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NJORD

Strategy of the Njord Centre 2023-2027

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Missions of the Njord Centre 2023-2027

- Develop a world leading cross-disciplinary research centre in physical sciences at UiO with a focus on a fundamental understanding of the dynamics of fluid-solid natural systems
- Build the next generation of computational competences and experimental laboratory facilities for the study of transformation processes in fluid-rock and fluid-porous media systems in 4D from molecular to field scales
- Provide a unique basis for making predictions relevant for CO_2-sequestration, exploitation of natural resources, transport of contaminants in the subsurface, and geohazards (e.g., earthquakes, volcanoes, glacier instabilities, landslides), and for innovations in science-art interaction
- Generate an outstanding environment for research-based education at the Master, PhD and post-doctoral levels
- Make the complex Earth dynamics visible in the public sphere

Foreword

“Many simple problems (…) have complex solutions.”

– Giorgio Parisi

Solving complex scientific questions often benefits from a *cross-disciplinary approach*. Outstanding scientific problems such as the prediction of geohazards, the complexity of flows within porous media, and the evolution of minerals under natural and anthropogenic perturbations require a convergence of methods from geosciences, physics, chemistry, and computer science.

The Departments of Geosciences and Physics at the Faculty of Mathematics and Natural Sciences at the University of Oslo (UiO) created the Njord Centre in 2018. The Centre hosts around sixty persons, including nine permanent professors, who advance the *understanding of transformation processes in the Earth and synthetic porous materials*. The Njord Centre aims to be an *internationally leading research environment* for the future development of Physical Sciences at UiO, and one of the main contributors to the domain “Earth and Space Sciences”, one of the four main research directions defined by the Faculty of Mathematics and Natural Sciences until 2030[1]. The main *strength of the Centre is the ability to share and combine competences, methods, and equipment* that researchers leverage to study complex systems. The research approaches combine field observations, laboratory experiments, and numerical and theoretical modelling, including recent developments in machine learning and computational science. The Centre is a diverse, inclusive, and supportive environment for cross-disciplinary education of early career researchers.

The approach at the Njord Centre is mainly curiosity-driven and designed toward *basic research*. Researchers also perform studies with *important societal applications in the domains of geo-energy* (carbon dioxide geological sequestration, geothermics, radioactive waste disposal), *geohazards* (earthquakes, volcanoes, glacier instabilities, landslides), and *engineering* (porous media, transport of pollutants, critical raw materials). These topics fall within several Sustainability Goals identified by the United Nations (#4 Quality Education, #11 Sustainable Cities and Communities, #12 Responsible Production and Consumption, #13 Climate Action).

These domains of applications are also embedded into four cross-disciplinary research initiatives implemented in the strategy of UiO: *UiO:Energy*[2], *dScience*[3], cross-disciplinary research environments (*EarthFlows*[4]), and the *Sustainable Development Initiative*[5]. The Njord Centre receives competitive funding from these local initiatives. The board of the Njord Centre ensures that the activities of the Centre integrate fully into the research strategies of the Department of Geosciences, the Department of Physics, and the Faculty of Mathematics and Natural Sciences, and supplement them.

The Njord Centre’s scientific strategy for the period 2023-2026 complements the 2021 Annual Report that highlights the activities in the Centre. Two internal seminars held in November 2021, where early career and senior researchers contributed actively, prepared the strategy. The board of the Centre provided suggestions and approved the present document February 21st, 2022.

[1] https://www.mn.uio.no/english/about/strategy/
[2] https://www.uio.no/english/research/strategic-research-areas/uio-energy/
[3] https://titan.uio.no/teknologi-blogg-english/2021/dscience-and-running
[4] https://www.mn.uio.no/forskning/sentre-satsinger/endringsmiljoer/
[5] https://www.mn.uio.no/english/about/news-and-events/news/kd-positions-sustainable-development-initiative-20.html

Njord consists of:

9 professors

3 support staff

7 adjunct and emeritus professors

ca. 40 early career researchers

ca. 10 master students

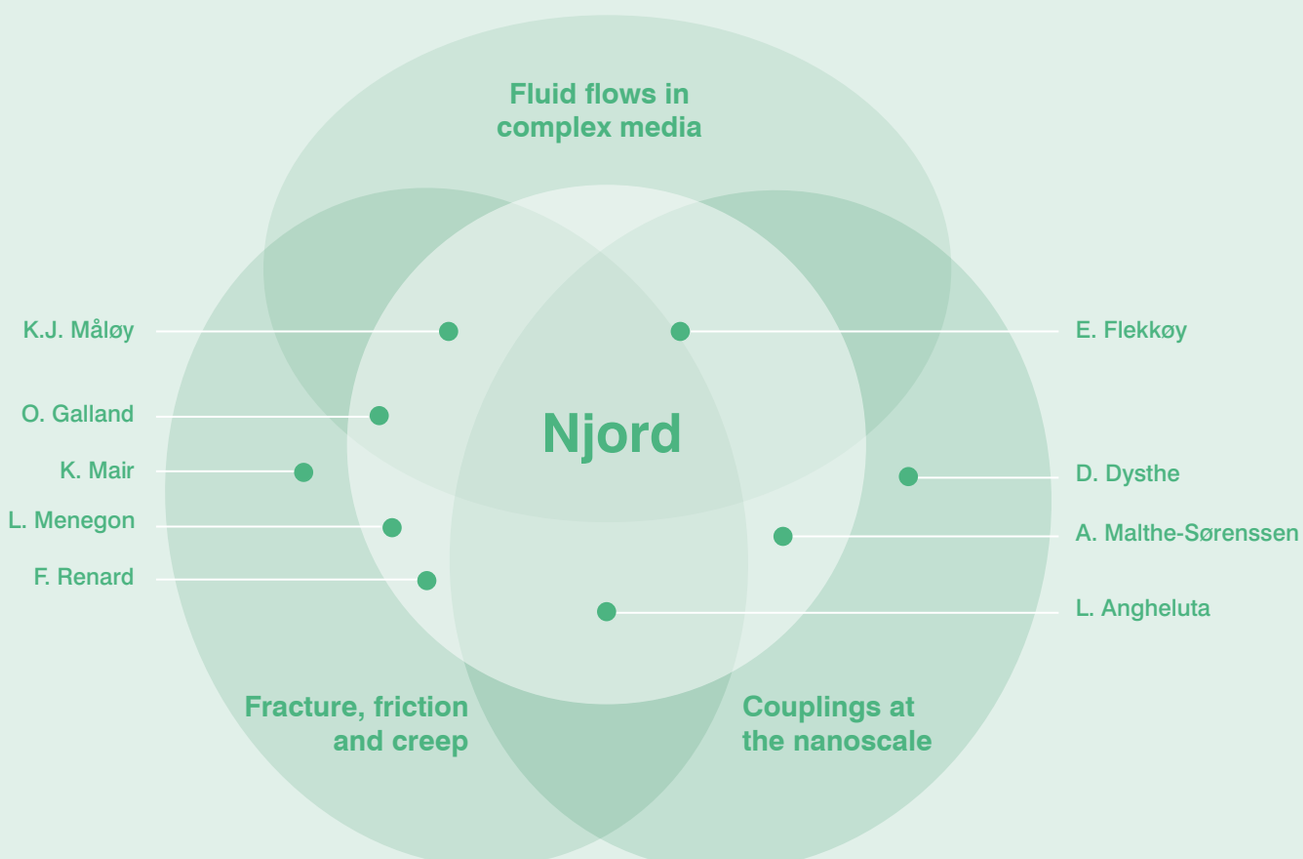


Figure 1: Research topics and permanent professors in the Njord Centre.
The 2021 Annual Report contains the names of the ca. 60 employees and the students.

Part 1.
Research topics

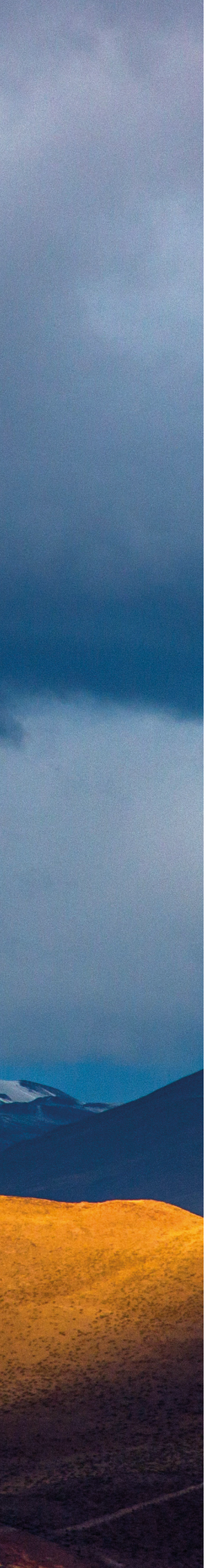
Part 2.
Guidelines and objectives

The present document contains two parts. The first one describes the research topics the Centre will focus on in the coming years. The second part provides guidelines and objectives for the implementation of this strategy. For the period 2023-2027, researchers at the Njord Centre have identified *three main scientific directions* that integrate physics and geosciences. Several scientific questions lie at the intersections of these scientific directions. Transversal to these directions, the Centre will explore various *methods to analyse and disseminate scientific data* (field, laboratory, numerical simulations), with recent machine learning techniques, sound design, and collaborations with artists. These methods will also help engage researchers across disciplines and toward the public. Several of the topics below build on research projects recently submitted to or already funded by the Research Council of Norway (RCN), the Horizon2020 European programme (CoFund, ERC), and the University of Oslo (UiO). The web site of the Njord Centre[6] and the 2021 Annual Report display the activities and results of these projects.

[6] https://www.mn.uio.no/njord/english/research/projects/

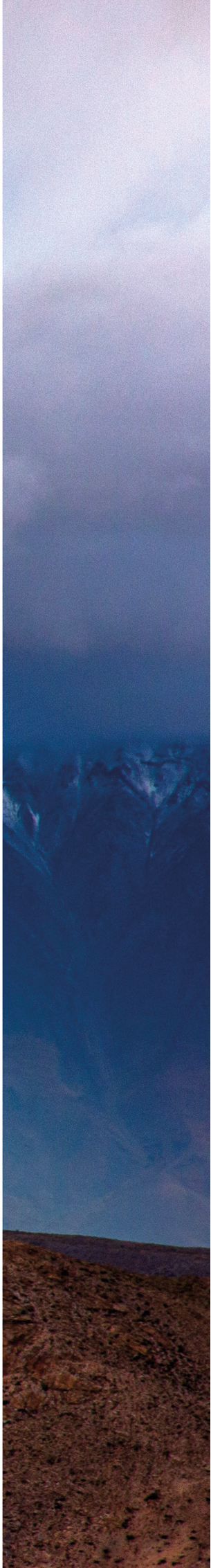
Lava flows in Faroe Islands. Njord's researchers willstudy the possibility to permanently store carbon dioxide in basalts in the North Sea

Sunset over the large Payunia back-arc volcano, southern Mendoza province, Argentina



01

Research topics



"In the coming years, the Njord Centre will perform studies in three research directions: 1) Fluid flows in complex media, 2) Fracture, friction and creep, 3) Couplings at the nanoscale"

1.1 Fluid flows in complex media

Flows in porous media are widespread in the Earth and engineered systems, from the transport of groundwater and contaminants in the subsurface, to the storage of carbon dioxide in geological reservoirs, and the flow of magma in volcanic plumbing systems. They also matter in everyday life, when preparing a cup of coffee for example. In these systems, one or several fluids circulate within a solid matrix and may interact mechanically and chemically with it. The force exerted by the fluid may deform the solid, inducing a two-way coupling between solid and fluid dynamics. Sometimes, macroscopic upscaled laws, such as the Darcy law for single-phase flow in porous media, can describe the dynamics of these systems. However, these systems may also show intermittent and scale-dependent behaviours because processes at scales much smaller than the system size control their dynamics. This happens, for example, when interfacial tension controls the displacement of two non-miscible fluids in an aquifer, or when the crystallization of minerals (e.g., the formation of a crystal mush) changes the rheology of magmas. An important paradigm is how to propose upscaled flow laws in such complex systems, based on microscopic processes.

In the coming years, researchers at the Njord Centre will work on the following objectives.

- Upscale processes observed in small-scale physics to the dynamics of multiphase flows at large scales
- Build models on how the matrix microstructure at small scales (pores, fractures) controls the permeability, dispersion, diffusion, and mixing properties of single and multiphase flows in porous media
- Predict how frictional forces between fluid(s), including thin fluid films, and solid control flow patterns in porous media
- Develop models on how the two-way coupling between fluid flow and solid deformation controls the dynamics of fluids in volcanic systems and in fault zones
- Develop reactive-transport models in the context of fluid-rock interactions in basaltic systems and in fault zones

To pursue these objectives, researchers will 1) perform field observations in volcanic systems (Oslo rift, Faroe Islands, Iceland, Argentina) and fault zones (Norway, California); 2) develop original laboratory experiments (flow in porous media, 3D printing of fractured and porous systems, 4D neutron, synchrotron, and optical imaging); and 3) develop numerical and theoretical models on fluid transport in evolving porous media (phase field, finite elements, analytical methods).

Active projects:

PoreLab (Måløy, Flekkøy, RCN), FlowConn (Moura, RCN), M4 (Linga, RCN), EarthFlows (Angheluta, UiO), COLOSSAL (Renard, Måløy, RCN).

Submitted projects:

SuperCritical GeoEnergy (Galland, UiO:Energi), Frictional Flow Patterns (Måløy, RCN), Beyond elasticity: revisiting the paradigm of dyke emplacement (Galland, RCN).

1.2 Fracture, friction, and creep

How solids break and slide along pre-existing solid-solid interfaces (i.e., friction) controls a wide range of fundamental and engineering processes. Deformation processes along pre-existing interfaces involve the release of strain energy from the surrounding bulk volume, as well as more localized processes along the surface itself. These deformation types control the nucleation of earthquakes and the onset of landslides and glacier instabilities. In these systems, fracture and friction processes are highly coupled and slow aseismic deformation, called creep, may influence the timing and magnitude of destructive seismic deformation. These processes nucleate at the nanoscale, and propagate across space and time scales to produce large and sometimes catastrophic events. The dynamics are often highly intermittent, with episodes of material weakening and material hardening, and transient releases of heat. Fracture, friction, and creep processes control the dynamics of the Earth's crust and the strength of engineered materials. An important paradigm is how deformation and fluid flow in the solid volume around an interface control the onset of instabilities.

In the coming years, researchers will work on the following objectives.

- Build a minimum model of frictional rupture that reproduces the variety of slip rates observed in the Earth's crust
- Build a minimum model of plasticity that reproduces transient deformation processes in materials and rocks
- Model how heat release and plasticity couple at a crack tip to control rupture dynamics
- Predict the evolution of a fluid within and around a fracture during its dynamic propagation
- Measure residual stress in deformed mineral grains, and embed the results in models of fracturing and creep processes
- Perform experiments of laboratory earthquakes by coupling synchrotron

4D X-ray imaging and acoustic emission monitoring
- Measure and quantify how interface dynamics control the onset of landslides and glacier instabilities
- Model the emergence of fracture networks from the development of and interactions between single fractures

To pursue these objectives, researchers will 1) perform field observations of fault zones (California, Norway); 2) process field data (landslides, glaciers); 3) develop original laboratory experiments (nanoindentation, neutron and synchrotron 4D imaging, analogue fracture modelling); and 4) implement numerical models (phase field, molecular dynamics, finite elements, machine learning).

Active projects:

Break-Through Rocks (Renard, ERC, EU), History Dependent Friction (Malthe-Sørenssen, RCN), Emergent Fracture Networks (McBeck, RCN), EarthFlows (Angheluta, UiO).

Submitted projects:

Uncovering the origin of fault dilatancy controlling seismic rupture (Barras, RCN), Conditions for earthquake nucleation in the lower crust (Menegon, RCN), HotTips (Toussaint, RCN), SerpRateAI: Using artificial intelligence to estimate serpentinization rates in Oman peridotite (Aiken, RCN).

1.3 Couplings at the nanoscale

Many geological processes occur in dissipative systems where first-principles physics at the nano- and micro-scales describes the separation of spatial and temporal scales during the injection, transport, and dissipation of energy. The paradigm of driven, dissipative systems can also be extended to biological matter such as cellular tissues, where the interplay between scales and energy fluxes are even more complex due to the active matter constituents that consume energy from the environment to convert into motion and mechanical forces. At the Njord Centre, researchers study this complexity in the framework of the theory of dynamical systems, developed by physicists in the past fifty years. They study processes at the nano- to the micro-scales to predict the onset and dynamics of pattern formations and material properties on larger scales. Universal behaviours can emerge because mechano-bio-chemical processes are coupled at a small scale (grain, pore, cell), where interfacial energy interacts with bulk strain energy. They have developed a new numerical framework that uses molecular dynamics to study the mechanics of gas hydrates, the crystallization of silicon carbide nanoparticles, the nanoscale friction along solid-solid interfaces, and the dynamics of fracture propagation. These simulations rely on defining atomic potentials that reproduce realistic material properties. Researchers have also developed unique competences to measure forces and image strain with sub-atomic resolution, for example using a surface force apparatus and atomic force microscopy. An important paradigm is the convergence of experimental and numerical advances in recent years that moves the field of nano-bio-geoscience to a next level of understanding.

In the coming years, researchers at the Njord Centre will work on the following objectives.

- Implement a new atomic potential for the $SiO_2 + H_2O$ system and perform molecular dynamics simulations to study geological processes such as pressure solution creep or nano-crystallization in confined space
- Develop a machine-learning framework to model frictional processes along nanoscale solid surfaces from first principles
- Measure the forces exerted by crystals growing in tight confinement
- Predict how the coupling between small scale dissolution, mixing, precipitation, and transport processes may control rock transformations, including the serpentinization of the oceanic crust and carbon dioxide mineral trapping in basalts
- Develop a minimal physical model and develop experimental tools for tracking collective interactions of cells during morphogenetic evolution

To pursue these objectives, researchers will 1) perform field observations (Iceland, Faroe Islands, Oman ICDP, and North Sea IODP); 2) develop original laboratory experiments (atomic force microscopy, surface force apparatus, microfluidics, large synchrotron and neutron facilities); and 3) use machine learning modelling and direct numerical modelling (molecular dynamics, finite elements).

Active projects:

CO2Basalts (Renard, Sustainability call, UiO), ITOM (Dysthe, Angheluta, Life Science Convergence Environment, UiO), CompSci (Malthe-Sørenssen, CoFund, EU)

Submitted projects:

Reactivity in confinement: in situ mineral recrystallization within tiny volumes (Dziadkowiec, RCN), CO_2Mix: Control of fluid mixing on CO^2 mineralization in fractured basalts (Le Borgne, RCN).

Volcanic sill injected into a sedimentary sequence, Svalbard (Photo: Olivier Galland)

02

Organization and objectives

2.1 People

The Centre is hosting nine permanent professors, one tenure-track assistant professor, one associate professor who is temporarily replacing a professor, two permanent laboratory engineers, and one permanent administrative coordinator. Another professor, Bjørn Jamtveit, who was the director of the Njord Centre between 2018 and 2020, is holding a mandate (2021-2025) as vice-dean for research of the Faculty of Mathematics and Natural Sciences. The permanent academic staff at the Njord Centre and the two laboratory engineers are employed in the two departments, which have their own recruitment strategy. The administrative coordinator is the only permanent employee hired under the Centre and paid by the departments. The other employees are non-permanent early career researchers and adjunct professors.

The Centre is responsible for the persons hired temporarily on externally funded projects. The senior researchers and engineers ensure that early career researchers receive a high-level training and acquire competences and methods that are transferrable to jobs inside and outside of academia. The early career researchers have access to dedicated training organized by the departments (master courses), the Norwegian PhD schools, and the Faculty of Mathematics and Natural Sciences (ethics, management, leadership, and teaching). The senior researchers have the responsibility to support early career researchers when they search for jobs outside of UiO by providing, for example, strong and supportive recommendations.

Because seeking funds is part of the academic work, early career researchers are encouraged to apply either to small travel grants, or to large research projects (Young Research Talent programme at the Research Council of Norway, EU Marie Skłodowska-Curie individual fellowships). The Centre supports them by providing scientific guidance, and offering internal reviews and administrative support for their proposals. This comes in addition to the support offered by the Faculty of Mathematics and Natural Sciences for research projects in the form of reviews and webinars.

In 2027, three professors involved in the Centre will be close to retirement: Knut Jørgen Måløy (experimental physics), Bjørn Jamtveit (petrology), and Eirik Flekkøy (theoretical physics). The Njord Centre will contribute to the discussions organized in each department on the future of these positions.

Objectives for the period 2023-2027:

1. Ensure the level of administrative and technical support is sufficient to run the research activities developed in the Centre, as it was the case for the period 2018-2021.
2. Prepare the early career researchers to get jobs inside or outside of academia.
3. Contribute to the discussions on the recruitment of professors in the departments.

2.2. Funding and resources

The Njord Centre is hosting the Oslo node of the Centre of Excellence (SFF) *PoreLab*[7] until 2027, led by Knut-Jørgen Måløy and Eirik Flekkøy. One ERC advanced grant (*BREAK*, Renard) starts in 2022 and will last until 2026; another ERC advanced grant (*DIME*, Jamtveit) ended in 2022. Three major grants funded by UiO (Sustainability call, Life Science Convergence environment, Cross-Disciplinary Research Environment) and seven grants from the Research Council of Norway (RCN) will be active in the next years. The Centre benefits from the EU-CoFund programme *CompSci*[8], by hosting 3-6 PhD students hired in 2021 and 2022. Researchers at the Centre have regular interactions with the Centre of Excellence in Education (SFU) *Center for Computing in Science Education*, led by Anders Malthe-Sørenssen, and receive some funding from another SFU, *iEarth*[9].

In 2021, the consolidated budget of the Njord Centre is 45 MNOK (4.5 M€). The University of Oslo funds the salaries of the permanent staff, the rental cost of the premises, and several PhD and post-doctorate positions through the departments of Geosciences and Physics, and the Faculty of Mathematics and Natural Sciences (22.5 MNOK). The Centre obtains external funding from highly competitive research grants (Research Council of Norway, European Union, Equinor), with a yearly amount of 22.5 MNOK in 2021. The Centre uses some operational funding for common activities and strategic recruitments, with an amount of 1.5 MNOK in 2021. During its first two years of existence (2018-2019), the Centre received a total amount of seed funding of 0.5 MNOK/year given by the two departments, and one post-octorate position given by the Faculty of Mathematics and Natural Sciences. Since 2020, the Centre has self-funded its operational costs by receiving 40% of the overheads of externally funded projects, while the departments receive 60% of these overheads and 100% of the RBO[10].

The Njord Centre expects to maintain an operational budget based only on external funding in the range 15-20 MNOK/year and to use around 10% of this amount (in the range 1.5-2 MNOK/year)

[7] https://porelab.no/
[8] https://www.mn.uio.no/compsci/english/
[9] https://www.mn.uio.no/geo/english/research/networks/iearth/
[10] Resultatbasert omfordeling (RBO) is funding UiO receives from the Norwegian state, based on performance in research.

for common activities and for seeding research activities. The common activities involve weekly seminars, field activities between geologists and physicists, organization of a yearly international seminar in Oslo, support of early career researchers hired in externally funded projects and guest students (e.g., laptops), and the annual report. Since 2021, the Centre is able to self-fund one post-doctorate fellow and one international adjunct researcher (15% full-time equivalent position) on strategic topics. For the period 2023-2027, the Centre plans to maintain this high level of activity. If a growth of the operational budget occurs, the Centre will prioritize hiring early career researchers and adjunct researchers, for example by seeding activities in cross-disciplinary projects that received excellent evaluations but were not funded.

To reach the expected level of funding, the Centre needs to obtain one major grant every year. Therefore, researchers plan to submit altogether between five and ten applications to the Research Council of Norway every year and one application to the Horizon Europe programme every second year (ERC, Doctoral Network, CoFund), on average.

The Njord Centre operates state-of-the-art laboratories hosted at the Department of Physics (see the Annual Report 2021). Njord's researchers also use large international facilities (synchrotron and neutron sources) and participate in national and international infrastructures (Goldschmidt national laboratory[11], EU INFRAIA EXCITE[12]), and other international programmes (e.g., *Oman Drilling* and *Collisional Orogeny in the Scandinavian Caledonides* projects from the International Continental Drilling Programme). Competences in scientific computing and machine learning have diffused to the Centre, particularly with the numerical developments in *PoreLab* and the interactions with the *Center for Computing in Scientific Education*.

The Centre collaborates with the local environment and benefits from the presence of research organizations and companies located in Oslo: Norwegian Geotechnical Institute (NGI), Norwegian Seismic Array (NORSAR), Institute for Energy (IFE), SINTEF, Simula Research Laboratory, Volcanic Basin Petroleum Research AS (VBPR), and GeoModelling Solutions. The collaborations with these organizations occur mainly through the joint supervision of students and collaborative research projects.

Objectives for the period 2023-2027:

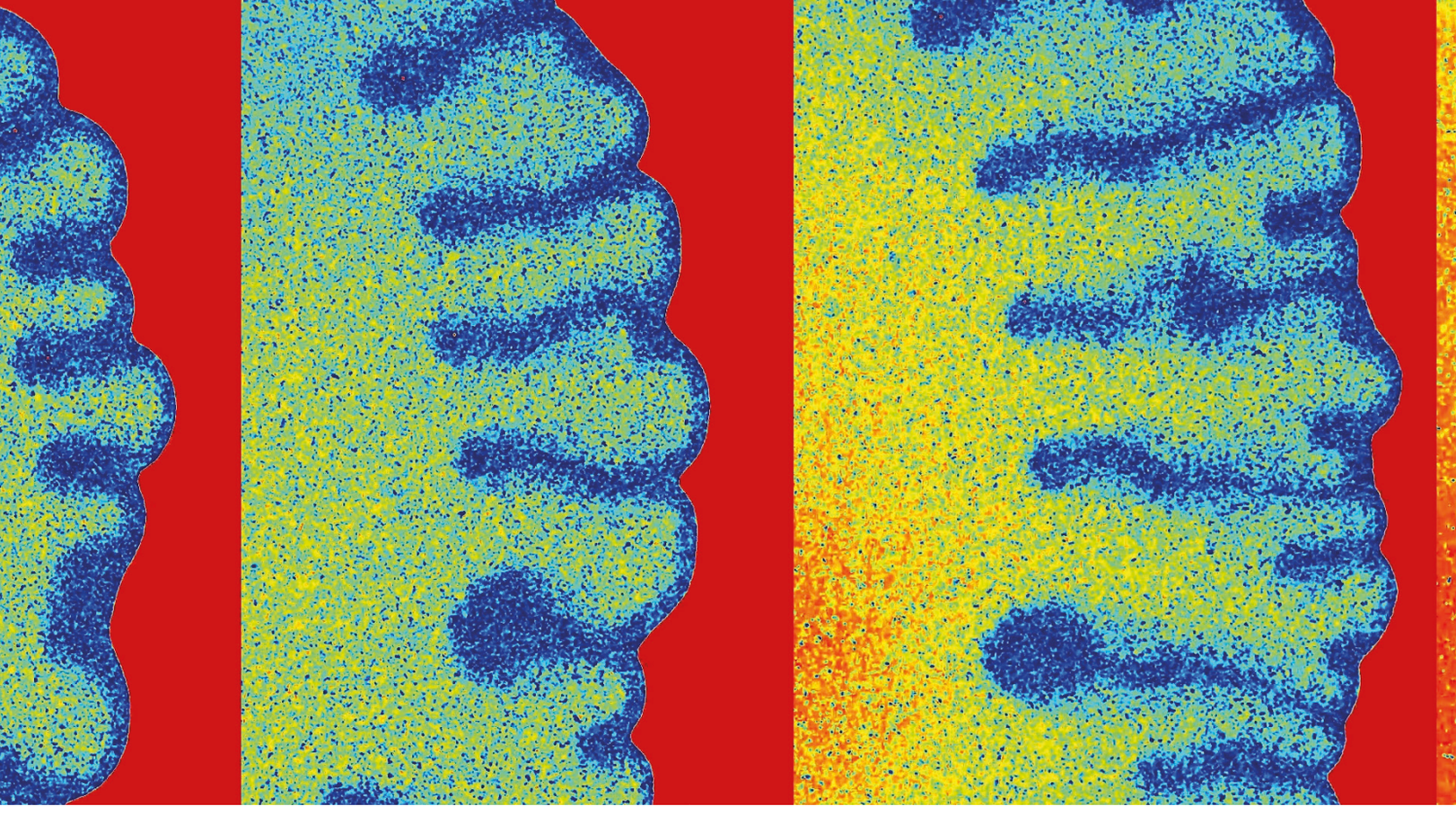
1. Obtain one successful project funded from RCN or other source every year on average.
2. Obtain one successful European grant funded over the period (ERC, Doctoral Network, or CoFund).
3. Maintain state-of-the-art laboratories and participations to large synchrotron and neutron facilities (European Synchrotron Radiation Facility, Institut Laue-Langevin, Paul Scherrer Institute).
4. Contribute to the success of the Goldschmidt I national laboratory (high-resolution scanning electron microscopy, geochemistry) and to the follow-up proposed Goldschmidt II (microprobe, focused ion beam scanning electron microscopy) in 2023.
5. Submit one collaborative proposal to seed common activities with other units of our local environment at UiO and beyond (in the same spirit as *Earthflows*[13], for example in the Large Interdisciplinary Programme of RCN[14]).

2.3. Internationalization

The Njord Centre is already highly international, with twenty nationalities for sixty employees. Internationalization is critical to ensure that our research questions are at the forefront of science and that early career researchers can confront themselves with international research from the beginning of their training. In addition to the attendance of researchers to international conferences, workshops, and summer schools, the international activities of the Centre are the following.

- The Centre organizes one international seminar every year in Oslo. Since 2016, researchers organize the two-day international seminar *EarthFlows* every spring. This seminar follows the Kongsberg seminar series organized by Bjørn Jamtveit between 1998 and 2013.
- The Centre is currently hosting an INTPART grant, *Collaboration on Flow across Scales*[15], funded by the Research Council of Norway until 2025. This project funds outgoing and ingoing mobility of students and researchers. The key partners are in USA (University of Southern California, University of Minnesota, University of California Santa Barbara, University of Maryland), France (ENS Lyon, University Grenoble Alpes, University Rennes), and Brazil (University of Parana, University of Pernambuco).
- Every PhD student should have the opportunity to spend at least three months abroad and researchers are actively seeking funding to reach this objective.
- UiO offers the possibility to hire international researchers on adjunct positions (Professor II, ≤20% full time

[11] https://www.mn.uio.no/geo/english/research/goldschmidt/
[12] https://excite-network.eu/
[13] https://www.mn.uio.no/geo/english/research/groups/earthflows/
[14] https://www.forskningsradet.no/en/call-for-proposals/2021/large-scale-interdisciplinary-researcher-project/
[15] https://www.mn.uio.no/njord/english/research/projects/colossal/index.html



equivalent contract). In 2022, five adjunct professors work part-time at the Njord Centre (Renaud Toussaint, Tanguy Le Borgne, Joachim Mathiesen, Einat Aharonov, and Geir Helgesen). They contribute to the training of early career researchers, help writing grants, and bring additional scientific competences.

- The Centre aims to host at least one international experienced researcher every year in the framework of a sabbatical programme.
- Every year, the Centre hosts one to two PhD students from abroad, as part of their PhD degree. They receive joint supervision with another university (e.g. from, Grenoble, Strasbourg, Padua, Lyon, Swansea, China). The Centre will continue to participate to these programmes either in a formal way (cotutelle agreements, CSC China) or in a flexible way by hosting PhD students for long-term internships in Oslo and providing them with high-quality supervision.
- Njord's researchers are already involved in several international facilities and programmes (Long Term Proposal at the European Synchrotron Radiation Facility, International Ocean Drilling Programme, International Continental Drilling Programme, EU INFRAIA EXCITE) and have the ambition to maintain this level of activity.

Objectives for the period 2023-2027:

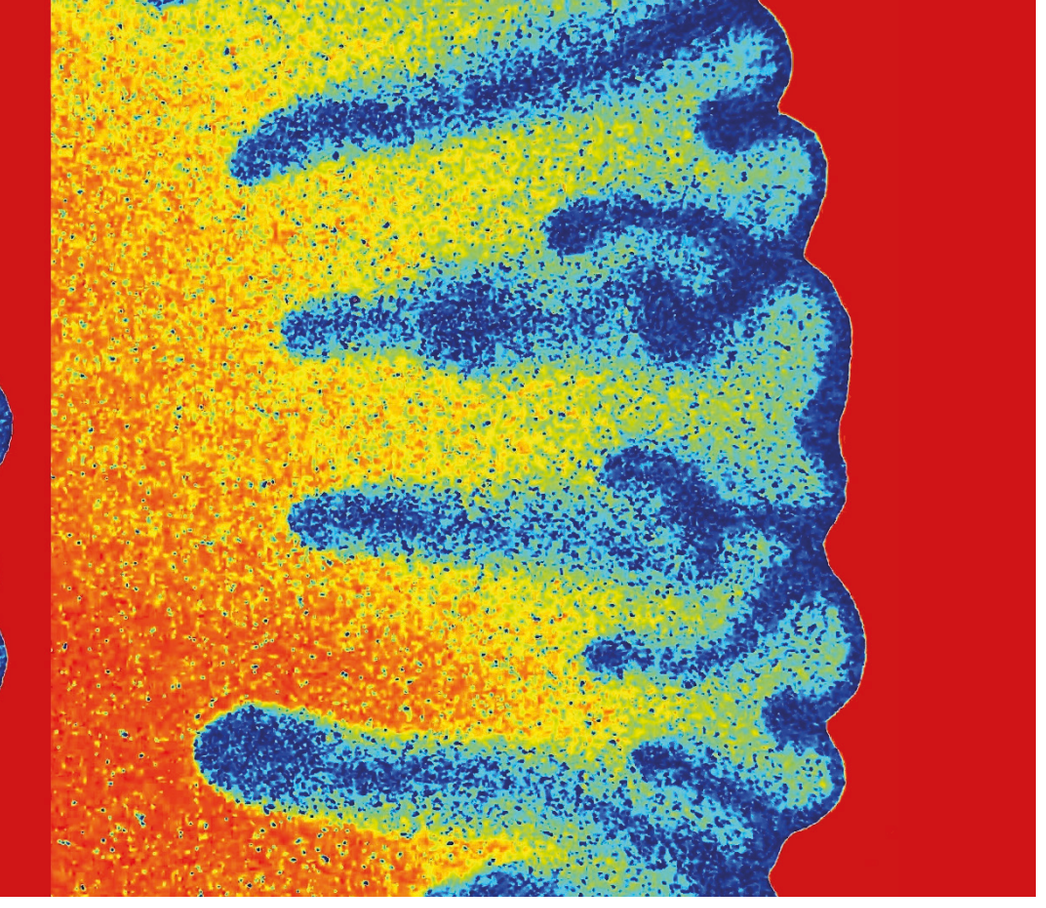
1. Apply for another INTPART grant after 2025.
2. Maintain the level of international activities described above.

2.4 Dissemination, outreach, and innovation

With nine permanent professors and around forty early career and experienced researchers, the Njord Centre publishes between 70 and 80 scientific articles every year in international journals, which represents a very high production considering the size of the group. Between 5% and 10% of these articles are published in high-impact journals in physics and geosciences (Nature group, Science group, PNAS, Physical Review Letters, Geophysical Research Letters, Earth and Planetary Science Letters, Geology, Environmental Science & Technology). For more than 50% of the publications, the leading author belongs to the Njord Centre and early career researchers author most of these publications. In 2019, a survey showed that the Njord Centre contributes significantly to the high ranking of the University of Oslo in the domain of Earth and Environmental Sciences[16].

The Njord Centre also disseminates research to the public in Norway and

[16] https://www.mn.uio.no/njord/english/news-and-events/news/nature-index.html



Different stages of a fluid mixed with glass beads being injected between two parallel glass plates. As the fluid flows, grains are accumulated along its front and an instability is observed with the formation of small ripples. (Photo: PoreLab)

abroad, with around twenty items per year in various supports (e.g., NRK television, newspapers, titan.uio.no). The Njord Centre has a twitter account (@NjordUiO) used to highlight activities and promote successes. Njord's researchers have a long tradition to collaborate with artists (graphic design, sound design, film production), and several art pieces are exhibited on the walls of the Department of Physics at UiO and in a virtual exhibition[17].

The Centre contributes to innovation in the geological reservoirs, and engineering of porous media through joint research projects with non-academic partners and the training of master students in private companies. Innovation also comes through the collaborations developed with artists.

Objectives for the period 2023-2027:

1. Encourage that every researcher publishes high quality articles in the best journals of their domain.
2. Continue to produce ca. 70 scientific articles per year, including around 5-10% in high impact journals, with ca. 60% of these articles with a first author belonging to the Njord Centre.
3. Increase the dissemination toward the public.
4. Expand the visibility of the Twitter account.
5. Develop collaborations with artists and host at least one artist for a long internship.

2.5 Life Sciences at Njord

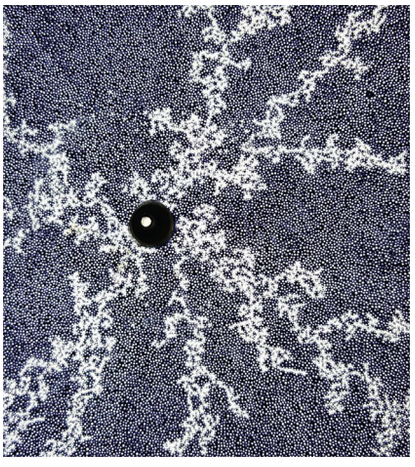
In recent years, and through the Life Science initiative[18] at UiO, researchers of the Njord Centre received funding for early career positions and for a new laboratory facility dedicated to technological research in biophysics, LagLivLab[19], which uses three experimental rooms of the Njord Centre. In this laboratory, researchers study the mechanics of biopolymers and the behaviour of human cells under mechanical solicitations. The Department of Physics has the responsibility for the equipment and for the running costs of this laboratory. Here, the Njord Centre hosts emerging activities in biophysics, where the competences of researchers in soft matter physics and microscopic imaging lead to new research directions. If these activities would develop into larger projects, Njord's leadership, in concertation with the researchers involved in these activities, will decide whether these projects will be hosted inside or outside of the Njord Centre, for example in the Department of Physics or in the new Life Science building that will open in 2025 at UiO.

[17] https://porelab.no/science-is-art-art-is-science/
[18] https://www.uio.no/english/research/strategic-research-areas/life-science/
[19] https://www.mn.uio.no/fysikk/forskning/prosjekter/laglivlab/

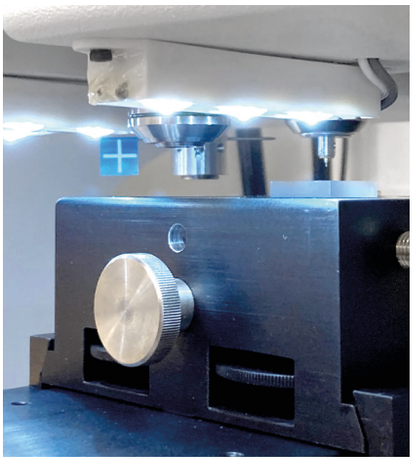
Art produced from results of rock deformation experiments. A long term collaboration with artist Ellen Karin Mæhlum has led to artwork series that are displayed in the premices of the Njord Centre at the University of Oslo.

“Since fall 2021, Njord's leadership has taken several actions to mitigate some of the identified weaknesses and threats”

Zeolite minerals in basalt, Faroe Islands.



Flow instability in a porous medium.
Photo. Marcel Moura



Nano-indentation of minerals.
Photo: Luca Menegon.

2.6 Relations with the Departments and the Faculty

The Njord Centre also has a long tradition to collaborate with other research groups at UiO. For example, the initiative EarthFlows involves researchers from the sections GeoHyd and MetOs at the Department of Geosciences, the section of Mechanics at the Department of Mathematics, and the section of Condensed Matter Physics at the Department of Physics.

The two department heads and the vice-dean for research of the Faculty of Mathematics and Natural Sciences constitute the board of the Njord Centre. The director of the Njord Centre contributes to the management meetings of the Geoscience department and receives weekly information from the management of the Physics Department and the Faculty of Mathematics and Natural Sciences. The board members and the Njord director ensure that the activities in the Centre are complementary and provide additional values to activities done in other groups of the departments, and that a two-way flow of communication exists on research topics at the interface between the centre and other research units.

2.7 SWOT analysis

During two internal seminars organized in fall 2021, the early career and senior researchers prepared a self-assessment of the Njord Centre through a SWOT analysis (Strength – Weakness – Opportunities – Threat). The following page summarizes the results of this analysis.

Since fall 2021, Njord's leadership has taken several actions to mitigate some of the identified weaknesses and threats.

- The project CO_2Basalt[20] (Sustainability call, Faculty of Mathematics and Natural Sciences, UiO) was successfully funded. It involves three early career researchers, physicists and geologists, who will develop cross-disciplinary research on the permanent storage of CO_2 in basalts of the North Sea.
- Among the eight research proposals submitted to the Research Council of Norway in February 2022, seven of them are cross-disciplinary projects that involve both geologists and physicists.

[20] https://www.mn.uio.no/njord/english/news-and-events/news/co2basalt.html

Field work in the Lofoten archipelago, Norway, in June 2021.
Photo: Stephen Michalchuk.

- Researchers will actively search for women candidates for the next recruitments of early career researchers.
- The updated web site of the Njord Centre integrates physics and geosciences activities better.
- The seminar series is open to internal speakers in spring 2022 to facilitate exchange of ideas.
- A quarterly internal newsletter prepared by the administrative coordinator of the Centre enhances communication.

2.8 After 2027

After ten years of existence, the Njord Centre may be phased out at the end of 2027, unless the faculty and the departments decide to extend the Centre for another period of five years. The Njord Centre will prepare for this transition in the next five years by strengthening its scientific identity at UiO and at the interface between the two departments, through high quality publications, dissemination, and research training. Researchers will also prepare an application to become a Centre of Excellence (SFF) after 2027. To reach this goal, researchers will narrow a common research topic and prepare a proposal for the next SFF call in 2025-2026.

Objectives for the period 2023-2027:

1. Strengthen the scientific identity of the Njord Centre at the interface between geosciences and physics.
2. Apply for a Centre of Excellence.

SWOT analysis of the Njord Centre

Strengths

- Positive group dynamics – everything is shared (methods, equipment, ...)
- Combination of field work, lab, and numerical modelling
- Diversity (scientific background, nationalities)
- Freedom – academic and time wise
- Horizontal hierarchy, inclusive environment
- Co-localisation in the Physics building
- Competent support staff
- Fully equipped laboratories, new equipment
- Attract excellent early career scientists
- Support of the Departments of Physics and Geosciences and the Faculty of the Mathematics and Natural Sciences

Weaknesses

- Different backgrounds can make communication challenging
- Not one unit yet, but rather two groups and some people in the middle
- Difficulty to recruit master students, particularly in physics
- Gender balance (only 24% women)

Opportunities

- Diversity develops new perspectives and train us to communicate efficiently with each other
- Easy for early career researchers to develop their own research topics
- Mobility is encouraged
- Good financial situation due to successful proposals
- Motivation to submit shared proposals
- Access to large national and international facilities (ESRF, PSI, Goldschmidt, ...)
- Participation to international programs (IODP, Excite, ...)

Threats

- Talking too much to ourselves and too little to other parts of the Departments and the University
- The Njord Centre could be shut down
- Scientific dispersion (Njord becomes a "hotel")

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