The Norwegian University of Science and Technoloy

Faculty of Engineering Science and Technology

Research Excellence

NTNU

Norwegian University of
Science and Technology

Faculty of Engineering Science and Technology – Research Excellence

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Technology for sustainability and innovation

The Faculty of Engineering Science and Technology at NTNU is the major provider of engineering education in Norway with a total of about 3000 students. It is also one of the primary research organizations in engineering science and technology with about 400 PhD students.

Through research, education and dissemination the faculty develops solutions for a better society and the human capital of tomorrow. Both the ever increasing demand for engineering competencies, and the intense competition in the global arena to secure these competencies, compel a greater emphasis on research excellence in the years to come. Only through advanced technological research can many of the current problems connected to our environment, welfare, and standard of living be solved. While the faculty is already strong in several fields, we continue to develop by founding and joining international research collaborations efforts of quality.

Norway has a strong position in several engineering fields. Some examples are offshore and sub sea oil and gas development, shipbuilding and marine structures, energy and environment, large concrete structures (platforms, bridges, etc.), project management and safety and reliability.

In this prospectus, you will find a brief description of the strongest research groups and centres at the faculty. These are:

- Centre for Ships and Ocean Structures (CeSOS)
- Hydraulic Engineering
- Reliability, Availability, Maintainability and Safety (RAMS)
- Structural Impact Laboratory (SIMLab)
- Center for Research-based Innovation in Integrated Operations
- Operations Management
- Water and Wastewater Engineering

The Norwegian Research Council conducted an international peer review of engineering research in Norway in 2004. In total 27 research groups were evaluated in terms of three criteria: scientific quality and productivity, relevance and impact, and strategy, organization and research co-operation. Six of the groups at the Faculty of Engineering Science and Technology were deemed excellent and are amongst the groups presented in this prospectus.

An action plan for engineering research was developed based on the abovementioned assessment. The plan delineates four priorities:

- Energy production in the north
- Renewable energy
- Sustainable infrastructure
- Food from the north

These four areas are now focal points at the Faculty of Engineering Science and Technology. A total of 35 research fellowships were earmarked for this research in 2007 and 2008.

One of NTNU's main goals is to provide Norway with internationally competitive technological know-how. The university has prioritised six research areas in which NTNU aims to be among the internationally leading universities. The Faculty of Engineering Science and Technology is the host faculty for two these strategic research areas:

- Energy and petroleum – resources and environment

"Technology for a cleaner future" – NTNU is engaged in improving knowledge about sustainable production and the consumption of energy. Knowledge about new sources of renewable energy and energy carriers is particularly important.

- Marine and maritime technology

The strategic area seeks to strengthen the knowledge required to maintain competitive and sustainable marine and maritime industries. During the last 30 years aquaculture and the offshore development of petroleum resources have been significant activity areas at NTNU. Approximately 250 man-years are devoted to such research at this university.

To enhance quality in research the Norwegian Research Council has established two facilitating classifications:

- Centres of Excellence – One of the 21 centres, CeSOS, is hosted by the faculty.
- Centres for Research-based Innovation – The faculty is involved in 6 of the 14 designated centres and is the host institution for two.

While the faculty has numerous research partnerships with industry and is involved in many projects funded under the EU's Research Framework Programmes, we are also actively seeking new partnerships that can contribute to our research excellence.

The faculty comprises 10 departments, each of them briefly described in this prospectus together with the seven outstanding research groups named above.

Dr. Ingvald Strømmen
Dean

Marine Technology for extreme environments

The research activities of the Division of Marine Structures are governed by the fact that the Norwegian marine industry operates in some of the harshest environments on the globe. A combination of strong winds, large waves, deep waters, low temperatures, and safety concerns requires unique technological solutions. The research activities of the division are broad, spanning the disciplines of hydrodynamics, structural mechanics, and cybernetics, with ten full time and five adjunct professors. Four professors are currently affiliated with the Centre for Ships and Ocean Structures (CeSOS). Over the next few years approximately 10-12 PhD candidates annually will graduate from the division, inclusive CeSOS.

Strategic research programmes

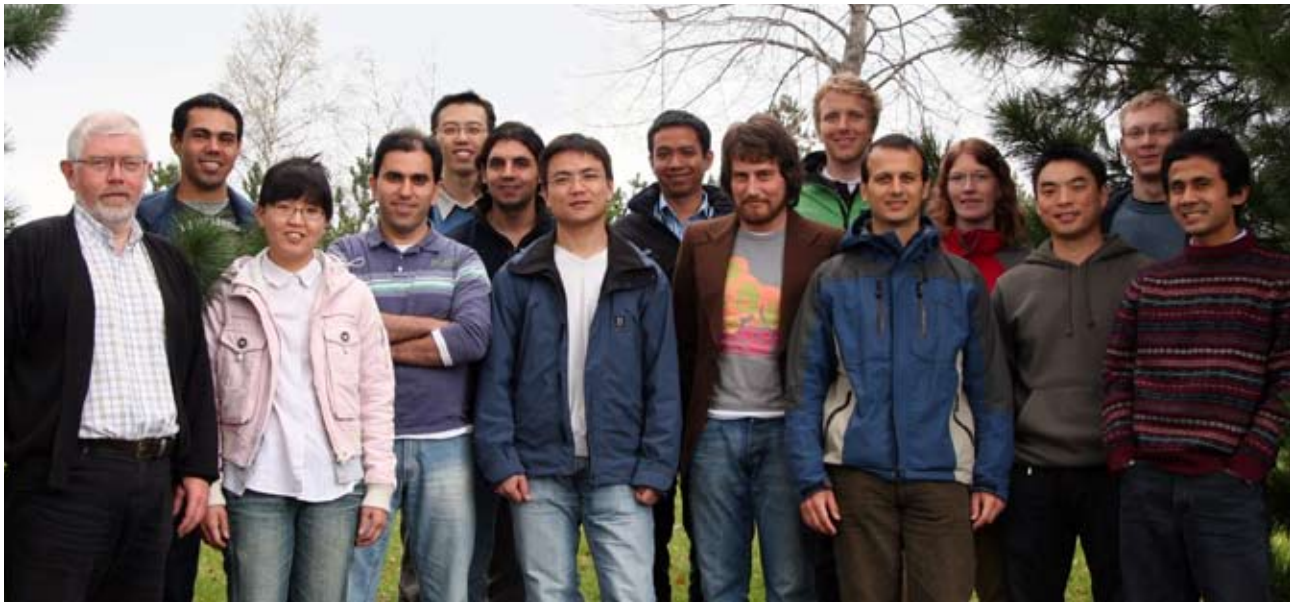
The Division of Marine Structures is engaged in several strategic research programmes, funded by the Norwegian Research Council and industry:

- Extreme Wave Load Effects in Sea Structures (Professor Torgeir Moan)
- Scenario-based Risk Assessment of Ship Collisions and Groundings (Professor Jørgen Amdahl)
- Marine Computational Fluid Dynamics (Professor Bjørnar Pettersen)
- Materials and Structural Integrity (Professor Stig Berge)
- Performance in a Seaway (Professor Sverre Steen)
- Energy from the North – Arctic Technology (Professors Jørgen Amdahl and Bjørnar Pettersen)

Unique laboratories

Laboratory facilities are operated in co-operation with MARINTEK, a research company within the SINTEF group. MARINTEK has 180 employees and is one of the largest marine technology research institutes in the world.

- Towing Tank: 260 m long; two sections with a water-depth of 4 m and 10 m respectively; wave-maker.
- Ocean Simulation Basin: 80 x 60 m^2; variable depth up to 10 m; wave-makers along two sides for generation of 3D sea-states; facilities for generation of current and wind.
- Marine Cybernetics Laboratory: for testing ships, rigs, underwater vehicles, and propulsion systems in a dynamic system.
- Particle Image Velocimetry System: measures hydrodynamic flow around structures.
- Cavitation Loop: for testing propellers.
- Marine Structures Laboratory: including a number of dynamic test rigs; a facility for full scale dynamic testing of flexible risers and umbilicals; corrosion fatigue cells with CO_2 and H2S environments.



Centre for Ships and Ocean Structures

The Centre for Ships and Ocean Structures (CeSOS) is one of thirteen national Centres of Excellence, so designated in 2003 by the Research Council of Norway. CeSOS is located together with the Department of Marine Technology and will maintain operation in its current form through 2012.

CeSOS engages key researchers from the Departments of Marine Technology, Engineering Cybernetics, and Mathematics at NTNU and is hosted by the Faculty of Engineering Science and Technology. A total of 80 researchers from nearly 20 nations are affiliated with the centre. In 2006 the CeSOS team carried out more than 50 man-years of research.

The mission of CeSOS is to develop fundamental knowledge about how ships and other structures behave in the ocean environment; a mission accomplished using both analytical and numerical studies in addition to controlled experimentation in the unique laboratories of the Marine Technology Centre. An emphasis is placed on basic research in hydrodynamics, structural mechanics, and automatic control—and in the synergy between these disciplines. The principal applications of this knowledge are the assessment of structures and operations for sea transport and oil and gas exploitation. However, the applications for CeSOS research increasingly extend to facilities and operations associated with food production through aquaculture and the exploitation of renewable energy from the oceans.

CeSOS

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Effective manufacturing, satisfied customers

The manufacturing of a product must be efficient, effective, and adhere to strict quality standards if it aims to satisfy demanding consumers. "We help manufacturing companies find good manufacturing solutions" says Asbjørn Rolstadås, contact for the Production Management Group.

The group comprises three fields; logistics and production management, project management, and quality and performance management.

Logistics and production management

Ola Strandhagen supervises research in logistics and production management. "Our objective is to build and manage manufacturing systems that best meet customer demands," he claims. "The swivel chair manufacturer HÅG delivers so many different chairs that mass production to stock is infeasible. The company had a depressive delivery precision track record. Together with HÅG we developed a production management system that enables them to assemble customized chairs to order, while reducing delivery lead time from 20 to 4 days, and achieving a delivery precision of almost 100%."

"Currently we are working on how manufacturing systems can be monitored and controlled by real time information and we are developing dashboard systems similar to those applied in the process industry. Real-time monitoring will allow for corrective actions to be taken as errors occur and the production pace can be adjusted to demand. We also use RFID technology to monitor product movements and surrounding conditions. This is essential for reducing expensive inventories in the supply chain," Strandhagen says.

Photo: Oracle

Project management

"We research the factors that predict success in a project. This allows us to develop tools for managing projects well, and we study how projects should be organized," says Asbjørn Rolstadås, who directs the research within project management. "The way we combine technology and management makes a difference when compared with many of the other research institutions we compete with. How do you make use of new technology in a project? How does the project manager role change as the technology is developed? How do you manage risk? How does one ensure success in global projects? And so on. These are important research topics for us. Our research is put to use, for example, in the oil and gas industry, in complex road projects, in hydropower projects, and in industrial development," says Rolstadås. He adds that they cooperate extensively with Norwegian industry through the Norwegian Centre for Project Management.

Quality and performance management

"Our mission is to strengthen the competitiveness of companies and this can be done in many different ways. In one project we developed a computer game," says Bjørn Andersen, who leads the research within quality and performance management. "The computer game is used to train young managers in dealing with complex situations that they will probably face some day in the real life. A virtual business world is constructed – where multiple players face each other as competitors, suppliers, or customers – and decisions must be made about which products to sell, where to produce these, whether to lower prices or invest in new products that command higher prices, and so on. Through trying out different strategies in the risk-free environment of the game the players develop a tacit understanding of likely reactions and consequences. This is quite similar to entertainment games like SimCity™ and Capitalism™, though the aim is not only having fun, but also learning important skills. The so-called PRIME project is financed by the European Commission and involves 13 partners across Europe."

Close collaboration

"Close collaboration with the research organization SINTEF and industry, broad international aspirations, and not least, a unique combination of theory and practice has made the group a world leader. In addition, we depend on close collaboration across the different disciplines to ensure effective manufacturing. This has made us very good at working cross-disciplinarily," concludes Rolstadås.

NORMAN

Centre for Research-based Innovation:

Norwegian Manufacturing Future

Among the six elite units selected for this prospectus, the group is actively involved in the large research programme called NORMAN. The centre and programme is hosted by SINTEF, and has been awarded eight years of financing from the Norwegian Research Council.

"NORMAN focuses on how we can ensure a prosperous future for Norwegian manufacturing industries in the face of global competition and the trend toward sourcing from low-cost countries. Involving the strongest Norwegian manufacturing companies, the centre aims to conduct leading-edge research concerning cost-effective manufacturing, collaborative product and process development, transparent and robust supply chains, and other relevant topics," says Odd Myklebust, the director of the centre.

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Other relevant projects:
Norwegian Center of Project Management:
http://www.nsp.ntnu.no
PRIME: http://www.prime-time4all.com
PROMISE: http://www.promise.no

Offshore operation via remote control

Today, most of the oil in place in the Norwegian oil fields will remain in the ground when the fields are closed. Petroleum technology researchers would like to improve results through better technology and better interaction between disciplines

The group

The Petroleum Technology Group is a leading group internationally, both in education and research related to the exploration and production of oil and gas. The group's research encompasses seismics, rock physics, drilling, production, and reservoir technology. In addition, the group works closely with other departments at NTNU, with SINTEF, with industry, while engaging in extensive international collaboration. Approximately 50 PhD students are in the group.

Recognition

In 2004, the Norwegian Research Council awarded the group high marks in terms of quality. In 2006 the Centre of Excellence application evaluation of the group's seismic and rock mechanics research received 6 of 7 points. Moreover, subsequent a 6 of 7 rating in the Research Council's 2006 evaluation of integrated operations research, Centre for Research-based Innovation status was awarded to the group together with SINTEF and IFE. Now hosting Integrated Operations (IO), the group will retain its top-tier status for 5-8 years. In seimics the group has established itself as a developer of both technology and methods for seismic processing and interpretation. Trondheim, a host to research groups from NTNU, StatoilHydro, EMGS, Seabed, and SINTEF, is now on the map as "The seismic city". Rock mechanics is another area in which the group, in close collaboration with SINTEF, has been recognized. Shell proclaimed us "the leading rock mechanics researchers in Europe". The group has contributed substantially to the development of horizontal drilling, and to improved production and better oil recoveries in Norway. Two of the professors in the group have received the prestigious Statoil Research Prize.

Research programs

The largest research programs in the group are:

- ROSE – Rock Seismic Programme
- 4D Seismic – Reservoir Simulation Programme
- Improved Oil Recovery Programme
- Seafloor Separation Programme
- Subsea Programme
- New Drilling Methods Programme
- Integrated Operations Programme

The hub of the new Centre for Research-based Innovation in Integrated Operations in the Petroleum Industry

Integrated Operations

The Centre for Research-based Innovation in Integrated Operations is a national research centre. The centre is grounded in the new petroleum era, with remote control of offshore activities based on multi-disciplinary collaboration in control rooms with digital environment and real-time data. The centre is a partnership between NTNU, SINTEF and IFE, and was awarded Centre for Research-Based Innovation status by the Research Council of Norway in 2006. Twelve industrial companies support the centre, which may run for a period of 8 years. The centre collaborates with Stanford University, Technical University of Delft, Carnegie Mellon University, and Kyoto University.

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With focus on safety

"We develop methods for system reliability and maintenance optimization. The offshore oil and gas industry and the railways are two of our main application areas," says Marvin Rausand, contact for the RAMS group.

The RAMS group is part of the Department of Production and Quality Engineering and is also a main partner in the ROSS Gemini Centre. ROSS is an acronym for "risiko- og sårbarhetsstudier" the equivalent of "reliability and safety studies" in English. The research activities of the RAMS group can be classified into the following categories:

- system reliability theory
  - reliability of safety-critical systems
  - reliability assessment of oil/gas well equipment and subsea production systems
- risk-based maintenance management
  - maintenance management and effectiveness
  - maintenance and safety
  - maintenance optimization
- risk analysis
  - risk analysis methodology
  - risk influence modelling

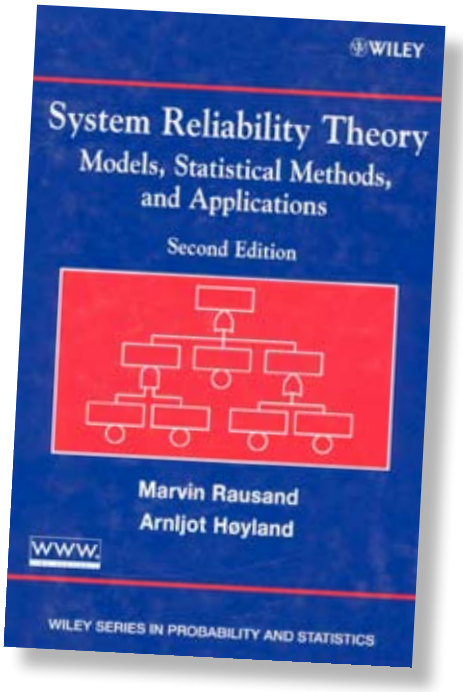

Illustration: FMC Kongsberg / StatoilHydro

Safety instrumented systems

"The RAMS group's collective competency related to reliability assessment of safety instrumented systems is eminent. Safety instrumented systems are used in many sectors of our society, for example, as emergency shutdown systems in the oil and gas industry, in chemical plants, fire and gas detection systems, and in automatic train stop systems. The systems comprise a number of sensors that are connected to a logic solver. When a process deviation is detected, the logic solver initiates a set of actions, such as the closure of valves and activation of circuit breakers. Our research provides a basis for developing safety systems with the highest possible reliability," says Rausand.

Rail breakages

"We are also developing mathematical methods and tools for maintenance optimization – to minimize both the life cycle cost and the risk of accidents," says Rausand. He mentions the railway infrastructure as an example. Minor cracks may occur in railroad rails, and after some time cause breakage. This may lead to derailment with significant consequences. To prevent rail breakages a special rail-car equipped with ultrasonic inspection equipment is used to inspect the rails. "These cars are complex and expensive. We try to determine how often the inspections have to be carried out to maintain an acceptable safety level. This requires detailed knowledge in a wide range of areas. We must estimate the growth rate of the cracks and the probability that the inspection rail-car will be able to detect cracks of a specific size," says Rausand. Maintenance optimization is important for many applications, including oil and gas pipelines and rotating machinery.

Close cooperation with industry

The RAMS group has always cooperated closely with Norwegian and international industry. "Our strategy is to extend this cooperation and develop methods and tools that can be used to prevent accidents and damage to the environment," concludes Rausand.

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Structural Impact Laboratory

"The group's research profile is characterized by the mathematical modelling of materials, material and component testing at various loading conditions, and implementation of material models suited for large scale structural analyses," says Magnus Langseth, leader of the research group.

The competencies of the group serve as a basis for research activities on the structural behaviour of components and structures, taking into account the interaction between material behaviour, structural geometry, and manufacturing process. "We have developed extensive experimental facilities for dynamic testing of materials, components, and structural subsystems," Langseth adds. "Furthermore, we participate in the development of structural design codes at the national level, and in international organizations such as ISO and CEN." Langseth imparts that the group is also working with the European automotive industry.

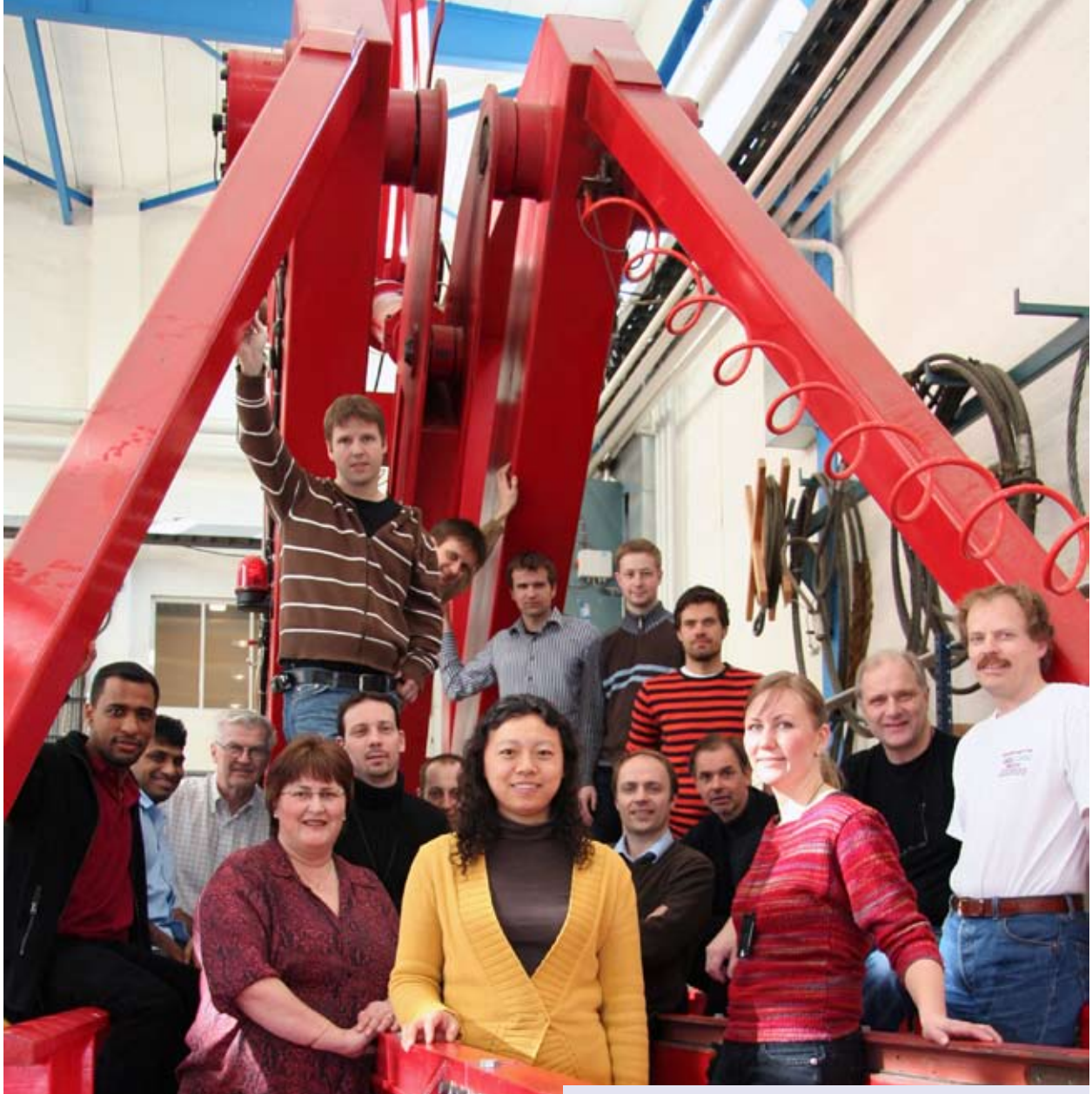
Research activities

Research activities primarily concentrate on determining the strength and ductility of load carrying steel and aluminium structures. Special emphasis is placed on the crashworthiness of automotive structural systems, such as bumper systems and crash boxes. This involves the modelling of plastic anisotropy, strain rate dependency and failure, and the development of appropriate algorithms for large scale analyses are carried out. The energy absorption of such systems is governed by inelastic material behaviour, the interaction between local and global buckling, development of folding mechanisms, and by connection design. The latter is related to activities on the behaviour and modelling of welded connections and self piercing rivets. In the offshore and maritime sector the group's research activities focus on energy absorption of sub-sea installations and topside protective systems, and the behaviour of stiffened aluminium panels for use in living quarters and high speed boat and ferries. Another activity area is that of penetration mechanics and blast loading, applicable to protective systems both in the oil and gas industry, as well as the development of mobile protective systems used in international peacekeeping operations. Material modelling has important applications in plastic forming and formability. Recently, activities concerning the modelling and design of cast aluminium and magnesium structures and polymers have been initiated.

Centre for Research-based Innovation

The Norwegian Research Council awarded elite centre status to SIMLab – with partners the Department of Materials Technology and SINTEF – designating it a Centre for Research-based Innovation for the period 2007-2014. The objective of the Centre for Research-based Innovation scheme is to strengthen Norwegian research groups that work in close collaboration with partners from industry and public enterprises and encourage long-term research that promotes innovation and value creation.

The main objective of SIMLab is to develop a technology platform for safe and cost effective structures in aluminium, high-strength steels, and polymers through advances in research areas such as materials, solution techniques, and structures.



Host institution: NTNU
Reseach partners: Department of Structural Engineering and Department of Materials Technology, NTNU and SINTEF
Industrial partners: Hydro Aluminium, BMW, Renault, Audi, StatoilHydro, SSAB, Swedish Steel and Plastal.
Public partners: Norwegian Defence Estates Agency, Norwegian Public Roads Administration
Man-year: Approximately 20 per year

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Clean water for all!

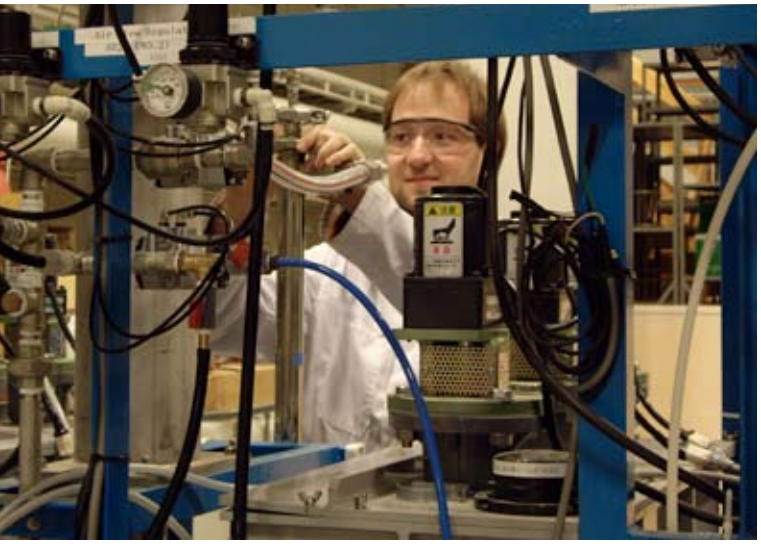
"Clean water and sustainable infrastructure – this more or less sums up the research goals and activities of the water and wastewater engineering research group," says Liv Fiksdal, leader of the group.

The world is running out of clean, safe, fresh water. By 2025 one third of humanity – almost three billion people – will face severe water scarcity. This has been described as the "single greatest threat to health, the environment and global food security". Water is fundamental for life, is by far the most important food item, and is a commodity that modern societies rely on in many aspects including potable water, agricultural water, industrial water and recreational water. Water is essential and preservation of its safety in quantity and in quality is critical to the sustainable development of any society.

In 2002, the UN Committee on Economic, Social and Cultural Rights affirmed that "sufficient, affordable, physically accessible, safe and acceptable water for personal and domestic uses" is a fundamental human right of all people and a prerequisite to the realization of all other human rights. The Water and Wastewater Engineering Research Group is committed to meeting these challenges.

Potable water supply

Supply of high quality drinking water through enhanced and innovative treatment technologies and distribution systems is a core activity for the group. Water quality issues are primarily directed towards removal of natural organic matter (NOM), removal of organic micro-pollutants and securing the hygienic quality of water supplied to the consumers. Applying membrane technology in production of potable water is currently a focus area. Compact, efficient and economic treatment schemes by integrating membrane filtration with advanced oxidation processes and biological treatment are being investigated within the EU-project TECHNEAU. With the increase in waterborne diseases, observed world wide in recent years, the development of effective disinfection methods is also a priority activity. This is coupled with studies of the change in water quality in distributions systems, alternative piping technology and tools for maintaining and ensuring high standards in the water distribution infrastructure. Risk assessment and rehabilitation of distribution systems is therefore also a key activity.



Wastewater management

From a global perspective, the available fresh water resources are increasingly under threat through over exploitation and deterioration by pollution. In part, this is due to poor management of wastewater discharge back to the environment. The group has a broad experience in advanced wastewater treatment, both physical and chemical processes, and biological treatment. Current activities are primarily directed towards the development of membrane bioreactor (MBR) technology, coupling biofilm processes and membrane filtration in particular. The EU-project EUROMBRA, dealing with the development of MBR technology, is coordinated by the group. The high quality of today's treated water enables the development of wastewater recycling and reuse strategies, a policy that is increasingly being embraced by water authorities worldwide to meet the future demands in water scarce regions and mega cities. However, reuse of wastewater requires reliable collection systems. Integrity of the pipe network, impact of storm water management and flood control represent a series of challenges for sustainable infrastructure, which the group also investigates.

Urban hydrology and storm water management

With the increasing trend towards urbanization, management of surface water runoff in urban areas is an important challenge. The research group has focused on challenges related to urban hydrology in cold climate regions. A major achievement is the establishment of the Risvollan Urban Hydrological Field Laboratory, Risvollan (20 ha) in Trondheim. This long-term activity is the basis for the ongoing comprehensive research on urban runoff in cold climate. Research activities are directed towards developing mathematical models and processes to prevent flooding and pollution of the environment.

Pipe management systems
In the area of water and wastewater systems, the major achievement of the group is the development of methods for computer aided rehabilitation of sewer and storm water networks through the EU-projects CARE W, CARE S and City Net. Rehabilitation issues are complex and an attempt to resolve them in a realistic and scientific way requires tapping into advanced tools that are already common in other industries.

Industrial applications
The research group is also involved in water quality issues in specific industrial applications. These include developing novel systems for wastewater treatment on ships, treatment of produced water during the extraction of oil and gas in the North Sea, and the development of advanced water recycling systems used in aquaculture.

Due to the global dimension of water and wastewater issues, the group has a strong international portfolio and contact network. The group is heavily involved in research projects within the EU Research Framework, both as a project partner and in various coordinating roles. Through several bilateral research programs members of the group are involved in all regions of the world. This international dimension is mirrored in that the research group is comprised of members representing between 10–12 different nationalities, giving a unique and inspiring perspective within the ongoing research activities.

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Focus on hydropower – the most important source of renewable energy

The research group is determined to improve and to develop new hydropower technology, with a strong focus on environmentally friendly solutions. Research includes methods for hydrological analysis, numerical and physical models for water and sediment flow in rivers and reservoirs, optimal design of hydraulic structures, and dam safety. Development and application of numerical models is important within most of these areas.

The role and importance of hydropower

Nearly all electricity production in Norway comes from hydropower. Globally the contribution is nearly 20%, about as much as from nuclear power. Hydropower is by far the largest and most economical source of renewable energy today, and will probably remain so a long time into the future. Despite the fact that some of the oldest hydropower stations are more than 100 years old and much of the technology is mature and well proven, the need for technological improvement and innovations persists in order to meet new environmental demands, changing political views on resource management, and new technological opportunities.

Hydropower and the environment

All types of electricity generation will impact the environment, also hydropower. The research group is therefore studying the impacts of hydropower on the environment, in particular in rivers and lakes. The resultant knowledge makes it possible to develop technologies and operational strategies to avoid or reduce negative impacts. Our main research tools are numerical models and field studies. In the context of climate change, hydropower is particularly important as it is usually free of greenhouse gas emissions, and can therefore contribute significantly to reducing climate change.

Flood, erosion, sediment transport, and deposits

Water is not only a vital resource; water can also be a threat to lives and property. Flood is the natural disaster that creates most damage and takes most lives, according to UNESCO. Floods affect both infrastructure and people, often creating erosion and landslides. When the eroded sediments are later deposited, they can fill up reservoirs and intake structures, rendering the structures useless. We develop numerical models and use computer simulation to study how sediment is generated, transported and deposited, and how river morphology can be changed by these processes. We use physical laboratory models and field studies for designing important hydraulic structures like intakes, and for developing new sediment handling facilities. Such studies are important in order to design protection schemes to reduce dangerous erosion, as well as the potential breakdown of bridges, embankments and dams.

Water and energy in developing countries

The research group is significantly active in developing countries, both in terms of research and training. The main focus is on hydropower development and water resources management, often in combination. In Nepal the main research activity is on improving technology for hydropower develop-

ment in steep rivers with very high sediment loads. In East Africa we are working in several countries, while focusing on Tanzania, Ethiopia and Uganda. Here as in most developing countries, good water management means finding the optimal use for limited water resources, sharing water between irrigation, hydropower, and water supply.

Climate change and water

The predicted changes in climate are expected to profoundly affect water and water infrastructure. We are currently studying the effect of climate change on river morphology, hydropower resources, floods, and dam safety. We conduct research in cold climates and the Arctic region, given that the climatic change is predicted to be greatest in these regions.

Laboratory facilities

Our hydraulic laboratory has good facilities for building physical models for hydraulic research. The laboratory has modern equipment for field data collection. Over the next five years the laboratory will be further developed, according to a plan approved by NTNU, the Norwegian Research Council, NVE (Norwegian Water Resources and Energy Directorate) and the hydropower industry. It is also worth noting that we have a long-term working relationship with our sister institution, Hydrolab, in Nepal. Our hydrological research basin, located a short distance outside Trondheim, is equipped with modern instruments for the monitoring of climate, river runoff, snow, soil and groundwater. The Sagelva Research Basin is used for teaching and for studying hydrological processes, often combined with the development and testing of hydrological models.

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A story in the sign of the twins

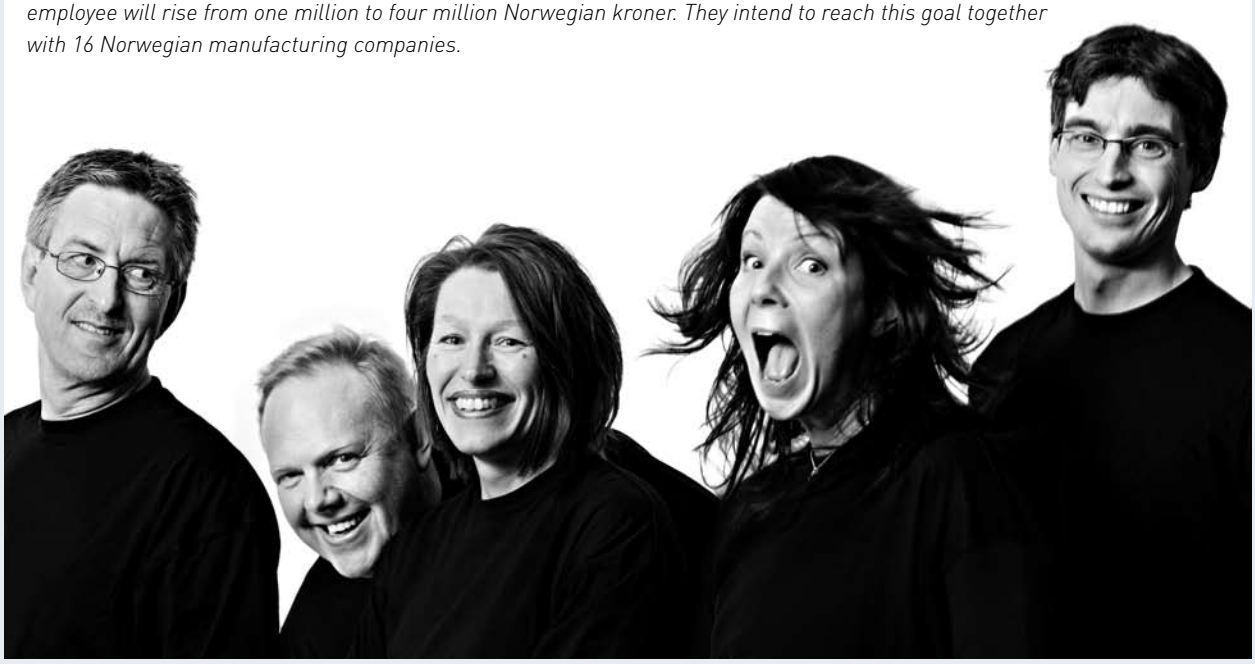
More than 50 years ago, the SINTEF Foundation emerged from what was then called the Norwegian Institute of Technology (NTH was its Norwegian acronym). SINTEF was to carry out contract research and provide support for Norwegian industry, and then as now, the vision for its activities could be summed up as "Technology for a Better Society".

The plan met with success: SINTEF grew, and the twins lived in a state of fruitful symbiosis, as they do today, though NTH is now known as the Norwegian University of Science and Technology (NTNU). This symbiosis entails the sharing of laboratories, personnel, projects and equipment, not least exchanges of both knowledge and projects.

As of today, SINTEF and NTNU have established 16 Gemini Centres, joining forces in a variety of science and technology fields. We also participate in eight of this country's 13 Centres for Research-based Innovation, in many cases collaborating with clients in private industry and the public sector as well.

Because when knowledge is shared, it grows

NORMAN: Champions League in manufacturing.
These persons have an ambitious goal for Norway's manufacturing industry: the value of goods produced per employee will rise from one million to four million Norwegian kroner. They intend to reach this goal together with 16 Norwegian manufacturing companies.



From the left: Sverre Narvesen, RTIM; Odd Myklebust, SINTEF; Heidi Dreyer, NTNU; Catrine Larsen, SINTEF and Tormod Jensen, Teeness.

FACTS ABOUT THE SINTEF GROUP

SINTEF is the largest research group in Scandinavia. The value that we create through our knowledge, research and innovation helps to improve the quality of life and contribute to sustainable development. SINTEF sells research-based knowledge and related services based on deep insight into technology, the natural sciences, medicine and the social sciences.

The SINTEF Group has 2000 employees, who generated NOK 2 billion worth of research-based knowledge in 2006.

SINTEF and NTNU's Gemini Centres

Acoustic Research Centre

Marine Structural Engineering

Applied Refrigeration

Materials & Energy

Advanced Robotics

PV- Solar Cell Materials

Better resource utilisation of oil and gas - BRU

Robust Materials Selection and Design - Offshore Applications

Sustainable Architecture and Property

Transmission Electron Microscopy - TEM

Electrical Energy and Energy Systems

Underground Technology

Energy and Climatization in Buildings

Road and Transport

Fisheries technology

Health Services Research

Centres for Research-based Innovation in which SINTEF and NTNU are participating

COIN – Concrete Innovation Centre
CREATE – Centre for Research-based Innovation in Aquaculture Technology
NORMAN – Norwegian Manufacturing Future
IO – Centre for Integrated Operations
INGAP - Innovative Natural Gas Processes and Products
MILab – Medical Imaging Laboratory for Innovative Future Healthcare
SIMLab – Structural Impact Laboratory
FACE – Multiphase Flow Assurance Innovation Centre

SINTEF

Technology for a Better Society

Developing the built environment

"The research field of this department is crucial to the further development of the community's infrastructure. The huge environmental challenges we are facing present the department with a demanding responsibility in terms of the development and dissemination of new expertise for a sustainable society," states Asbjørn Hovd, Head of the Department of Civil and Transport Engineering.

Cross-disciplinary research

"The six research groups of the department often work cross-disciplinarily, in project teams involving two or more research groups as well as other research environments both in Norway, such as SINTEF, and abroad. While we primarily conduct basic research, we also engage in commissioned research initiatives in cooperation with partners in industry and the public sector. We consider this cooperation very important for our research work, and we emphasize the development and strengthening of this cooperation," says Professor Hovd.

The Department of Civil and Transport Engineering comprises six research groups:

- Building and Material Technology
- Geomatics
- Geotechnical Engineering
- Marine Civil Engineering
- Project Management and Construction Engineering
- Road and Transport Engineering

Natural hazards

"The Geotechnical Engineering Research Group is heavily involved in the International Centre for Geohazards (ICG), hosted by the Norwegian Geotechnical Institute (NGI). Research is conducted in close cooperation with NORSAR, the Geological Survey of Norway (NGU), the University of Oslo (UiO) and international partners, and is in the forefront internationally regarding the modelling of geological materials, particularly when it comes to instability and landslides. ICG was recently awarded top marks in an international evaluation," states Professor Steinar Nordal. More information: **www.geohazards.no**

Arctic technology

"The objective of the PetroArctic team, a team within the Marine Civil Engineering Research Group, is to expand knowledge about arctic and cold climate technology for a reliable and sustainable petroleum production from Arctic areas. The team works on the scientific frontier in several areas, including ice ridges and the use of moored icebreaking ships in pack-ice," says Professor Sveinung Løset, PetroArctic's Project Leader. More information: **www.ntnu.no/petroarctic**

Front-end management of major investments

"The Concept Programme, financed by the Norwegian Ministry of Finance, aims to achieve increased benefits from extensive governmental investments. The programme group follows a large number of projects over many years and has already branded itself internationally within what we now call 'Project Governance'," states Professor Knut Samset, the programme's director.
More information: **www.concept.ntnu.no/index_engelsk.htm**

Sustainable infrastructure

The Department of Civil and Transport Engineering coordinates this faculty defined research focus area. "The aim of long-term research regarding sustainable infrastructure is to contribute to the design and construction of new infrastructure as well as the further development, improvement, and management of existing infrastructure. Key issues are: consequences of climate change; the risk, vulnerability and safety of infrastructure; construction and management of infrastructure; and environmental aspects. A central challenge is to exploit knowledge and expertise from other research areas, such as: information technology, nano and biotechnology, geomatics, geotechnical engineering, industrial ecology, and risk analysis," says Professor Per Jostein Hovde. More information: **www.ntnu.no/sustainability**

Photo: Statens vegvesen

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Technologies saving the environment

"The social focus on climate change and environmental threats has made research at the Department of Energy and Process Engineering (EPT) progressively more attractive. We are riding on a wave of increased environmental awareness which gives us extra motivation to do research on those technologies that are best for the environment," says Johan E. Hustad, Head of the Department.

"Many companies and appropriation authorities are willing to use considerable resources on our research because we can find solutions for many of the environmental problems connected to the conversion of energy," says Hustad. He mentions natural gas power plants with CO_2 capture as an example. Other examples are renewable energy, industrial ecology, which aims to make environmental assessments from various energy technologies, and the use of energy in buildings. "Our list of technological environmental solutions is long. In short, our research will contribute to better use of energy, thereby creating a better environment. This is a research area in which we are going to invest great effort over the next few years," states Hustad.

Spin-offs

A number of companies, both domestic and foreign, are based on research from EPT. Energos, Dtech, Shecco, Ecoxy and Small Turbine Partners are a few examples of EPT's spin-off companies. These companies engage in everything from waste combustion to freeze drying of food products. "Shecco is an example of a unique company, which has made use of licensed technologies from the department in order to produce heat pumps based on the use of CO_2 as a heat carrying medium," says Hustad. The technology has already gained wide use in Japan.

Trust and responsibility

"Much of the reason environmental concerns can have such a preeminent position at our research institution is undoubtedly due to the fact that people at the department are given the trust and responsibility necessary to develop themselves. We are a large department with many research projects that are able to provide world class results. It is important for us to have a streamlined organization so that we can channel more energy into the actual research work. The freedom and responsibility our professionals have helps explain why we have become a leading research community within bioenergy, small scale water power, energy from the ocean, natural gas power plants with CO_2 capture, energy use in buildings, food technology, fluid engineering, and industrial ecology," says Hustad.

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The big picture: From materials to products – from cradle-to-cradle

Research, development, the design and innovation of products, engineering materials, manufacturing technologies and systems are complex multidisciplinary activities that require information flow and collaborative actions along the value chain—from the mining, recovery and processing of raw materials, through manufacturing, logistics, functional use and maintenance, to end-of-life processing—a cradle–to-cradle circulation flow is needed. In order to predict the behaviour of a product or material throughout its life cycle—its processing, functional life and recovery—a designer needs access to extensive scientific knowledge concerning a material's behaviour and microstructural evolution, information available through computer based multiscale interaction models of nano-, micro-, meso- and macro-scale phenomena.

Organisation for collaboration

Based on our own competencies we see ourselves as part of a wider picture, which includes materials science, production and quality engineering, solid and computational mechanics, industrial design, economics and ecology, as well as methodological know-how concerning the overall engineering design process. Our strategy is to form transdisciplinary teams that can collaborate with industry and in international consortia to further innovation and commercial success. In accordance with this strategy our scientific staff is self-organized for better interaction between the scientific depth of our fields of specialisation and the wider scope. This is supported by well managed secretarial services, technicians, our laboratories and workshop.

Laboratory testing, prototyping, characterisation, sensors and actuators

- metal forming, casting, and joining technologies
- polymer forming processes
- composites production and testing
- corrosion protection and surface technology
- materials testing and characterisation of mechanical, thermal, and chemical properties

Worlds first full-scale crack arrest testing of pipelines for transport of hydrogen gas

Computer modelling, simulation, inverse modelling, and validation

- FEM – structural dynamics
- fracture mechanics
- fatigue
- extrusion, forming, casting, and joining

Product life information and management. Reuse of knowledge through knowledge-based engineering (KBE)

- design for sustainability, life cycle assessment (LCA) and life cycle costing (LCC)
- KBE-modellng and semantics for reuse of product and process knowledge
- product simulation with respect to durability and functionality
- universal design

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We increase safety and supply society with geological expertise

"Our knowledge of geology ensures safer tunnels, roadcuts, caverns, and mines and helps secure access to the new materials needed in our modern society, while minimizing the environmental impact," says Terje Malvik, Head of the Department of Geology and Mineral Resources Engineering.

Accidents and geohazards

Recently, both Norway and other countries have seen rock falls in tunnels. Add to this those natural geological disasters such as rock avalanches on steep mountain sides and it becomes quite clear that we have an important task: saving lives by ensuring safety where people and mountains meet.

Solar panels and mineral resources

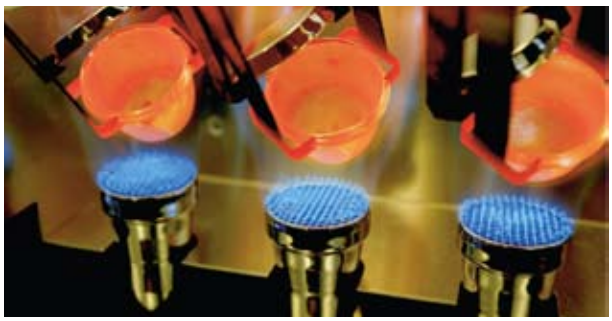
Quartz research is an important priority area for us, particularly because quartz is used in the production of silicon which is the most important component of solar panels. Through our research we provide knowledge about the raw material, technology and processes that ensure the separation of high quality quartz. Research on mineral resources of platinum and nickel are also in focus, as are research on other natural resources such as water, oil, and gas.

Cross-disciplinary

Our research is not confined by rigid disciplinary boundaries. We need cross-disciplinary cooperation to succeed. Material technology, civil engineering and the petroleum milieu, among others, are important partners for us. The Department of Geology and Mineral Resources Engineering supplies research and expertise to the oil and gas industry, the civil engineering branch, the mineral and stone industry, consultancies, renewable energy and environment-related concerns, as well as public administration.

Research groups:

- Geology
- Mineral production and HES
- Engineering geology and rock mechanics



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Excellence in water engineering research

"A flourishing society and nature require water of a minimum quantity and quality. However, the negative environmental and social impacts of water stress and scarcity, water pollution, and solid waste generation are problems of an increasing scale. Clean, running water provides life and joy to people of all ages: hence, hydraulic and environmental engineering is a cornerstone in sustainable engineering for the future," says Helge Brattebø, Head of the Department of Hydraulic and Environmental Engineering.

International horizon

The department's research has a very strong international orientation, in terms of its themes, project types, and staff. Water challenges are everywhere, in different forms and the technology is developing at high speed. Norwegian water competence is internationally well recognised, and our department has contributed significantly, due to committed individuals, innovative projects, high quality laboratories, strong international networks, and close collaboration with SINTEF and industry, through decades.

Research groups

The research is organised in three groups:

- Hydraulic Engineering
- Water and Wastewater Engineering
- Waste Engineering and Industrial Ecology

The first two groups are the largest, and are described more in detail on pages 14–17 in this brochure. All groups are strongly engaged in international projects and relations, and a growing number of the department's MSc and PhD students and staff hail from abroad.

Research priorities in hydraulic engineering:

- hydrological analysis
- numerical and physical models for water and sediment flow in rivers and reservoirs
- optimal design of hydraulic structures and dam safety, and
- development and application of numerical models is important within most of these areas

Research priorities in water and wastewater engineering:

- potable water supply
- wastewater management
- urban hydrology and storm water management
- pipe management systems, and
- industrial applications of water treatment technologies

Research priorities in waste engineering and industrial ecology:

- environmental and economic evaluation of novel waste recycling solutions
- material flow and life cycle analysis for built environment and urban systems

Cutting edge research topics

"Particularly noteworthy are our research achievements in numerical and physical models for water and sediment flow in rivers and reservoirs, and our innovations on the development of moving bed bioreactor and membrane bioreactor technologies for water and wastewater treatment. In these fields we have succeeded in placing NTNU on the international map and can claim that our research qualifies as both global and cutting edge. Our combination of international projects and our many laboratories attract research partners and PhD students from all around the world," says Brattebø.

Photo: Ivar Helleberg, Norsk Vann BA

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Energy, transport and food

The Department of Marine Technology serves essentially three sectors of Norwegian industry: offshore oil and gas, shipping, and fisheries/aquaculture. These are the three largest export industries of Norway that cater to the basic needs of the society: energy, transport and food.

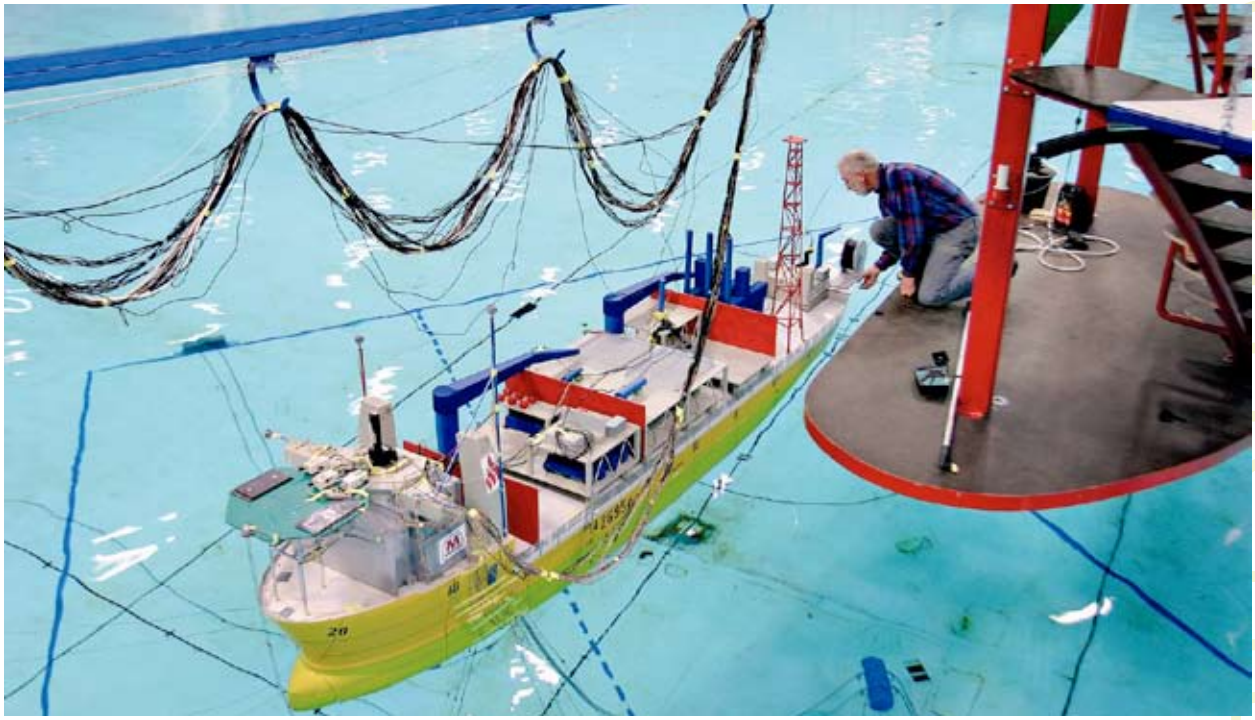

Photo: SINTEF/Marintek

Department of Marine Technology
NTNU's Department of Marine Technology is the largest and most complete university department within its field in the western world. The department is located alongside MARINTEK (a research institution with 180 employees) and CeSOS (Centre for Ships and Ocean Structures), with extensive laboratories for teaching and research. Over the next few years, between 80–90 candidates will graduate annually from the MSc level programme, and 12-15 annually at the PhD level. In addition, 8–10 candidates will be graduating each year from a two year international MSc program.

PhD programmes
The department is engaged in a number of strategic research programmes funded by the Norwegian Research Council and industry:

- Extreme Wave Load Effects in Sea Structures
- Scenariobased Risk Assessment of Ship Collisions and Groundings
- Marine Computational Fluid Dynamics
- Materials and Structural Integrity
- All-electric Ships
- Conceptual Design Methods for Complex, Customized Ships
- Performance in a Seaway
- Coping with Risk and Maritime Logistics – Managing Vulnerability, Risk and Resilience in Maritime Logistic Chains
- Energy from the North – Arctic Technology

Through these programs and through CeSOS, 70 PhD students and postdocs are currently engaged in a wide range of studies. The department is very internationally-oriented, the latest count (Sept. 2007) showed students and scientists from 17 countries.

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Technology for improved oil recovery

The primary task for the department is to contribute to the highest possible recovery of Norwegian oil and gas resources through education and research; bettering exploration and production using technology that puts people and environment in the front seat.

People

The activities in NTNU's Department of Petroleum Engineering and Applied Geophysics are grouped into drilling, production, reservoir, and applied geophysics. In cooperation with the Department of Geology and Mineral Resources Engineering the department covers a range of education and research programmes related to the upstream petroleum industry. The department has a total of 23 professors (including associate, assistant and adjunct varieties) and 13 administrative and technical support staff. More than 50 PhD candidates, post docs and researchers are currently engaged in research concerning both exploration and production.

Strategy plan

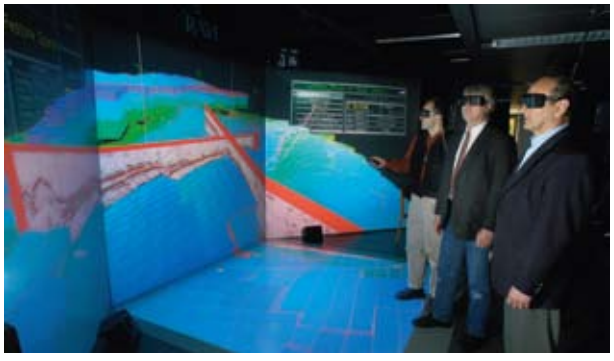
In 2004-2005 the department developed a new strategy plan for education and research (the BRU report) based on interviews with 50 companies, research institutions, and government agencies. The bulk of today's activities at the department are based on this plan.

International student body

The MSc programs in Petroleum Engineering and Petroleum Geoscience at NTNU rank among the largest in the world, with 80-90 MSc graduates per year. The programs are taught in English, and currently around 40% of all the students are from coutries other than Norway. Students from 50 different countries have been enrolled over the past few years.

Laboratories

Key laboratories at the department include: the Visualization and Virtual Reality Laboratory, the Computing Laboratory, the Rock-Physics Laboratory, the Reservoir Fluid Flow Laboratory, the Calorimetric Laboratory, the Reservoir X-Ray Laboratory, and the Multiphase Flow Laboratory.



Research

Current research projects include phase behavior investigations, reservoir laboratory experiments, well test analysis, reservoir simulation, drilling methods, subsea production systems, rock-physics experiments, hydrates and natural gas experiments, production system analysis, visualization and Virtual Reality applications, petrophysics, 4D seismic analysis, geomechanics-seismics analysis, 4D-reservoir simulation analysis, seismic data analysis and processing, seismic modeling and seismic interpretation.

Gemini Centre

NTNU and SINTEF collaborate on petroleum research in several areas; collaborating in particular in rock-physics, seismics, and experimental reservoir projects. Formalization of the cooperation between the department and SINTEF Petroleum Research was achieved through the establishment of the Gemini Petroleum Centre.

Close collaboration with industry

Long-term cooperation agreements are maintained with the major operators in Norway, and individual research projects are supported by virtually all oil companies and service companies. Around 75% of all PhD candidates in the petroleum area are financed by industry.

Applied field courses

Geological field courses are important elements in the department's MSc programmes. In addition to the regular field courses that are included in basic geology courses, NTNU and industry have developed applied field courses that place a greater emphasis on seismics, drilling and wells, and fluid flow. StatoilHydro, BP, and Shell collaborate with NTNU on field courses at Svalbard, in the Pyrenees, in the UK, and in Oman.

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Design brings humans and technology together

In a global context, technological, societal, and economical developments succeed each other with increasing speed. At the same time people rely on traditional values and attainments. This causes an increasing diversity in life styles and material environments. Using their understanding of changing contexts, of individuals and groups, and of technical, aesthetic, ergonomic, and managerial principles, product designers develop products and services that are cherished by users and enable companies and institutions to reach their goals.

The designer's role in technology valorisation.
More than before, product designers will be involved with defining and developing knowledge-intensive concepts that will go beyond traditional products, and as such address product-service combinations, introduction strategies, interfaces, websites, identities, environments, et cetera. The Design Council (2005) found that UK firms use design not only for product development, but for advertising, packaging, R&D, marketing, production engineering, marketing research, sales and marketing, and strategic planning as well.

Being able to organise chains of involved stakeholders, and interact with teams of specialists in various parts of the world will increasingly become a key quality. This requires foresight, hindsight, overview, prediction, and matching, which makes product design emphatically an intellectual and academic activity.

Research focus
At the Department of Product Design, the human being, in its role as user, consumer, and customer often takes a central position in research activities. Be it as an individual or as a part of society, humans are studied as they are the key to successful, sustainable application of innovative technologies and ideas in society.

For example, the feedback of product designers and end users to photovoltaic technology specialists has created the flexible solar panels available today that provide the necessary degrees-of-freedom to design products that consumers want to use and that can be commercially successful.

In our research strategy sustainability is an important application area. Many of our research activities aim to understand how product design can contribute to environmentally, economically, and socially preferred solutions for technology application in products.

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World class customized manufacturing

The Department of Production and Quality Engineering encompasses fields at the intersection between technology and management. A holistic view of industrial solutions rooted in a production engineering and manufacturing technology characterizes the department. Our strong industrial focus, extensive international collaboration and a good work environment has earned the department an international reputation for its research within manufacturing systems, production management, and the field of reliability, availability, maintainability and safety," says Per Schjølberg, Head of Department.

World class customized manufacturing

"How can industry deliver customized products on time and at minimum cost? This is a major research topic at the department. We have developed manufacturing solutions for industry with high degree of automation and extensive use of robotics," says Schjølberg. Department research also led to the development of a metal printing process that uses metal powder to build a product layer by layer to exactly the desired shape. The process may be applied to manufacture both complex prototypes and spare parts, even hip prosthesis, and the technology is in use by spin-off companies.

Intelligent products

Radio-frequency identification, or RFID, is a promising technology to make products more "intelligent". The department uses RFID within the food safety sector. Meat products are transported in boxes where quality parameters, such as temperature, are monitored throughout the logistics chain. Another application is in closing the information gap in the product lifecycle chain. By means of sensors on products or parts, information concerning condition, wear, and lifetime can be recorded and used for maintenance, end of life decisions, product design and improvement. The department is involved in an EU integrated project in this field called PROMISE.

Photo: NRK

A safety focus

Optimization and management of maintenance operations, as well as safety and reliability analysis of complex industrial facilities – such as oil development platforms and sub sea installations – is a field in which the department is world renowned. How do we know if the risk level on offshore platforms is increasing or decreasing, for example? The risk level is dependent on the frequency of accidents, their probability and their consequences. As the probability of accidents cannot be measured on a daily basis, we must instead, identify measures with a strong correlation to accidents to study the development of the risk level.

NORMAN

The department is the leading academic partner in the Centre of Research-Based Innovation on the Norwegian Manufacturing Future (NORMAN). NORMAN supports new and multi-disciplinary research on manufacturing to build theory, methods, models and management tools to enable Norwegian manufacturers to thrive in global competition. The main research areas are product and process development, manufacturing networks and global value chain development, adaptive factories and customized mass production. Key disciplines are manufacturing systems, automation, assembly, logistic operation and maintenance, and there are close relations to the 16 industrial partners of the NORMAN consortium. See page 7 for more information.

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Structural design, mechanics and material technology

Structural design and safeguarding against the failure of structures and components based on material technology, computational mechanics, and experimental validation is our research focus.

We combine a theoretical knowledge of mechanics, numerical methods, structural design, and structural analysis. Material mechanics, dynamic analysis, and the modelling of loads from impacts, explosions, wind and earthquakes constitute the basis for our research activities. Our graduates gain employment both within civil engineering, offshore engineering and the manufacturing industries. Over the next few years we will graduate between 70-90 candidates from MSc level programmes and 10-12 on PhD level.

Computational mechanics

Modelling the mechanical behaviour of materials, structures, and various components is essential in most of our research. This knowledge enables basic and applied research in a number of areas. Recent examples include biomechanics and nanomechanics. Multi-scale computations are essential for developing engineering aspects of nano technology. The modelling of components and materials calls for a close cooperation with material science also associated with biomaterials. Research on lightweight metals for impact and forming operations have been a significant activity area for many years.

Structural analysis as a basis for design

Structures that require modelling of nonlinear material behaviour and the description of large displacements and strains have been subject to research associated with non-linear finite element methods. Typically these are structures subjected to dynamic loading from wind and earthquakes, or impacts and explosions, as in the case of automotive and protective structures. Examples of said structures are: offshore pipelines, large bridges, high rise buildings, towers, masts and offshore structures in Arctic areas.

Concrete technology

The design and production of concrete structures requires first hand knowledge of concrete materials. Recent research topics include fresh concrete proportioning and rheology; the hardening of concrete including stress and strain development; the material structure of hardened concrete; and the durability and sustainability of concrete under various service life conditions.

Research funding

Our research is partially funded through research programs supported by the EU Commission and the Research Council of Norway and through various industrial partners. We conduct research in cooperation with international partners, universities, research foundations and industry. Important customers of our research projects are oil companies, the building industry, the automotive industry, mechanical and metal industries, and companies working with medical technology.

Research programs

The department is host to the Structural Impact Laboratory (SIMLab) awarded elite status as a Centre for Research-based Innovation. We partner with SINTEF in the Concrete Innovation Centre, and with SIMULA in the Centre for Bio-medical Computing (a Centre of Excellence, or CoE). These research centres are funded by the Research Council of Norway.

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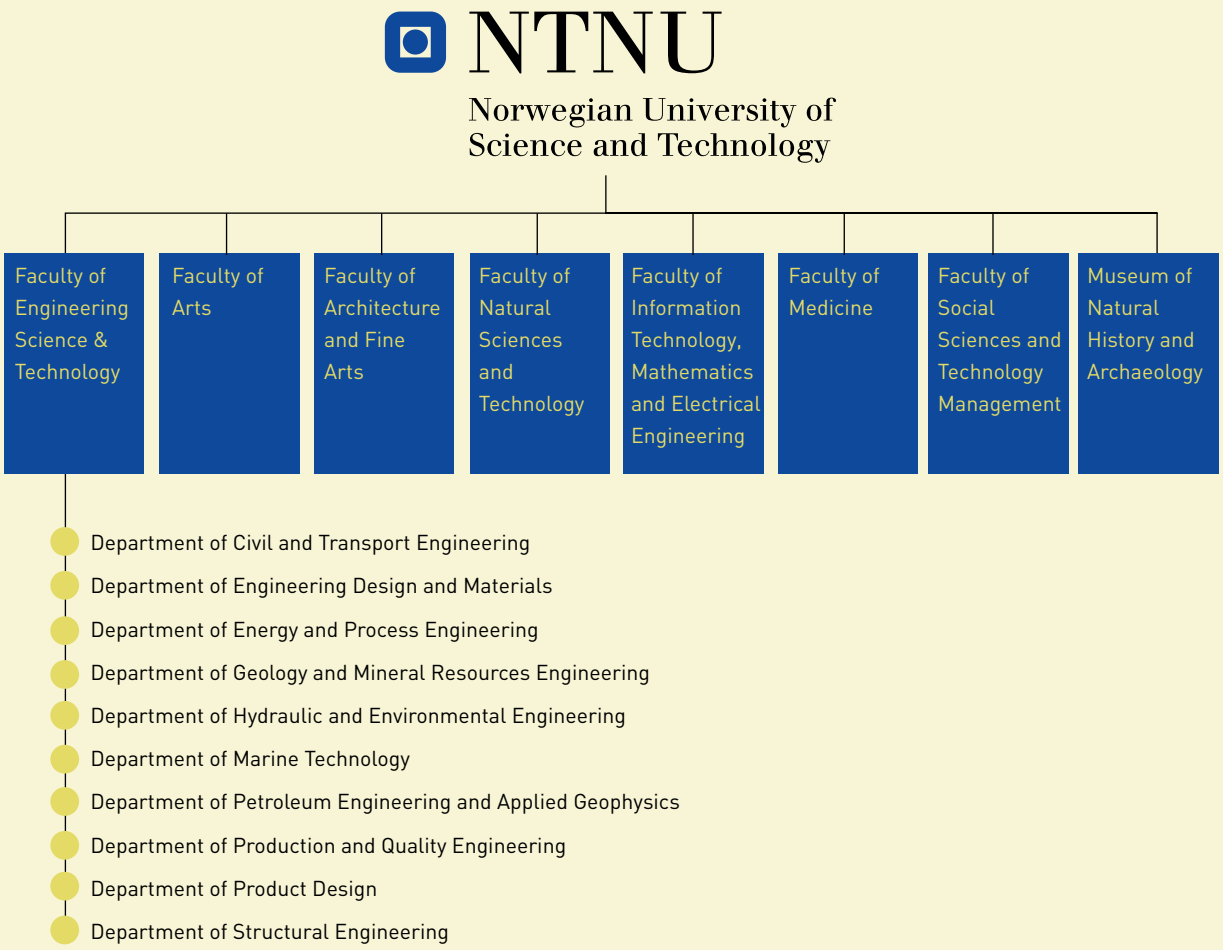
Organisation



About NTNU

- 8 faculties and 57 departments
- 2500 employed as research and academic staff
- 550 professors
- 1000 PhD students
- 250 doctoral degrees awarded annually
- Over 2000 research projects
- 20 000 students, 7000 students admitted every year
- 40 PhD programmes
- 110 two-year master's programmes, of which more than 30 are taught in English
- 25 five-year master's programmes
- 50 bachelor's programmes
- Professional degrees in medicine and psychology
- Annual company establishments based on business ideas and patents from NTNU
- Research and education cooperation with more than 200 universities worldwide

contact

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