Evaluation of Natural Sciences 2022-2024

Evaluation report NORSAR Foundation (NORSAR)

January 2024



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Statement from Evaluation Committee III – Institutes I

The members of this Evaluation Committee have evaluated the following administrative units at the research institutes within natural sciences in 2022-2023 and submitted a report for each administrative units:

- NORSAR Foundation
- SINTEF Industry
- SINTEF Digital
- Norwegian Geotechnical Institute (NGI)
- Geological Survey of Norway (NGU)

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 has consisted of the following members:

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Professor Christian Moorman	Dr Peter Tom Jones	
University of Stuttgart, Germany	KU Leuven Institute of Sustainable Metals and Minerals	

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Description of the administrative unit

NORSAR is an independent research foundation in Norway specialising in seismology, geophysics, and related fields. It plays a crucial role in providing geoscientific knowledge and expertise to support sustainable resource management, environmental protection, and hazard assessment.

Research activities at NORSAR are structured around a single comprehensive research group. In addition to this overarching structure, projects and researchers are organised into interdisciplinary teams, forming a matrix-style setup. Most of the research projects span one to four years. Teams are designed to optimally achieve project objectives, leverage learning opportunities, and align with individual researchers' academic interests and educational requirements. In terms of diversity, NORSAR has a small team of around 50 people (38 of whom are researchers) with 30% women and 70% men, representing 12 different nationalities.

NORSAR's main missions is event detection (e.g., nuclear tests, earthquakes, etc.) based on seismology and aided by machine learning and geoscience software developments. NORSAR states that they aspire to become world-leaders in applying fibre technology for event detection and subsurface descriptions aided by distributed data processing. NORSAR's research strategy is therefore primarily focused on advancing the understanding of seismology, geophysics, and related fields. NORSAR actively collaborates with national and international institutions to promote knowledge exchange and enhance global seismological capabilities.

A third of NORSAR's funding comes from RCN for funded projects and their based funding, whilst a further third (35%) supports their role in monitoring compliance to the Comprehensive Nuclear Test Ban Treaty and some disarmament initiatives (joined funding from Ministry of Foreign Affairs and CTBTO). The remainder of NORSAR funding comes from other sources, including 4% from European sources, 4% from the US government and 23% from industry-funded projects. They have achieved a success rate of 15% in highly competitive EU projects, indicating their capability to secure funding.

NORSAR's main sectoral and societal contribution is the monitoring of compliance to the Comprehensive Nuclear Test Ban Treaty on behalf of Norwegian authorities. NORSAR's advances in detection seismology are used to improve the international monitoring system and the way the network of the seismic stations is operated. NORSAR supports the Ministry of Foreign Affairs in their work to build a strong international body supporting the Treaty. Additionally, NORSAR contributes with real-time monitoring of potential nuclear explosions and near-real time analysis of explosion impacts near nuclear power plants in Ukraine. NORSAR is also in active dialogues with stakeholders and decision makers on monitoring of CO2 storage sites and towards safe implementation of CO2 storage.

NORSAR actively engages in research commercialisation activities and supports this through their subsidiary, NORSAR Innovations AS. In its self-assessment, NORSAR lists a range of successful innovation and commercialisation results including seismic modelling software solutions, digital zonation maps, and detection and warning of avalanches over roads, for example.

NORSAR prioritise open-access publications and the sharing of data, contributing to the dissemination and accessibility of research findings. NORSAR is involved in the Seismica open-access journal and actively participates in national and international networks for data sharing, particularly within the European Plate Observing System (EPOS) and the European Integrated Data Archive. NORSAR is also in the process of developing a data management plan, with open-access data being the norm through its website.

In its self-assessment, NORSAR identified the following strengths to enable in the future: (1) established and leading in the specialised research topic on detection seismology; (2) its size and strong financial position allow it to quickly adjust course if required or when an opportunity may arise; (3) its unique infrastructure with seismic arrays and newly developed fibre optic cable deployments allows for unique research opportunities together with proprietary software solutions. The threats related to NORSAR's internal weaknesses are: (1) changes in the national research

funding by RCN and EU programmes; (2) competition on a national and international scale from larger research organisation in newly developed research areas like machine-learning and fibre optic sensing that can pose a threat on the availability of relevant researchers that are out-competed by high industry salaries or that NORSAR's research and development may not be exploited as much as it could.

Overall assessment

As a whole, the evaluation committee finds NORSAR's performance to be exceptional.

This evaluation finds that NORSAR excels in seismology, earthquake monitoring, and related research. Their cutting-edge studies and advanced technologies provide valuable insights into seismic activities and supports their positive impact on society. With an extensive network of seismic stations, and fibre optic cables, newly installed and maintained, NORSAR's sophisticated monitoring systems enable the detection and analysis of earthquakes, contributing to global monitoring efforts and aiding disaster management and early warning systems. NORSAR's technical capabilities, including innovative technologies and data analysis methods, have led to significant advancements in earthquake research. Through collaborations with national and international organisations, academic institutions, and research agencies, NORSAR promotes knowledge exchange, joint projects, and international cooperation in seismology. Their dedication to public outreach and education helps raise awareness about earthquakes and prepares communities for seismic events, contributing to resilient societies. Governments, policymakers, and organisations frequently seek NORSAR's expertise for seismic risk assessment, hazard mitigation, and disaster response planning, benefiting from their scientific advice and evidence-based recommendations in developing robust policies.

The threats and opportunities for the future identified by NORSAR are sensible (such as improving their competitivity in areas such as Artificial Intelligence and fibre optic technology). Though the self-assessment report does not provide many specific details on how they plan to address these opportunities, the explanations provided during the interview were convincing. The combined use of AI and fibre optic technologies is promising for NORSAR's research and applications.

In response to NORSAR specific request as part of their Terms of Reference for the evaluation, the committee agrees that NORSAR has strong societal relevance, and their work clearly aligns with several UN sustainability goals. This includes through its involvement in monitoring compliance with the Comprehensive Nuclear Test Ban Treaty on behalf of Norwegian authorities, earthquake hazard and risk assessment services, and supporting innovation to further improve safety, which the committee all find to be credible and demonstrate good application of NORSAR's expertise. These are detailed further in Section 5 (Relevance to Society), though suggestions for further research areas aligned with current objectives provided throughout the report.

Recommendations

The committee suggests that NORSAR continues to invest in innovation, new methodologies, and data analysis techniques to advance seismological science, expand capabilities and collaborate with Institutions. The committee recommends also continuing to foster partnerships with leading national and international research organisations for knowledge exchange, data access, and joint projects.

NORSAR is a relevant institution for the expansion of global monitoring networks by deploying more seismometers in strategic locations for improved detection and analysis of seismic events and fibre optic deployments. The institute should also expand its work in developing advanced techniques like machine/deep learning to extract insights from seismic data, enabling better event prediction and timely information dissemination. As recognised in the SWOT analysis, this research is promising for the future.

NORSAR has to continue to actively participate in discussions with policymakers and international organisations to shape regulations, influence policies, ensure the effective utilisation of research findings. Continuing to prioritise public awareness through workshops, seminars, lectures, and educational programs on seismology and nuclear test monitoring in a good way to foster collaboration and knowledge dissemination.

In terms of research funding, the committee encourages NORSAR to continue to explore partnerships with private organisations, apply for international/EU research grants, such as Marie Slodowska Curie

Grant (for hiring high-level post-docs), and consider commercialisation of technologies and expertise to diversify funding sources.

1. Strategy, resources, and organisation of research

NORSAR demonstrates a well-structured and cohesive research strategy and an approach for reviewing this strategy annually to keep the institute agile and responsive to opportunities and needs. This strategy emphasises collaboration with both national and international institutions to facilitate knowledge exchange and bolster global seismological capabilities. It is underpinned by clearly defined vision and mission statements that articulate the institution's long-term research objectives and aspirations.

NORSAR is proactive in identifying potential challenges and opportunities, particularly in terms of enhancing competitiveness in areas like artificial intelligence (AI) and fibre optics. However, the specific strategies for achieving this enhanced attractiveness require further elucidation.

NORSAR have been successful in securing competitive funding for research activities in addition to their base funding and funds to support their role in monitoring compliance to the Comprehensive Nuclear Test Ban Treaty and some disarmament initiatives.

NORSAR is well-connected at both national and international levels through its participation in networks such as EPOS (European Plate Observing System) and the European Integrated Data Archive. Additionally, it demonstrates a commitment to open-access publications and data sharing, promoting transparency and the dissemination of research findings.

The NORSAR's team, though only around 50 people strong, is diverse, comprising 30% women and 70% men, with representation from 12 different nationalities, fostering an inclusive and international work environment. NORSAR favours permanent positions for its employees. To strengthen their workforce, particularly in areas that require cutting-edge skills (AI and fibre optics), they hire post-docs. For hiring high-level post-docs, the committee advises them to apply to the EU's Marie Slodowska Curie calls.

Regarding best practices, it is noted that there is a positive inclination, although specific details are not available in the self-assessment report. Further information has been added to comprehensively evaluate and confirm the extent of adherence to best practices within NORSAR.

1.1 Research Strategy

The self-assessment form provides an overarching summary of NORSAR's approach to setting its research strategy and mission, however the document provided to the evaluation committee is both quite short and in Norwegian.

According to the self-assessment report provided, NORSAR's mission is focussed on nuclear tests detection and aims to excel in event detection through seismology, machine learning, and geoscience software. NORSAR also strive to lead in fibre technology for event detection and subsurface description aided by data processing, with their focus extending to earthquake hazard and risk assessments. Their specific strategies for working against this mission however are less clear.

Despite its paramount significance, NORSAR's emphasis on nuclear detection is not apparent in the majority of the documented research activities and outcomes presented at the research group level. NORSAR should therefore consider how to best incorporate its research work in other emerging fields and future objectives with its missions statement in seismic event detection.

NORSAR provide details on their approach for developing and updating their research strategies, which are positive. NORSAR updates its strategy annually through employee feedback and efficient decision-making. This enables the administrative unit to stay agile in its research and innovation activities and the flexibility clearly allows to react swiftly to changes and opportunities.

Weekly meetings encourage idea exchange and discussion with the whole group. Feedback goes to EU Framework solicitations and common arenas like FFA and ERA-NET. NORSAR combines fundamental and applied research for relevance to technological and societal needs, with a policy focus on safe society, natural hazards, geothermal energy, and safe CO2 storage.

NORSAR developed an extensive network of infrasound and seismic stations for providing new observations of weather and climate-related phenomena. Measuring infrasound signals that travel through the atmosphere, provides unique wind and temperature data from the mesosphere and stratosphere. These data could be used in weather and climate models. This network also records glacial movements due to temperature increases, opening up a promising area of research into associated hazards.

1.2 Organisation of research

Research at NORSAR operates within a single, cohesive research group and their research is projectbased and organised in interdisciplinary teams. From the institute's perspective this enhances their organisational agility. Most projects typically span one to four years, and project teams are carefully constructed to optimise project outcomes, promote learning opportunities, and cater to individual researchers' academic interests and educational needs. The self-assessment report also details NORSAR's processes for monitoring and managing project progress and potential risks. This structure is appropriate given the size and nature of the administrative unit's work.

The SWOT analysis documented in the self-assessment is relevant and appropriate and the evaluation committee finds the issues identified to be credible. The evaluation committee supports the recognition of the overreliance on particular funding sources (such as RCN or EU research programmes) to be a potential threat, but also that these threats could be mitigated by working towards realising opportunities for increased commercialisation of research and expanding their areas of activity into neighbouring research fields and markets.

1.3 Research funding

A third of NORSAR's funding comes from RCN for funded projects and their based funding, whilst a further third (35%) supports their role in monitoring compliance to the Comprehensive Nuclear Test Ban Treaty and some disarmament initiatives (joined funding from Ministry of Foreign Affairs and CTBTO). The remainder of NORSAR funding comes from other sources, including 4% from European sources, 4% from the US government and 23% from industry-funded projects.

The evaluation committee recognises that the administrative unit has a significant amount of funding for its small size. The committee recommends NORSAR continue to explore opportunities to further diversify their funding sources. This could include seeking partnerships with private organisations, continuing to apply for international/EU research grants, such as Marie Slodowska Curie Grant to support recruitment of high-level post-docs, and consider the commercialisation of technologies and expertise.

1.4 Use of Infrastructures

The administrative unit is highly active in research infrastructures, which represent an important enhancement of its own facilities. NORSAR is a participant in the Norwegian node (EPOS-NO) of the European Plate Observing System (EPOS ERIC), a partner in the Troll Observing Network in Antarctica, plays a significant role in ECCSEL-ERIC and in 2022, NORSAR re-established its membership in SIOS (Svalbard Integrated Arctic Earth Observing System).

1.5 National and international collaboration

NORSAR actively pursues collaboration on both national and international fronts, fostering partnerships within academia and industry. They recognise that through collaboration, they can engage a broader community and amplify the impact of their research efforts. NORSAR's involvement in the international seismological community is evident, including its representation as the secretary-general of the International Association of Seismology and Physics of the Earth's Interior (IASPEI). Additionally, NORSAR takes the lead in coordinating the Young Professionals Network within the CTBTO.

For collaborations of strategic significance, NORSAR has established formalised collaboration agreements and these long-term partnerships have proven to be not only fruitful but also essential for achieving their goals and aspirations.

1.6 Research staff

NORSAR has about 50 employees allowing a flexible organisation, quickly adjusted if an opportunity or requirement arises, however, the ability and capacity are limited to follow through on new initiatives. The balance of researchers to engineers, technicians and admin support are appropriate.

Overall, NORSAR's staff is highly qualified. NORSAR has recently undergone a generational shift, which provided an opportunity to enhance its gender diversity. They have processes in place to monitor progress toward equality (including representation of different genders, nationalities and qualifications at all organisational levels) which helps NORSAR to track the evolution of its efforts and identify potential measures to promote equality. Their Equal Opportunities document is up to date and sufficiently detailed to be convincing.

The majority of the employees fall within the age range of 30 to 50 years. Additionally, the staff is internationally diverse, encompassing individuals from 12 different nationalities. Among their research team, approximately 30% are women, while 70% are men. Additionally, the decision making structures are not male-dominated.

The evaluation committee finds NORSAR's approaches to supporting career development of their staff to be good. The NORSAR initiated research endeavour called "The Week" is forward-thinking, and their encouragement of NORSAR research staff to actively engage in international research networks, such as the Young Professionals Network of the CTBTO is also good. Their self-assessment report also provide details opportunities for staff and PhD students to apply for external research stays.

2. Research production, quality and integrity

NORSAR has global recognition as a renowned research institute, characterised by a robust and rising track record of high-level publications and commendable productivity. Their contributions consistently push the boundaries of the state-of-the-art in their field.

Furthermore, NORSAR is actively advancing the data management plan, with a strong commitment to open-access data accessible via its website and open-access journal. This approach enhances visibility while aligning with Norway's data policies to ensure compliance and harmonious data sharing.

2.1 Research quality and integrity

Research Integrity

The central management within NORSAR plays a vital role in supporting research quality at every stage. This support encompasses various aspects, including contributions to call preparation and

research policy, guidance and advice on prioritising research applications, notification of potential open calls to both research funding organisations and industry partners, and project oversight to ensure milestones and deliverables are met in accordance with the high-quality standards.

Based on the self-assessment report, the administrative unit has good process and values in place for ensuring research integrity. According to the self-assessment report, it is a cornerstone of NORSAR's values and is ingrained within their Ethical Guidelines, and the self-assessment report provides a range of commitments and policies throughout the institute that align with these values and guidelines.

In upholding these principles, NORSAR maintains a strong commitment to research ethics and integrity throughout all research activities.

Research Quality

Both the organisational environment and the research quality of NORSAR are excellent. Its contribution to society, in Norway and worldwide, is outstanding. The group acquires a remarkable amount of external funding by successfully identifying topics of future interest. That said, the stated mission of NORSAR is centred on nuclear event detection. While outstandingly important, this is not reflected in most of the listed research activities and outputs. Since seismic event detection is likely a topic in its asymptotic stage, this may require an adjustment of NORSAR's mission statement for the future.

2.2. Open Science

NORSAR's self-assessment report makes clear that their activities towards Open Science and FAIR principles are ongoing. NORSAR does support open access publication and this increased in recent years, from 3.8% archived in 2012 to 41.7% archived and 12.5% Gold Open Access in 2021. NORSAR is also supporting the new researcher-run journal SEISMICA for open science in earthquake science and seismology and is a part of the editorial board, exemplifying this future commitment to supporting Open Science more substantially in future.

NORSAR's open research data are available for non-commercial use, and are shared in well-defined, open formats. Raw data are available to research institutes via the Norwegian EIDA node, which was established jointly by NORSAR and the University of Bergen. Data products (automated and analysed bulletins) are available through a portal on NORSAR's website. NORSAR is also a part of the European Integrated Data Archive with Open-access publications and sharing of data.

NORSAR has a clear Data Policy as part of the management system, which defines the ownership of and responsibility for data, and exceptions to open access (for example where making the data available could threaten the safety of individuals or national security or be in in conflict with legal or contractual provisions). Data collected from NORSAR's stations belong to NORSAR unless ownership rights are reserved owing to how the data collection was financed. The self-assessment report also details clearly who is responsible for implementing the guidelines in the Data Policy (department heads and project managers) and how these are implemented in practice (through data management plans).

3. Diversity and equality

From the self-assessment report provided by NORSAR, it is clear the administrative unit seeks to foster equal opportunities for all, regardless of gender, ethnicity, religion, age, ability, sexual orientation, political beliefs, or cultural background. The documents provided detail the different responsibilities for ensuring diversity and equality across the organisation, with every employee expected to contribute to creating a discrimination-free and fair working environment. However, the self-assessment report does not include much detail on the impact or progress of their efforts in this area, so it is not clear how effective these measures have been. As the Equal Opportunities document

shared as part of the self-assessment was first created in 2021, it is not clear to the evaluation committee how such issues have been dealt with before this.

Though the NORSAR team is internationally diverse, the gender diversity could be further improved. As part of their self-assessment report, NORSAR provided details of the steps they take in hiring to ensure diversity and equality, which appears to be credible and sufficient to support this process well. Whilst they have good representation of women at senior leadership positions, among their research team, approximately 30% are women, while 70% are men. The administrative unit may therefor consider setting specific targets for the proportion of female staff (such as around 40%) to continue progress in this direction. The committee also recommend NORSAR consider implementing some specific actions to increase the number of applications from qualified women (perhaps through the national and international networks in which they are already active).

4. Relevance to institutional and sectorial purposes

NORSAR is dedicated to advancing societal safety through a range of impactful initiatives. The primary commitment involves monitoring compliance with the Comprehensive Nuclear Test Ban Treaty on behalf of Norwegian authorities. Leveraging innovative detection seismology, they significantly improved the international monitoring system and the operation of seismic stations worldwide. Actively engaged in supporting the Ministry of Foreign Affairs in bolstering international backing for the Treaty.

In addition, NORSAR conducts near-real-time analyses of explosion impacts near nuclear power plants in Ukraine and promptly shares findings with the Norwegian Radiation and Nuclear Safety Authority. NORSAR also actively collaborates with stakeholders and decision-makers to address the monitoring of CO_2 storage sites, with a focus on ensuring the secure implementation of CO2 storage, which is equally relevant to geothermal energy solutions.

Regarding commercialisation, NORSAR strongly emphasises converting research findings into practical societal benefits. The strategy evolves through annual discussions involving all employees and the Board. Projects with commercial potential have regular management meetings, and innovative ideas leading to patents are incentivised.

The innovation and commercialisation process are outlined in the document "Project Management and Leadership," focusing on safety, cost-effectiveness, timeliness, and high quality. Research ideas initially develop within projects, and if they show commercial promise, they transition to a comprehensive commercialisation process.

The NORSAR Innovations AS, which is a wholly-owned subsidiary of the research foundation NORSAR, enables the commercialisation of NORSAR research products and specialises in seismic modelling software and services for the E&P industry. NORSAR Innovations holds two patented inventions developed by NORSAR.

5. Relevance to society

NORSAR's work aligns with several UN sustainability goals. NORSAR's primary societal contribution involves monitoring compliance with the Comprehensive Nuclear Test Ban Treaty on behalf of Norwegian authorities (UN 16). NORSAR's advancements in detection seismology have significantly enhanced the global monitoring system, supporting the Treaty's international objectives. NORSAR's collaboration with the Ministry of Foreign Affairs strengthens international support for the Treaty.

NORSAR's expertise in earthquake hazard and risk assessment aids infrastructure improvement worldwide. They have recently updated earthquake risk assessments for Norway and Svalbard, available through a digital portal. This service reduces building design costs in Norway, as confirmed by Multiconsult (UN 9, 11).

Furthermore, capabilities in automatic event detection and fibre technology have led to innovations such as snow avalanches and traffic detection systems, contributing to safer roads (UN 9, 11).

Seismic event detection plays a crucial role in safeguarding the injection of substances like water, gas, and CO2 into the ground, vital for safe storage in Carbon Capture and Storage (CCS) and geothermal energy projects (UN 7).

NORSAR is also engaging directly with the public, through open science days, invites school classes and is active in social media, and also has a webpage informing citizens about earthquakes (www.jordskjelv.no) in Norway.

Comments to impact case 1 [NORSAR Case 1]

NORSAR's early research in CO2 injection and storage monitoring has paved the way for a deeper understanding of the intricate relationship between large-scale CO2 injection and seismic activity patterns. Through NORSAR's leadership and involvement in focused research projects with international partners, they have developed novel monitoring, data processing, and interpretation techniques tailored to meet the specific requirements of their industry collaborators. Numerous publications in journals have solidified the scientific significance of the NORSAR works, while collaborative projects with industry stakeholders have showcased the practical applicability and realworld impact of the discoveries. These findings are now making a broader impact by contributing to the establishment of best practice guidelines and regulatory standards for cost-effective monitoring procedures. This is a prime example of how NORSAR has a genuine, societally relevant impact.

List of administrative unit's research groups

Institution	Administrative Unit	Research Groups
NORSAR Foundation	NORSAR Foundation	NORSAR

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 (see appendix 3 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

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 hourlong 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 group assessment, and the interview. The Administrative Unit had the opportunity to fact-check this summary. The Administrative Unit approved the summary with minor adjustments.

Limitations

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

Appendices

- 1. Description of the evaluation of natural sciences
- 2. Invitation to the evaluation including address list
- 3. Evaluation protocol (including ToR template)
- 4. Template Self-assessment administration unit
- 5. Grading scale for research groups

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