernetics in Life Sciences-Biocybernetics

Terms of Reference (ToR) for the administrative unit

The board of the Faculty of Information Technology and Electrical Engineering, NTNU mandates the evaluation committee appointed by the Research Council of Norway (RCN) to assess the Department of Engineering Cybernetics (ITK) based on the following Terms of Reference.

Assessment

You are asked to assess the organisation, quality and diversity of research conducted by the Department of Engineering Cyberneticsas well as its relevance to institutional and sectoral purposes, and to society at large. You should do so by judging the unit's performance based on the following five assessment criteria (a. to e.). Be sure to take current international trends and developments in science and society into account in your analysis.

a) Strategy, resources and organisation

b) Research production, quality and integrity

c) Diversity and equality

d) Relevance to institutional and sectoral purposes

e) Relevance to society

For a description of these criteria, see Chapter 2 of the mathematics, ICT and technology evaluation protocol. Please provide a written assessment for each of the five criteria. Please also provide recommendations for improvement. We ask you to pay special attention to the following 4 aspects in your assessment:

1. NTNU has a national role in developing the technological foundation for the future society.

2. We aim to have a good balance in our portfolio between basic research based on small, cutting-edge research groups, and innovation-oriented requiring laborintensive activities.

3. ITK educates more than 80% of students nationally within Engineering Cybernetics at the MSc and PhD levels.

4. ITK's focus spans from academic research to industrial applications. Some researchers at the department are primarily dedicated to specific application domains of cybernetics.

In addition, we would like your report to provide a qualitative assessment of the Department of Engineering Cybernetics as a whole in relation to its strategic targets. The committee assesses the strategy that the administrative unit intends to pursue in the years ahead and the extent to which it will be capable of meeting its targets for research and society during this period based on available resources and competence. The committee is also invited to make recommendations concerning these two subjects.

Documentation

The necessary documentation will be made available by the mathematics, ICT and technology secretariat at Technopolis Group.

The documents will include the following:

- a report on research personnel and publications within mathematics, ICT and technology commissioned by RCN
- a self-assessment based on a template provided by the mathematics, ICT and technology secretariat

Interviews with representatives from the evaluated units

Interviews with the Department of Engineering Cybernetics will be organised by the evaluation secretariat. Such interviews can be organised as a site visit, in another specified location in Norway or as a video conference.

Statement on impartiality and confidence

The assessment should be carried out in accordance with the *Regulations on Impartiality and Confidence in the Research Council of Norway*. A statement on the impartiality of the committee members has been recorded by the RCN as a part of the appointment process. The impartiality and confidence of committee and panel members should be confirmed when evaluation data from the Department of Engineering Cybernetics are made available to the committee and the panels, and before any assessments are made based on these data. The RCN should be notified if questions concerning impartiality and confidence are raised by committee members during the evaluation process.

Assessment report

We ask you to report your findings in an assessment report drawn up in accordance with a format specified by the mathematics, ICT and technology secretariat. The committee may suggest adjustments to this format at its first meeting. A draft report should be sent to the Department of Engineering Cybernetics and RCN. The Department of Engineering Cybernetics should be allowed to check the report for factual inaccuracies; if such inaccuracies are found, they should be reported to the mathematics, ICT and technology secretariat within the deadline given by the secretariat. After the committee has made the amendments judged necessary, a corrected version of the assessment report should be sent to the board of the Faculty of Information Technology and Electrical Engineering and the RCN no later than two weeks after all feedback on inaccuracies has been received from the Department of Engineering Cybernetics.

Appendices

1. Description of the evaluation of EVALMIT
2. Invitation letter to the administrative unit including address list
3. Evaluation protocol
4. Template of self-assessment for administrative unit (short-version)

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