Norsk olje&gass

TECHNOLOGY TRANSFERS

FROM THE OIL AND GAS SECTOR

2017

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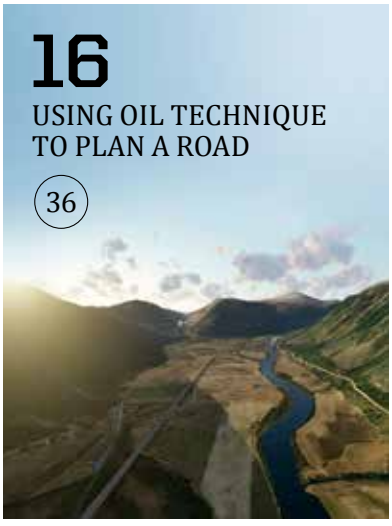
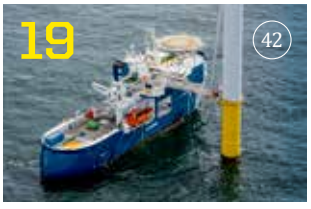
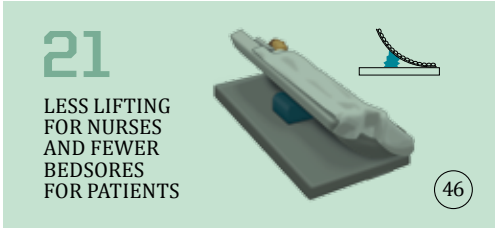






INNOVATING TO MAKE THE IMPOSSIBLE POSSIBLE

Giant fish farms far out to sea, satellite measurement of wind speeds in the upper atmosphere, and miniature measuring devices for acute medicine. Technologies from the oil and gas industry provide benefits far beyond their original purpose.

Norway's oil and gas industry is the most important driver of innovation and technology development in Norwegian society.

These innovations are also being transferred on a large scale to other social sectors. This is the second report from the Norwegian Oil and Gas Association to present examples of such transfers, now in collaboration with Sintef Technology and Society. A total of 26 cases document how technology developed for use in the petroleum sector is also being applied to create new and better products in other industries, new commercial activity and new jobs.

Technology is disseminated more widely through people's knowledge of it, their expertise, and their ability to apply it in new and different ways. That creates new value from the oil and gas industry, even if the technology has travelled a long way from the hot production wells on the Norwegian continental shelf (NCS).

Such transfers of technology, knowledge and new production methods from one industry to another is the subject of this report. Technology transfer from the oil and gas sector is very important for other parts of society and working life. The ability of the petroleum industry to make such a contribution depends crucially on its constant progress. This is an important reason in itself why provision must be made for new activity in the sector. That ensures it will meet new challenges, overcome them, and develop technology which can then be transferred to others.

The Norwegian oil and gas industry will be working in the future to reduce costs, boost productivity, operate in new areas, contribute to meeting the goals of the Paris agreement, and maintain stringent

requirements for health, safety and the environment (HSE). These are the challenges which mean the industry is still coming up with new solutions, seeking innovative methods and creating new technologies.

Over decades of oil and gas operations in Norway, a network has been built up nationally and internationally where technology transfer is driven forward, creates new jobs and secures progress and innovation in both new start-ups and established companies.

Look at Uptime International AS in Ålesund, for example, which moved from oil platforms to wind turbines and is producing a motion-compensated gangway able to cope with high waves. Or Presens AS in Oslo, delivering sensors to subsea installations and eventually also to the European Space Agency (ESA) for use in satellites.

And look at K Lerøy Metallindustri AS in Lonevåg, a supplier of components to the oil and gas sector. Its mastery of the tough standards set by this industry means it can also produce miniaturised components for an advanced heart pump.

The Norwegian petroleum industry is advanced, adaptable and forward-looking. It is working to make the difficult feasible, the complicated easier and the impossible possible.

Enjoy!

Karl Eirik Schjøtt-Pedersen
Diretor general
Norwegian Oil and Gas Association

01

CARBON CAPTURE USING MEMBRANE TECHNOLOGY

A solution is being offered for separating carbon dioxide from exhaust gases at very low pressure and without the use of chemicals or solvents.

Air Products AS, established in 1970, became the first company in the world to introduce membrane technology on ships and offshore oil and gas platforms. An initial nitrogen plant based on this approach was installed in 1984 on chemical tanker M/T *Stolt Integrity*, while the first such facilities were installed in the North Sea the following year on the Murchison and Oseberg A platforms.

Since then, Kristiansand-based Air Products has delivered more than 1 200 plants utilising membrane technology to ships and over 220 to oil and gas facilities.

The company began collaborating in 2013 with the Norwegian University of Science and Technology (NTNU) in Trondheim, which has been pursuing research for a number of years on a special coating process for removing CO_2 from flue gases. Combining Air Products' fibre membrane technology and the NTNU's coating

process allowed them to present the fixed-site carrier (FSC) membrane in 2015.

Backed by technology transfer from the oil and gas industry and the NTNU's FSC research, a new project was launched in 2015-16 together with the Climit research programme, the state-owned Gassnova company and cement manufacturer Norcem Brevik. This venture is known as membranes for carbon capture in the cement industry – MemCCC.

Its goal is to design and build a test unit based on FSC membranes for long-term trials with genuine cement flue gases at the Norcem plant in Brevik. Delivered by Air Products, this facility is now installed and operational. The main aim of the project is to demonstrate and qualify, in technical and financial terms, stable, high-efficiency and durable carbon capture from cement flue gases with the aid of FSC members. A final report and results are expected in the spring of 2017.

02

PRODUCING DRINKING WATER FROM THE SEA

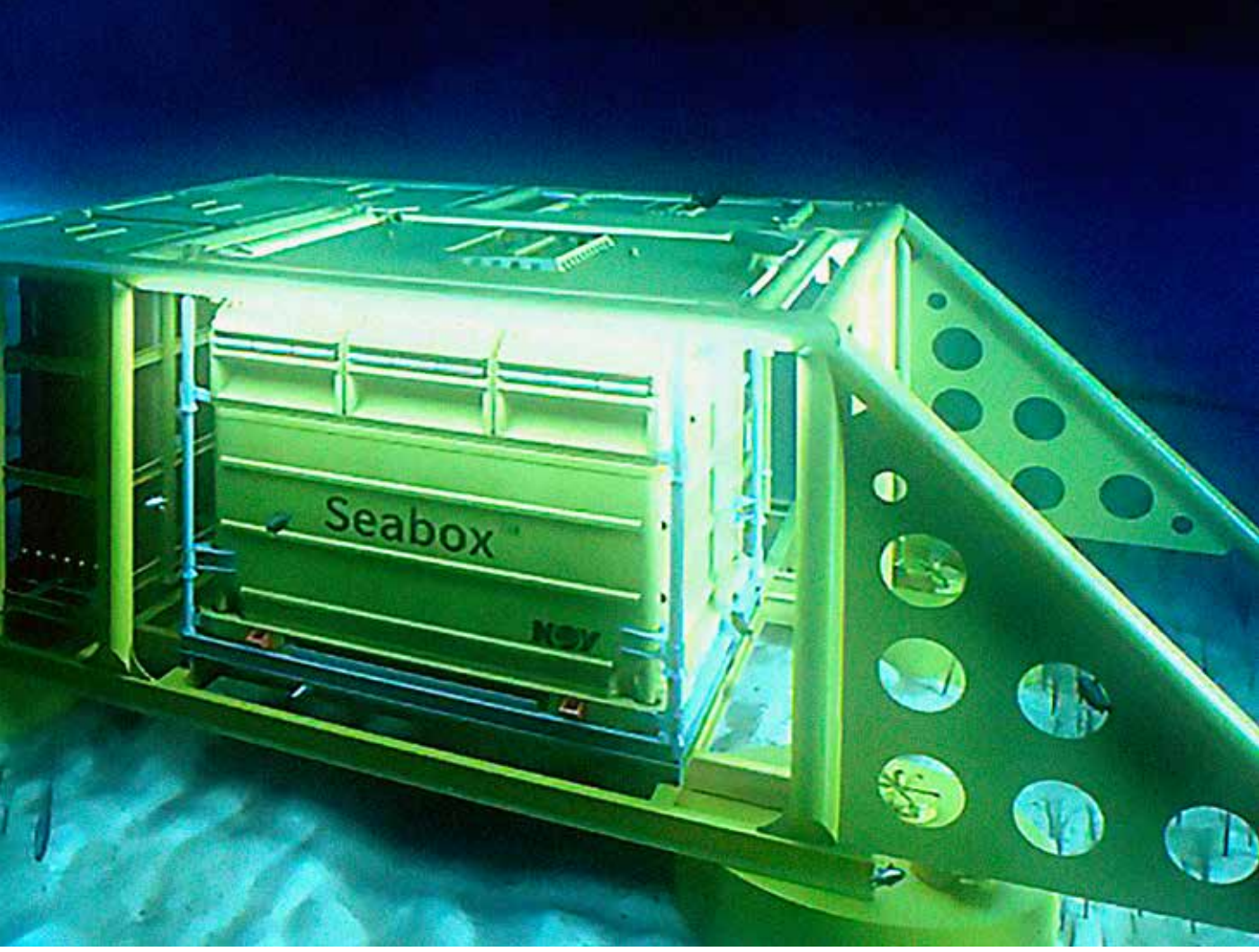
This seawater treatment plant is intended for use in connection with oil production, but it can also supply potable (drinking) water in hot regions.

Water injection is the most widely used method for energising oil reservoirs in order to improve recovery. The seawater to be injected must first be treated to remove bacteria and particles. The degree of such treatment will vary from field to field. Requirements for it have been tightened in recent times – with a reduction in salinity also desirable in a number of cases. Reverse osmosis is the principle utilised for producing desalinated water. Seawater gets treated at present with the aid of equipment on the platform, which takes considerable space and weighs a lot. Capital and operating costs are correspondingly substantial.

Seabox, now part of National Oilwell Varco (NOV), has come up with the subsea water injection and treatment (Swit) technology for processing seawater directly on the seabed. A clear goal for this development is to achieve better reliability, useful life and maintenance-friendliness than traditional solutions can provide. This is essential for subsea technology, which is difficult to access for maintenance and repair.

The solution has now been brought to the stage of commercial products. At the request of various oil companies, a full-scale prototype is under construction for testing in 100 metres of water. A big advantage of using reverse osmosis in deep water is that the process will then be much more energy-efficient than a traditional solution, and provide power supply savings of up to 50 per cent.

Seawater basically has a salt content of 35 000 milligrams per litre (mg/l). This is typically reduced to 5 000 mg/l for injection purposes. However, it could well be cut to potable water quality – in other words, less than 500 mg/l.



Producing potable water with reverse osmosis is a known approach. The special feature of the Swit technology in this context is the combination of Seabox microfiltration ahead of reverse osmosis, and the fact that the whole process can be done in deep water. Testing has shown that this yields very good results. Current applications of reverse osmosis to produce potable water involve substantial energy consumption and associated operating costs, and also require extensive maintenance. The Swit system takes out both particles and organic/bacterial activity ahead of reverse osmosis, so that the membranes only remove dissolved salts – which is what they have been developed to do.

When using Swit to produce potable water for general consumption, the natural solution is to move the Seabox ashore. However, the operational procedures developed for equipment on the seabed are also expected to be adopted for installations on land.

Feed pumps for reverse osmosis become virtually redundant for solutions in waters more than 450 metres deep, since hydrostatic pressure will then take over the job. The necessary depth will depend on the water quality to be produced. This effect can also be achieved for potable water with a plant of the type shown above if the microfilters and reverse osmosis membranes are placed in a rock cavern at a depth of 400 metres, for example, below sea level. That will also provide physical protection, which could be desirable in some regions. Norwegian tunnelling technology will be an important element in such cases.

A solution of this kind was presented to Middle Eastern countries, which see that it could offer big advantages for such applications as producing potable water. Seabox has developed this solution in cooperation with Multiconsult and Apply Sørco.

03 INTERVENTION SIMULATOR DRAWS ON OIL AND GAS RESEARCH

Scientific work for the petroleum industry is being used to simulate which medical operations will yield the best outcome for the patient.

Cardiovascular disease is the leading cause of death in western countries, and has the biggest social cost. Being able to simulate possible interventions so that health personnel are best schooled in responding to this condition would be beneficial. Replicating the specific blood flow in each individual heart will make it possible to predict the effect of a treatment. That allows various operations to be tested in advance, and can say something about which measures give the best result for the individual patient. Much of this simulation technology builds on research conducted in the oil and gas sector.

Developing such patient-specific simulation models provides knowledge at a level of detail which was only available before through experiments and imaging diagnostics. The goal is to utilise these models to learn more about blood flow in healthy and diseased hearts, to evaluate the effects of different surgical interventions in advance, and to tailor treatments for the specific patient.

The outcome would be more successful repairs, less need to repeat operations, improved quality of life for the patient and reduced health-care costs for society. A further aim is for such a system to give patients relevant information about their own treatment and thereby open the way to knowledge-based user involvement.

This CardioSIM solution has prompted scientists to envisage a more structured treatment process. Physicians will be able to supplement the information they currently get from such sources as ultrasonic scans with results from three-dimensional simulations of blood flow through the heart before and after the planned intervention. That gives them a more objective decision basis.

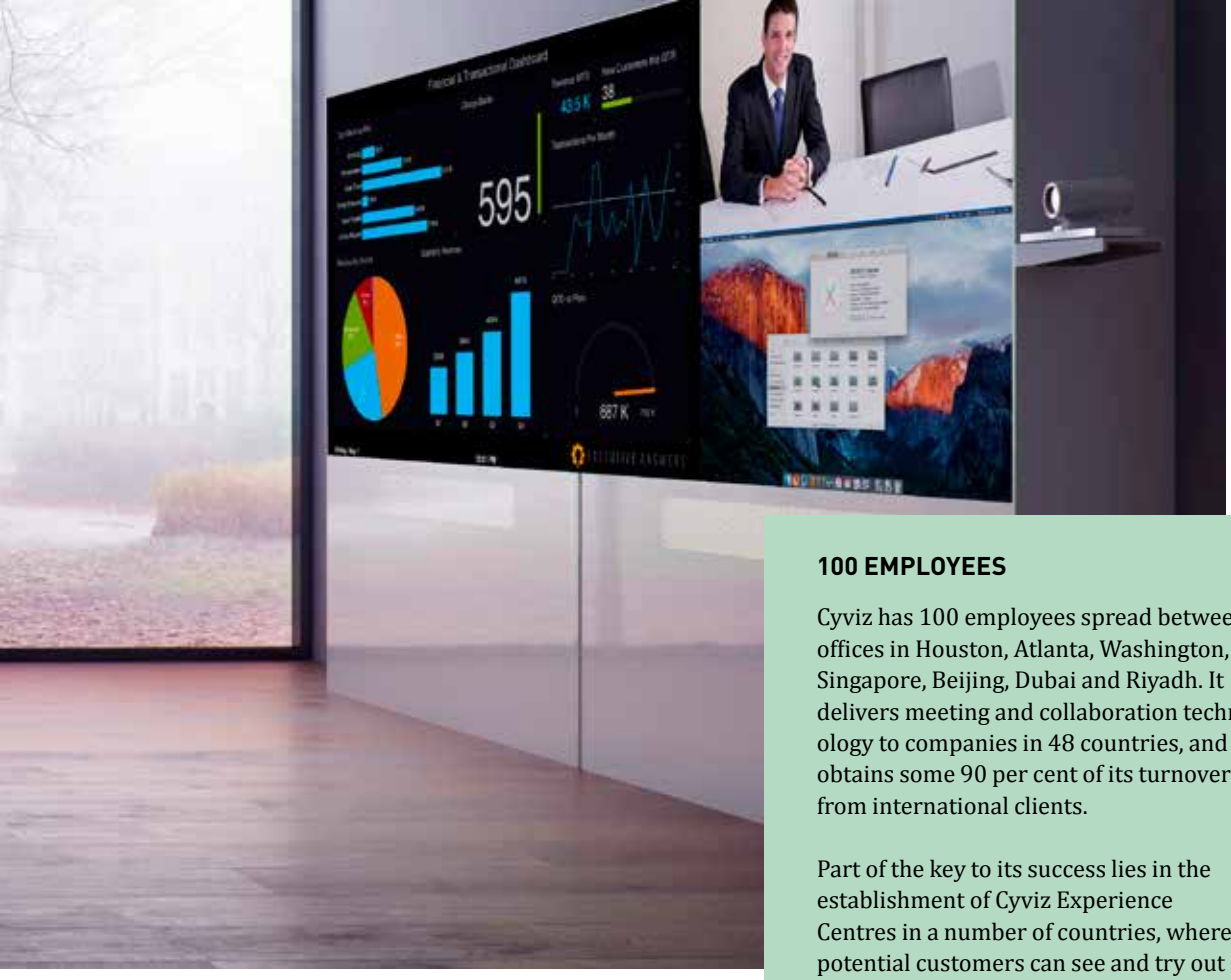
The CardioSIM vision is to develop a decision support system for clinicians based on patient-specific simulation models for diagnosing and treatment planning with cardiovascular diseases.

Biomechanics forms an important basis for the system, and is a rapidly expanding discipline internationally which deals with modelling and analysis of the body's tissues and organs. It involves several classic engineering fields, such as mechanics, flow, material technology and numerical calculation methods. The Sintef research foundation has acquired a high level of expertise in this field, in part through petroleum-related work, and the time is now ripe to transfer this knowledge to the medical sector.

04

BEGAN WITH SEISMIC DATA – NOW COUNTS NATO AND NASA AS CLIENTS

Cyviz started out working on three-dimensional visualisation of seismic survey data. Technology for meeting and control rooms are its main business today.



100 EMPLOYEES

Cyviz has 100 employees spread between offices in Houston, Atlanta, Washington, Singapore, Beijing, Dubai and Riyadh. It delivers meeting and collaboration technology to companies in 48 countries, and obtains some 90 per cent of its turnover from international clients.

Part of the key to its success lies in the establishment of Cyviz Experience Centres in a number of countries, where potential customers can see and try out the technology. The company is due to open five new centres in Oslo, London, Singapore and Atlanta to attract new business.

Founded in 1998 by Joar Vaage and Øyvind Hovland, the company was in its day a child of Stavanger's oil and gas industry and its activities were directed at that sector. The petroleum business has made groundbreaking use of new technology, and remains an important client, even though Cyviz is now experiencing greater growth in other areas – such as defence, finance, space and health. Its client list extends from Chevron and Aker Solutions, through the DNB bank and Norway's government pension fund – global, to Nasa, the US armed forces and Memorial Hermann. The last of these is the biggest hospital group in Texas, with 16 locations and more than 24 000 employees.

Cyviz began with 3D visualisation of seismic data, allowing geologists to analyse reservoirs wearing 3D glasses. Experience from this segment underpinned the development of visualisation solutions for extreme amounts of data – a field also driven by the oil and gas sector. Similarly, requirements for robust monitoring tools have defined the terms for Cyviz's control and collaboration solutions. These are used today by the world's largest companies, which have teams spread over many locations.

Solutions from Cyviz make it easy for a distributed workforce to meet, collaborate and solve complex challenges. The combination of visualisation and interaction adds a new dimension which contributes to better processes and rapid decisions. All the company's products build on the same platform, making life simpler and more secure for its employees. Launched in 2016, this Cyviz Easy platform changes the way modern collaboration solutions are built, used and managed. It has been standardised on the principle that everything becomes easy when everything is the same.

05

FROM DEEP WATER TO OUTER SPACE

Oslo-based Presens AS worked on subsea installations, but secured a contract from the European Space Agency (ESA) to transfer offshore technology to space flight. This has been a success.

The company's focus was originally on the oil and gas sector when it was established in 1996, concentrating on high-accuracy sensors for measuring pressure on subsea installations. As early as 2002, Presens won its first assignment from the ESA with the aim of "spinning in" technology from the offshore sector. This has proved a success, and the company has delivered a number of development jobs to the European agency. It is now negotiating with Airbus Defence & Space over commercial deliveries to telecommunication satellites and launch rockets. The first trip into outer space came in July 2010, when the Prisma satellite was placed in orbit.

In recent years, Presens has developed a low-pressure sensor for monitoring very low oxygen pressure as part of the atmospheric laser doppler instrument (Aladin) used for direct measurement of wind speeds in the outermost layers of the atmosphere on a global scale. This could result in a breakthrough for more reliable weather forecasting and climate studies.

Aladin will be the first satellite-transported laser with global coverage, and will map wind profiles from ground level to a height of 30 kilometres. The pressure sensors form part of an innovative system for flushing the laser optics with oxygen to avoid contamination and degradation. They were delivered to Airbus in late 2016 and the launch of the Aeolus satellite is planned for late 2017.

The ESA has identified accurate fuel measurement on telecommunication satellites as an important priority area. Current solutions for this function lack sufficient accuracy or reliability, and telecommunication companies – such as Norway's Telenor – must incorporate big safety margins when calculating the useful life of their expensive satellites.

A key component in a propellant gauging system is a sensitive differential pressure sensor which remains stable over a long period. Presens is a candidate for developing this device, and was commissioned by the ESA in 2009 to come up with prototypes and deliver sensors for a laboratory version of the gauging system. As a result, Presens and its existing technology was found to be capable of competing with the market's best differential pressure sensors.

Experience from this ESA project was fed back in turn to established customers in the oil and gas market in order to commercialise the technology for subsea applications.

PRESENS AS

Develops and manufactures pressure and temperature sensors for demanding applications. It was spun off from Sintef in 1996 by a small team of scientists on the basis of new proprietary technology developed at the Trondheim-based research foundation. Acquired by General Electric in 2012, Presens has continued its operations in Oslo. It currently has 40 employees, and 90 per cent of its sales come from customers outside Norway.

06

ROLE OF PHYSICAL FORCES IN CANCER SPREAD

Modelling tools from the petroleum industry used to visualise how liquids flow through an oil reservoir are being further developed to investigate the propagation of tumours through the body.

This project seeks to find new applications for knowledge and tools developed to describe the way various fluid phases move through a reservoir. For mathematical models to have any real value, they must be developed with a close understanding of the process to be simulated and the problems to be overcome.

Attention is concentrated primarily on developing a two-phase flow model which can simulate and visualise the growth and spread of malignant tumours. Cancer has long been explained mainly from a biological perspective, but forces other

than biochemical processes and genetic risk factors influence its progress.

The world is governed by physical laws, and that also applies to tumours and the surrounding tissue at the cellular level. Greater understanding of the way physical and mechanical forces affect cancer progress in interaction with biochemical processes will be important in developing new methods for detection and treatment. Establishing the basis for a cross-disciplinary approach to oncology issues will also be important in the project.

This work could help to build up a cross-disciplinary cancer research community combining mathematics, physics and oncology. The University of Stavanger (UiS), the International Research Institute of Stavanger (Iris) and Stavanger University Hospital (SUS) will be involved.

Support is being provided by Norway Pumps & Pipes, an initiative aimed at creating a meeting place for expertise transfer between the oil and health sectors in order to promote innovation and value creation. Strengthening education in science, technology, engineering and mathematics will be another goal.

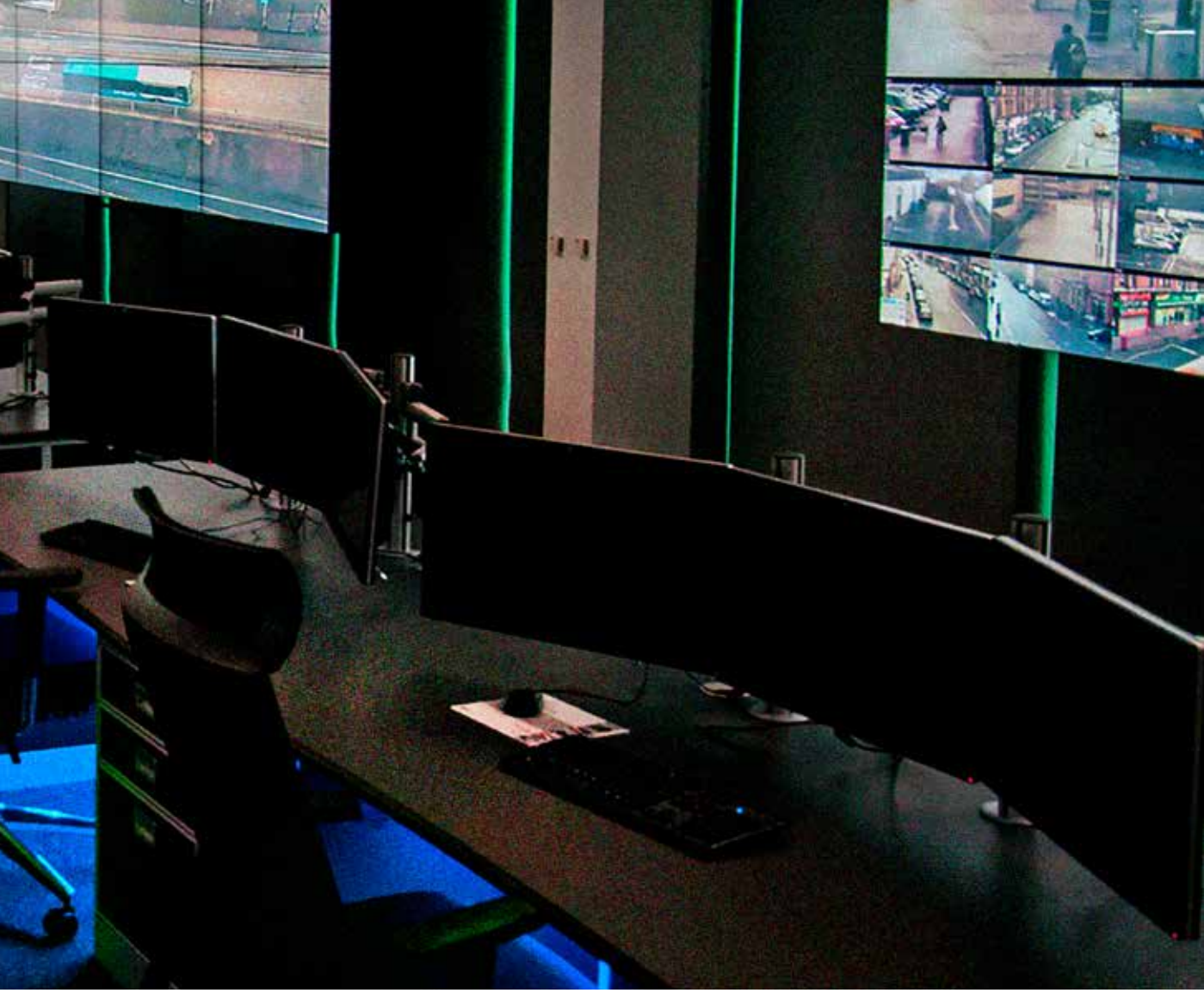
07

FROM SMART OIL TO CLEVER CITY

Organisational and technological solutions developed for the petroleum sector are being transferred to products and services for more intelligent urban communities.

The Oil2City concept builds on good and thoroughly proven technological solutions built up over many years on the NCS and by the oil industry in general. These can be adapted and further developed to contribute to good organisational and technological operation of intelligent cities. Low oil prices and challenges generally affecting the petroleum sector globally mean that both capacity and competence are currently in good supply.

One of the many areas where oil technology, expertise and experience can be applied on land is new forms of interaction in general and integrated operations



(IO) in particular. These approaches have revolutionised the petroleum industry over many years through new technical solutions and interdisciplinary collaboration to achieve efficiency improvements and financial gains.

The Stavanger region, for example, is taking steps to develop Norway's first regional response centre (RRC) for efficient operation of tomorrow's local authorities. During its first phase, the RRC will help to structure, analyse and present real-time and historical data on mobility, transport and travel flows in the region. It will interpret incoming information and present this visually to urban planners and the transport sector in the local authorities.

To achieve this, countless amounts of data must be acquired from such sources as the Norwegian Public Roads Administration, Norwegian State Railways (NSB), the local Kolumbus bus company, tunnel operators, road toll companies, taxis, cycling and the electric bike project. New sensors must also be installed to register and categorise travel by pedestrians, cyclists, cars, buses, lorries and so forth.

In later phases, open data will give private players access to sources which were previously closed. That will allow them to come up with new solutions to meet future needs for real-time information, journey planning, parking, and public and private carpooling options.

08

BETTER SEABED ANALYSIS FROM MEETING OFFSHORE NEEDS

The NUI sediment sampler was originally developed for seabed sampling around North Sea installations with an eye to working conditions for divers. But it can also be used for environmental monitoring and mapping elsewhere in the offshore sector as well as for fish farming, industrial ports and shipwrecks along the Norwegian coast.

This device provides a new and improved method for taking samples from sea-floor sediments. Despite the lack of industry standards for such sampling, it also succeeds in picking up gases and easily soluble chemicals which could form part of such deposits.

That has previously presented a challenge, since samples have generally been collected with open methods such as grabs or unsealed containers. Much valuable information can potentially be lost with these approaches on the way to the surface and to the laboratory. Along with sample results obtained by traditional methods, the NUI sampler provides a good deal of supplementary information.

Identifying gases and chemicals present in seabed sediments is important for the diver's working environment, since such pollutants can stick to their clothes. That in turn may poison the atmosphere in the diving bell/habitat as toxic gases vaporise. The NUI sampler accordingly represents an important innovation for obtaining samples which reveal such concentrations.

Samples are taken using a remotely controlled vehicle (ROV) and then transferred to a vessel with accompanying operational instructions. They are then frozen and sent to NUI by agreement for analysis.

The sampler is designed to contain gases and polluting particles and to prevent the sample being exposed to anything which could reduce its quality before analysis. It is leak-tested with helium.

Since the device is operated by an ROV, no operational depth restrictions apply.

09 OFFSHORE CONTRACTS CUT RAIL DEVELOPMENT COSTS

The biggest-ever construction project in Norway's railway system is utilising standard agreements drawn up for the oil and gas industry on the NCS.

Part of Oslo's overall InterCity development, the Follo Line project involves installing a new double track from Ski south of the capital. This will cut travel time between Ski and Oslo from 22 to 11 minutes and boost rush-hour capacity by 70 per cent.

Although the distance involved is only about 20 kilometres, some 64 kilometres of new track must be laid to meet the goal of maximum capacity. The existing Ski station is to be demolished and replaced by a new six-track facility. As much normal rail traffic as possible will be maintained in the construction phase. This project ranks as Norway's largest single railway development, and the biggest in the Norwegian transport sector at present.

A key aspect of the project's contract strategy is that as many jobs as possible will be outsourced to the market. Larger and fewer contracts will mean fewer interfaces, more efficient follow-up and greater integration of facilities. Good competition will be ensured both nationally and internationally through the choice of language, size of packages and greater use of turnkey assignments.

That approach was also supported by the Ministry of Finance's consultant in its independent review of the KS2 – Follo Line project. Also submitted to the Ministry of Transport and Communications, this report was completed in April 2014.

Turnkey contracts for the project have been developed on the basis of the Norwegian Turnkey Contract (NTC) standard developed for large and complex assignments of this kind. Compared with the general standard for turnkey jobs, the NTC provides a comprehensible contract structure, harmonised contractual documents and good management mechanisms through its change system.

The NTC model is widely used in Norway's oil industry, and many of the people leading the Follo Line development also have offshore experience. Substantial best practice has also been accumulated in project management from oil-related ventures in the NOK 600-1 000 million range, and this is reflected in the appendices to the NTC.

10

SEA FARMS BASED ON OFFSHORE TECHNOLOGY

Aquaculture facilities far from land combine the best from Norwegian industrial experience with fish farming and oil-related technology.

Fish farms in the open sea mean that new areas can be used for this activity in deeper waters with more stable currents. This means in turn that the biological burden of such installations can be cut while reducing space conflicts in the fjords.

Ocean Farming AS, a company in the SalMar group, has been established with the goal of developing open-water aquaculture. It has come up with a catenary-moored semi-submersible plant with fixed structures which floats stably in waters 100-300 metres deep.

Standing 68 metres high and measuring 110 metres in diameter, it builds on the same basic properties as semi-submersible units offshore. All fish can be handled internally without the need for external boats or equipment.

The purpose of the project is to develop technology which will make it possible to utilise new, more open sea areas for aquaculture.

Ocean Farming has collaborated with key suppliers in the fish-farming and offshore sectors to overcome the challenges involved. Established construction norms for fish farms have been supplemented during the design work with regulations and building standards from the oil industry.

Nordlaks is another company developing an open-water farm, which involves a rectangular structure measuring 431 metres in length. This has been created in close collaboration with NSK Ship Design and other specialists. The result merges 25 years of aquaculture experience with leading-edge expertise in ship design and offshore technology. The sea farm project combines established knowledge from these disciplines in a new and creative way, which expands the horizons for tomorrow's aquaculture.

11 NON-INVASIVE WAY TO IDENTIFY NARROWED CORONARY ARTERIES

Reduced blood supply to the heart because plaque builds up in the coronary arteries is the main cause of angina – and ultimately of heart attacks, one of the commonest causes of death in Norway.

A new method for determining the seriousness of such stenosis (abnormal narrowing) is now being developed on the basis of a flow model traditionally used in the petroleum sector. Normal practice in this area at Norwegian hospitals today involves surgical intervention in the form of an invasive catheter-based examination to measure the pressure drop across the stenosis.

This method is called fractional flow reserve (FFR), and provides a quantitative measurement of how much the narrowing restricts blood supply to the heart muscle. That yields information about whether treatment is needed and, if so, in what form.

Because the body does not need to be entered, a non-invasive evaluation is much less demanding for the patient. Coronary arteries are imaged in three dimensions with the aid of computerised tomography (CT) scanning, and equations describing the blood flow through these vessels are solved. This allows blood pressure and flow speed in the area around a stenosis to be predicted.

The mathematical equations are the same as those used to describe the flow of oil and water through reservoir rocks. This procedure eliminates the need for surgery while providing more information about the blood stream than FFR, which is based solely on pressure measurements.

An important contribution could be made by this project to building up a leading research community for computer modelling in cardiovascular medicine. Its partners are Stavanger University Hospital (SUS), the University of Stavanger (UiS) and the International Research Institute of Stavanger (Iris).

Support is being provided by Norway Pumps & Pipes, an initiative aimed at creating a meeting place for expertise transfer between the oil and health sectors in order to promote innovation and value creation. Strengthening education in science, technology, engineering and mathematics will be another goal.

12

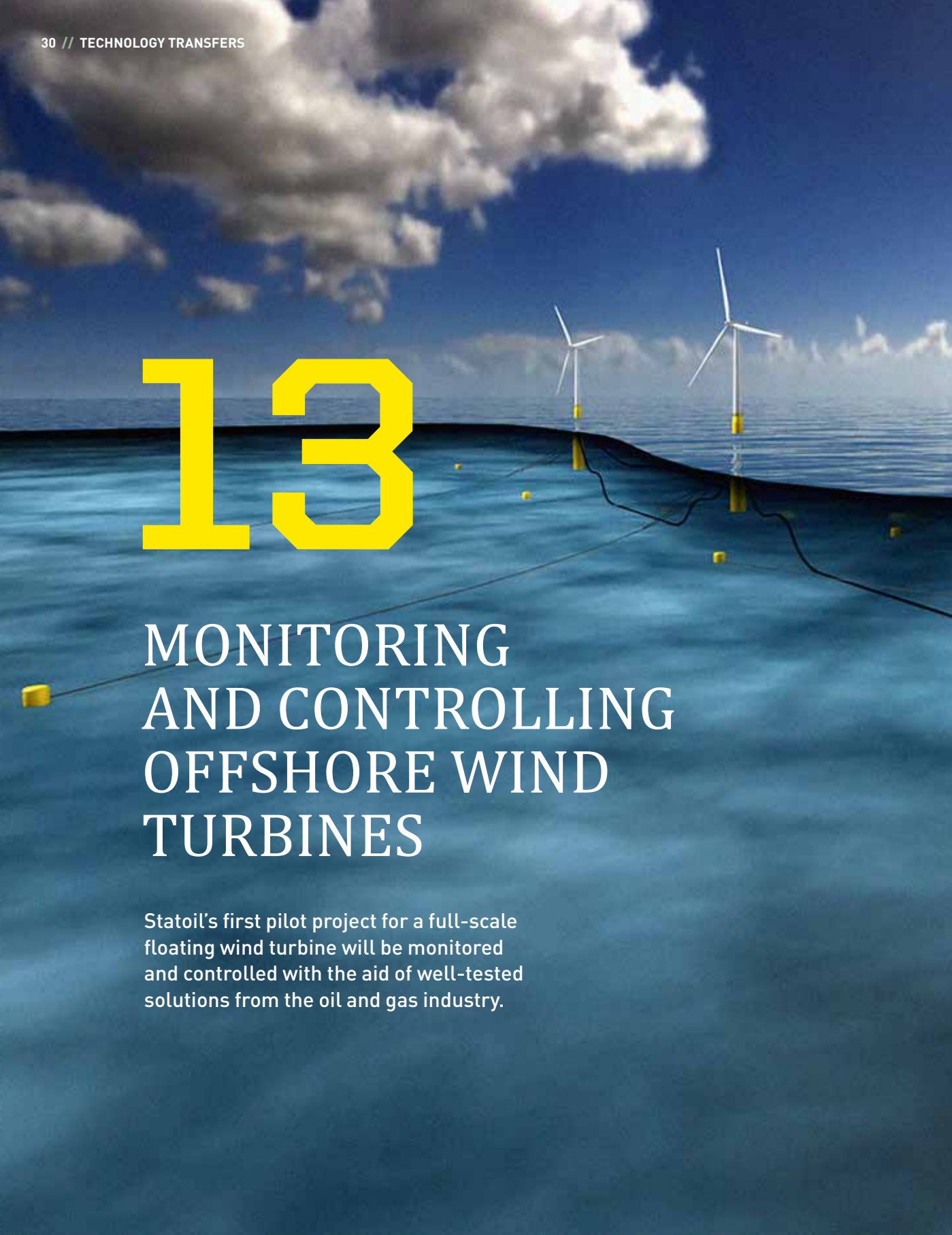
DOING AWAY WITH DIGGING UP ROADS

By transferring progress to the bit and replacing the drill string with coiled tubing, the Ultra No-Dig system can drive microtunnels in any desired direction for up to 30 kilometres.

The oil industry has developed costly, advanced and very competent systems for drilling wells. Aarbakke Innovation AS aims to produce a solution based on an umbilical and an electrically driven drilling system to drill and case microtunnels for district heating, water, sewage and electrical cables. The aim is to eliminate digging up the surface.

Ultra No-Dig achieves very accurate well paths by utilising the instrumentation for directional drilling currently used in the oil industry. Bit, drive, rotation mechanism and umbilical will be pulled out with the aid of an injection system located at the tunnel mouth. In many cases, this means that today's trench-digging can be eliminated – a big benefit in densely built-up areas.

The aim is also to use the system for drilling into geothermal reservoirs, where a large contact surface can be achieved while a potential also exists to reduce energy consumption in circulating water to and from the surface.



13

MONITORING AND CONTROLLING OFFSHORE WIND TURBINES

Statoil's first pilot project for a full-scale floating wind turbine will be monitored and controlled with the aid of well-tested solutions from the oil and gas industry.

Origo Solutions is a specialist supplier of automation and safety solutions. It has more than 35 years of experience in delivering solutions for monitoring, control and protection of installations offshore and on land, with the main emphasis on the oil and gas market. As an independent system supplier across a broad delivery range, the company has acquired great expertise with technology which can also be used in the renewable energy market. That includes Statoil's first pilot installation for a full-scale floating wind turbine off the Scottish port of Peterhead.

This facility will have a complete supervisory control and data acquisition (Scada) system to provide operational and output information as well as handling safety when running each turbine. The system can be remotely operated from an onshore control room at Great Yarmouth on the English east coast.

Operating data are acquired from various subsystems in the turbines, such as electrical control, ballast management, mooring-line monitoring, structural monitoring, motion monitoring and compensation, meteorological information on wind, waves, weather and so forth, and the safety systems for fire, break-ins and the like.

The Scada system is built up around equipment and sensors from a number of different suppliers. That calls for integration of a number of different communication standards and protocols.

This delivery from Origo Solutions demonstrates that experience and test solutions from system assignments in the oil and gas sector are very suitable for use in other sectors. It thereby helps to open fresh opportunities in new markets.

14

PROTECTING HISTORIC BUILDINGS FROM FIRE THREATS

An extinguishing technology used off Norway for than 20 years is now being used on land in everything from old houses like Fossesholm Manor (pictured) to ordinary homes.

Inergen's environment-friendliness and safety for people, combined with the offshore industry's high HSE standards, were among the reasons it was adopted in the NCS market at a very early stage. The Petroleum Safety Authority Norway (PSA) emphasised the importance of quick activation for extinguishing agents so that fires were put out as swiftly as possible. The oil sector also set high standards for operational continuity and reliability. All these requirements were met by Inergen, which eventually became the industry choice – initially while halogen-based extinguishing systems were being phased out and now as an alternative to CO_2 on offshore facilities.

The NCS is still one of the most important Norwegian markets for Inergen supplier Fire Eater AS, but the qualities documented for this blend of gases over many years of offshore use have clearly been attractive to users on land as well.

Initially, onshore installations were confined to protecting mission-critical technical facilities such as oil-company data rooms. More recently, interest among the owners of historic and protected buildings has increased sharply.

FIRE EATER AS

Tor Eystein Hovda secured a licence for Inergen gas in January 1993 from Fire Eater AS at Hillerød in Denmark. It was initially marketed to the offshore sector via Technor in Stavanger. The company is now a subsidiary of the Danish parent company, which owns 51 per cent of the shares with rest held by the employees in Norway.

Early activation through modern detection systems, no consequential damage, a high level of safety for people and environment-friendliness are key properties. These reflect a desire to avoid external and internal water damage.

If Inergen can be used in historic buildings, it will also be applicable to ordinary houses. Fire Eater is therefore developing products specially adapted to normal dwellings and care homes. Controlled installations can protect groups of houses with a shared bank of gas cylinders. Inergen is being considered more and more frequently as an alternative to sprinkler systems.

Opportunities for output reductions combined with great architectural flexibility mean that the company is constantly receiving enquiries in this area. Collaboration early in the building process will cut costs throughout a project's lifetime, which means innovation is not at the expense of profitability. Inergen's entry into these markets has met great resistance in a conservative industry based largely on preconceived solutions, and where developments have stood still for almost a century. Fire Eater is therefore in full swing with spreading information to consultants, architects, insurance companies, property owners and industry associations.

15 PRODUCING PARTS FOR ADVANCED HEART PUMPS

K Lerøy Metallindustri AS (KLM) is supplying components for ground-breaking medical equipment, using machinery originally acquired to deliver high-precision parts to the oil industry.

Collaboration between KLM and the Nuheart development company began when a mutual acquaintance in the subsea sector introduced them to each other.

Experience with machining advanced components in difficult materials has been crucial for KLM's ability to deliver the parts Nuheart needs for its pioneering prototypes. These pumps are transported into the heart through an artery, and must accordingly have a tiny diameter.

Components of the size and complexity required by the pump mean that the work is right on edge of the feasible in terms of machining, material properties and documentation of measurements. The ultra-thin wall of the pump housing, for example, demands tolerances measured in hundredths of millimetres, and internal parts can only be checked by the most advanced measuring equipment. As Nuheart optimises its design and approaches the final product, the requirements for documentation and quality systems will become ever-tougher. KLM then benefits from having worked with the oil and gas sector and its similarly stringent demands for the products it orders.

So a company which began life 60 years ago making parts for the furniture industry can now produce components to be introduced into the human body. That demonstrates the value of being able to transfer expertise and technology between different sectors and disciplines.

16

USING OIL TECHNIQUE TO PLAN A ROAD

When a consultant engineering team was called on to design part of a Norwegian highway at record speed, it looked in part to the petroleum sector for inspiration.

Sweco ranks among Europe's leading consultant engineers, working on a broad range of construction, energy and infrastructure assignments. Its building information modelling (BIM) strategists work continuously to identify the best technology and most suitable methods which will allow clients to implement projects in a good and efficient manner.

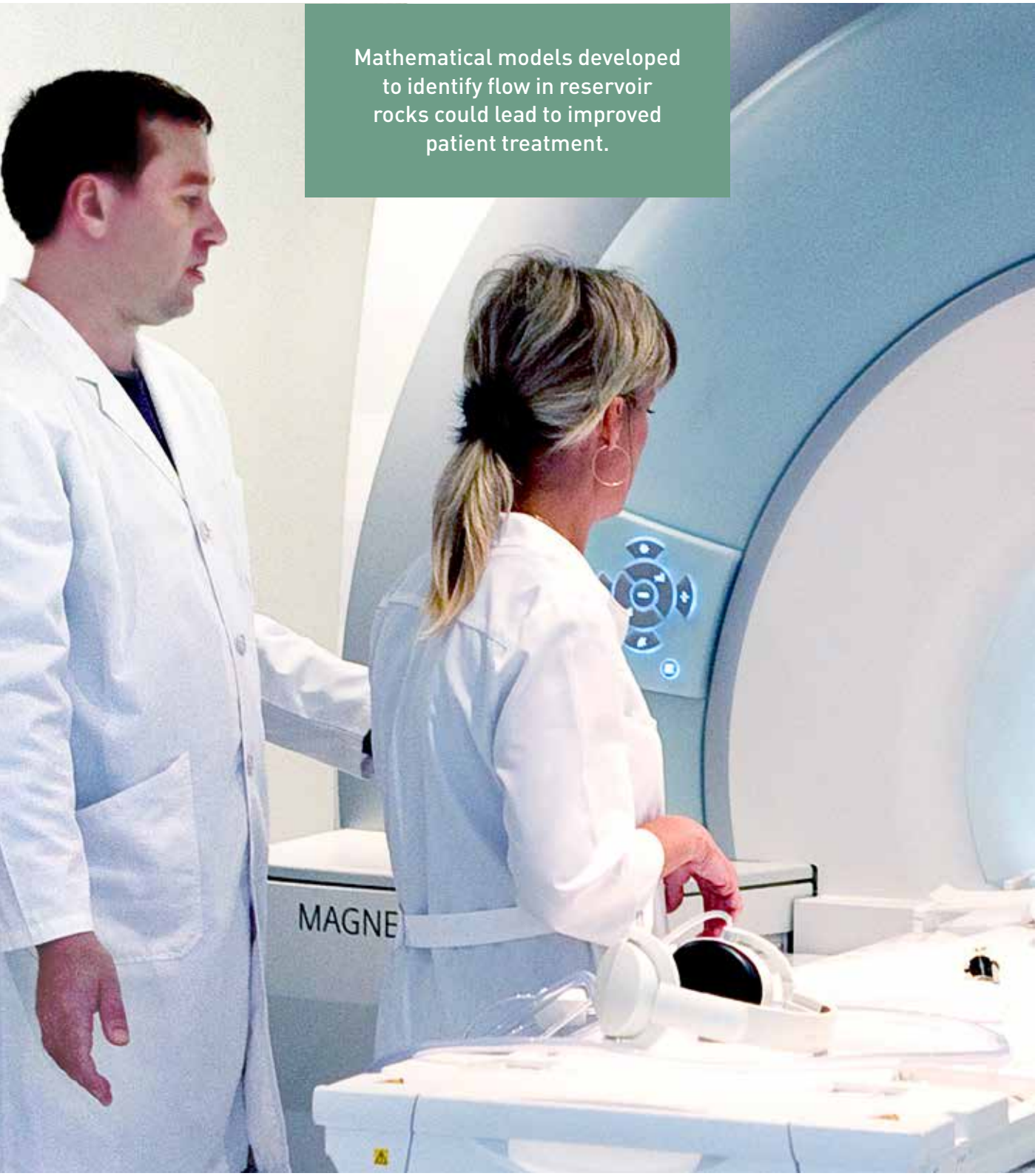
The company was commissioned by the Norwegian Public Roads Administration in November 2015 to come up with proposals for the early-phase route alignment of a 200-kilometre section of the E6 motorway across the Dovrefjell mountains between Støren in the Trondelag region and Otta in Oppland county. This job called not for detailed planning but for a feasibility study which indicated highway geometry and a rough cost estimate for the alignment. The result was to be used in work on the national transport plan (NTP), and time was short.

The BIM strategists had studied working methods in several industries, and derived inspiration in part from the oil and gas sector. Integrated planning – a methodology which involves simultaneous design and development – is well known in the petroleum industry but represents a relatively new approach for infrastructure projects.

Thanks to this methodology, the consultants succeeded in improving efficiency and drastically shortening the planning process. Sweco took only five days to establish a rough alignment for the stretch, and could conduct a workshop with the client on the sixth day.

Consultant engineers are seeing a growing demand among infrastructure clients for such working methods. The BIM strategists at Sweco and their client at the roads administration agree that integrated planning and its associated technology offer a big potential.

Mathematical models developed to identify flow in reservoir rocks could lead to improved patient treatment.



17

BETTER SCAN INTERPRETATION WITH RESERVOIR FLOW MODELS

Contrast-medium-enhanced dynamic magnetic resonance imaging (MRI) scanning is an important technique for identifying anomalies in human tissue and the cardiovascular system, such as tumours and kidney failure.

While the MRI image sequence provides a representation of concentrations in the contrast medium used, it must also be subjected to meaningful clinical interpretation. This project is a collaboration between the International Research Institute of Stavanger (Iris) and the biomedicine department at the University of Bergen.

The basic question to be answered is whether a mathematical model developed to study flows in porous reservoir rocks can provide better dynamic image interpretation than traditional methods.

This calls for formulating adequate flow models, establishing a method for adapting data and models, and comparing results from the proposed solution with those yielded by available state-of-the-art methods.

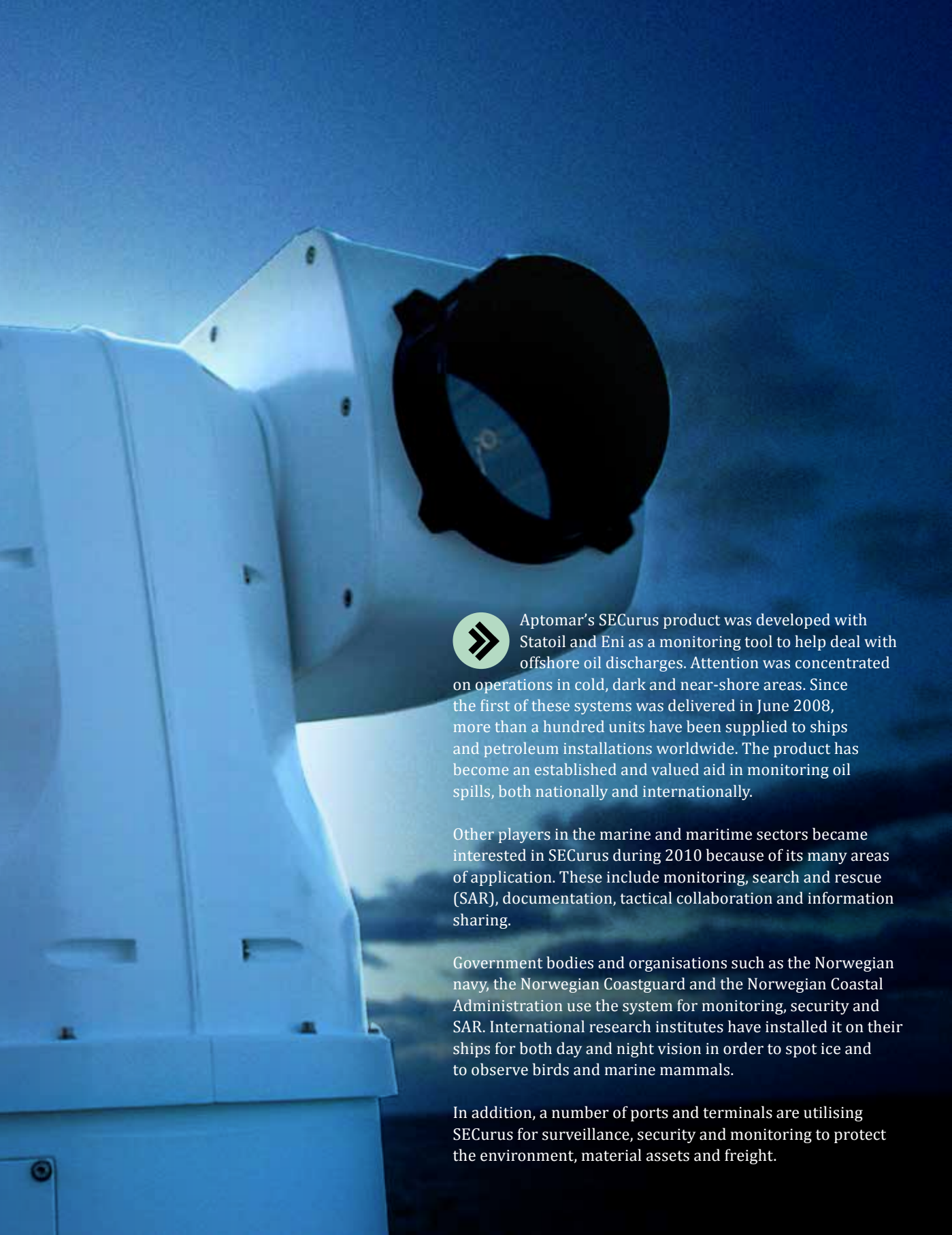
A new approach which provides better utilisation of dynamic MRI data will potentially improve patient treatment. But the initial goal is to inspire further research in this direction. Enhanced interpretation tools could also be interesting for companies which deliver hardware and software related to MRI.

The project is being supported by Norway Pumps & Pipes, an initiative aimed at creating a meeting place for expertise transfer between the oil and health sectors in order to promote innovation and value creation. Strengthening education in science, technology, engineering and mathematics will be another goal.

18

FROM OFFSHORE TO MARITIME, DEFENCE AND LAND-BASED INDUSTRY

Monitoring tools developed to combat oil spills at sea are being used to search for, rescue and observe birds and marine mammals.



Aptomar's SECurus product was developed with Statoil and Eni as a monitoring tool to help deal with offshore oil discharges. Attention was concentrated on operations in cold, dark and near-shore areas. Since the first of these systems was delivered in June 2008, more than a hundred units have been supplied to ships and petroleum installations worldwide. The product has become an established and valued aid in monitoring oil spills, both nationally and internationally.

Other players in the marine and maritime sectors became interested in SECurus during 2010 because of its many areas of application. These include monitoring, search and rescue (SAR), documentation, tactical collaboration and information sharing.

Government bodies and organisations such as the Norwegian navy, the Norwegian Coastguard and the Norwegian Coastal Administration use the system for monitoring, security and SAR. International research institutes have installed it on their ships for both day and night vision in order to spot ice and to observe birds and marine mammals.

In addition, a number of ports and terminals are utilising SECurus for surveillance, security and monitoring to protect the environment, material assets and freight.

19

FROM OIL PLATFORMS TO WIND ENERGY

A motion-compensated gangway from Uptime International AS allows personnel and materials to be transferred directly from a ship to an offshore turbine.

Marine Aluminium, which has been delivering personnel access systems from vessels to oil installations since 1979, joined forces in 2011 with ICD Industries AS to establish Uptime. This company is concentrating on the fast-expanding "walk to work" market in the offshore petroleum sector.

These solutions were further developed by Uptime in 2012 to extend their application to offshore wind turbines, providing simpler and safer access to such facilities. Subsequent progress with this equipment has been formidable.

From being a passive compensated solution for personnel, it has now become an active motion-compensated system. This carries materials directly from below deck on the vessel via an integrated

lift in an adjustable pedestal and across the gangway on electric trollies. That means technical personnel do not have to carry tools and equipment. Work on and maintenance of the turbines can be carried out without the need for cranes.

Uptime gangways are integrated with the vessel's dynamic positioning (DP) system and can therefore be used as an extra reference if desired, with a further increase in safety.

Previous access solutions meant that work on a wind turbine had to cease when significant wave heights exceeded about 1.5 metres. With the Uptime design, activity can continue up to roughly three metres of significant wave height, depending on the ship used. Service offshore vessels (SOVs) for wind turbines with Uptime gangways are configured for continuous use, and need less than 30 minutes between each connection in an offshore wind park. Uptime also plans to deliver its patented autolanding system for gangways in the offshore sector to the wind turbine market, which will further reduce the time required for the connection sequence.

20

COMMUNICATION FROM OIL TO SHIPPING

Experience acquired in the petroleum industry has equipped Harris CapRock to deliver services to the historic Hurtigruten cruise/ferry fleet along the Norwegian coast.

Part of the Harris group's critical network division, this company's core deliveries for many years have been tailored satellite-based communication solutions for the oil sector. End users range from oil rigs and support ships to merchant vessels and land-based facilities. From a primary concentration on the offshore industry, Harris CapRock has shifted some of its activities over to the shipping sector.

Long experience with oil industry deliveries means the company is able to deliver reliable services to the merchant and cruise fleets. Its office recently secured a contract to provide Hurtigruten with shipboard communication equipment.

Harris CapRock has thereby moved from being mainly an oil industry supplier which combines solutions involving satellite communication, 4G, radio links and new technology to enter a new and exciting market – as a good and reliable communication integrator.

HARRIS CORPORATION

Headquartered in the USA, this group has more than 22 000 employees and specialises in such areas as delivering mission-critical information in both commercial and non-commercial markets worldwide. Harris is a leader in designing and developing secure communication systems for various sectors. Transferring speech, data, images and video are among its specialities.

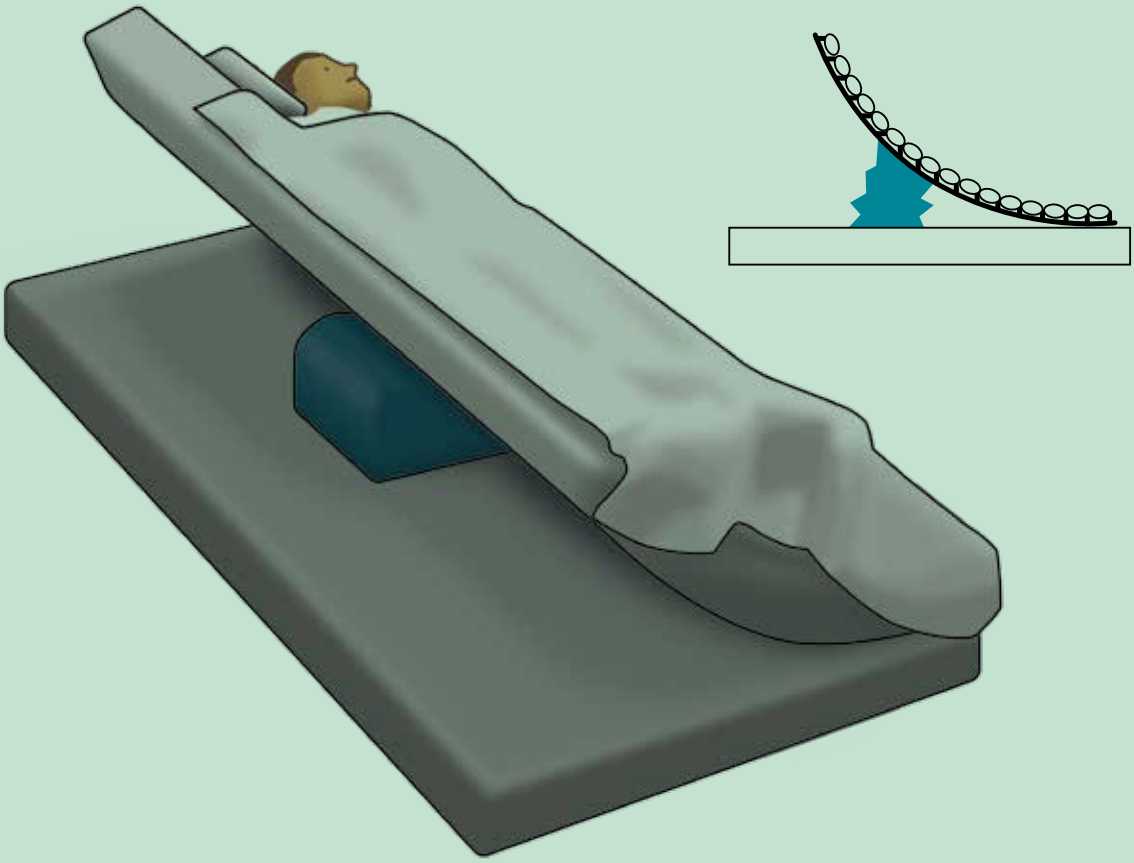
21

LESS LIFTING FOR NURSES AND FEWER BEDSORES FOR PATIENTS

Manual turning of bedridden people with little or no mobility has a number of drawbacks. Expertise transferred from the petroleum sector can now help to lighten this load.

Nursing staff spend many hours turning patients, and injuries or back pain related to manual lifting are the most important reason for sickness absence among such personnel. Health institutions devote substantial resources to this problem.

Treatment of bedsores accounts for four per cent of Norway's health budget. And manual turning is not least often painful for the patient. Available statistics show that at least 50 per cent of the roughly 45 000 residents in Norwegian nursing homes need such attention.

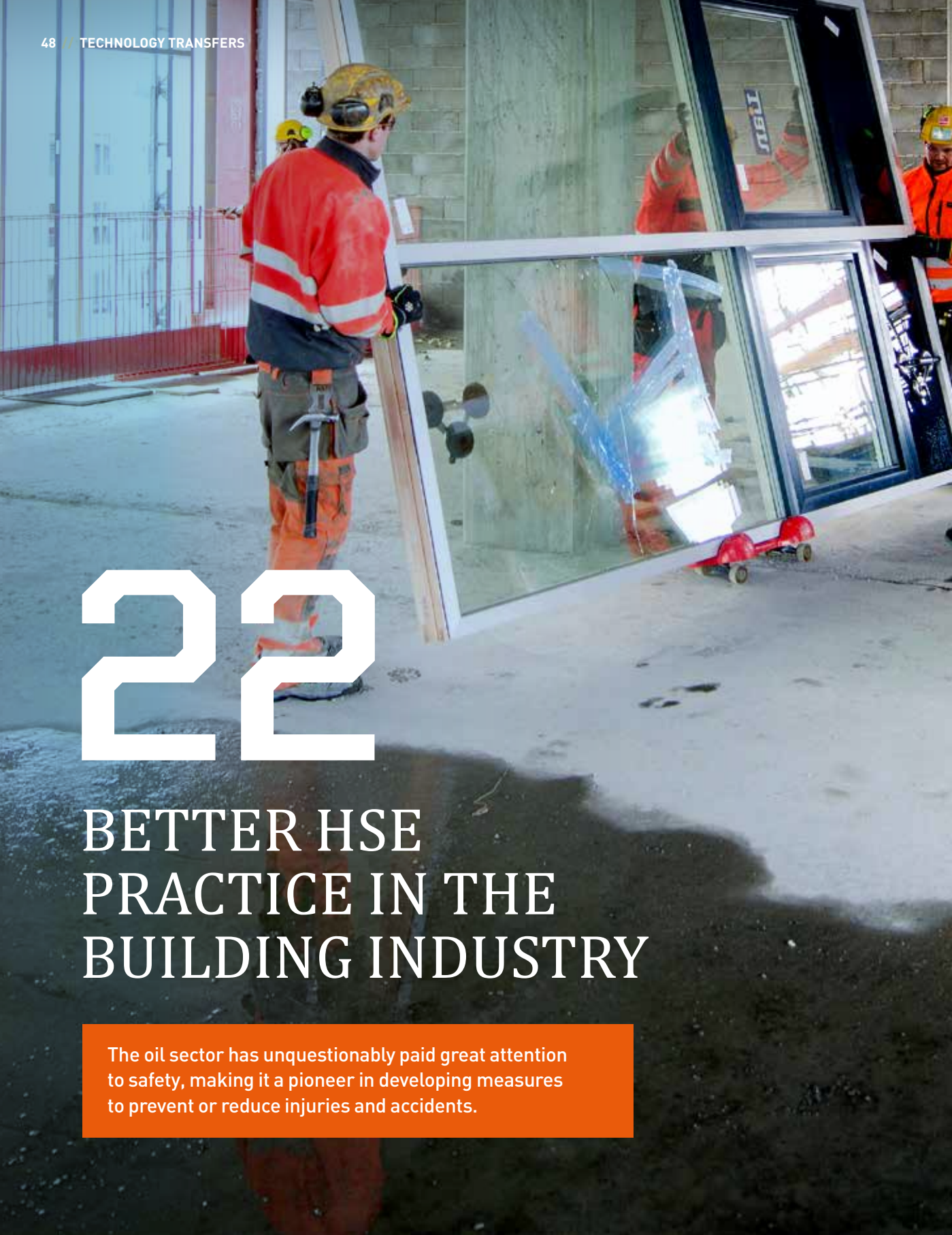


The global market for products which help to avoid pressure injuries is growing. That primarily reflects an aging population and rising obesity, as well as an increasingly better-functioning health service. Tidewave is offering a rotation module which can be installed on any bed base in combination with an overlying mattress.

This module curves with the aid of an automated pressure unit, and the motion turns the patient in line with a predetermined timetable. Such automated pressure management has been derived from the offshore business, and the project is a good example of expertise transfer from that industry to the health sector.

Production of such rotation modules will be handled for Tidewave by Aarbakke Innovation, a company with heavyweight expertise in and experience from the oil and gas industry.

The project is supported by Norway Pumps & Pipes, an initiative aimed at creating a meeting place for expertise transfer between the oil and health sectors in order to promote innovation and value creation. Strengthening education in science, technology, engineering and mathematics will be another goal.



22

BETTER HSE PRACTICE IN THE BUILDING INDUSTRY

The oil sector has unquestionably paid great attention to safety, making it a pioneer in developing measures to prevent or reduce injuries and accidents.

Declining injury statistics in the Norwegian petroleum industry have been a good motivation and driver for improving safety in the onshore construction business. A number of current measures for safe working in this industry are based on practice from the oil business, such as the safe job analysis (SJA) procedure.

Construction company Veidekke Entreprenør defines SJA as "a systematic review of all sub-tasks in a work operation to identify hazards so that measures can be taken to eliminate, reduce or control the dangers which might arise".

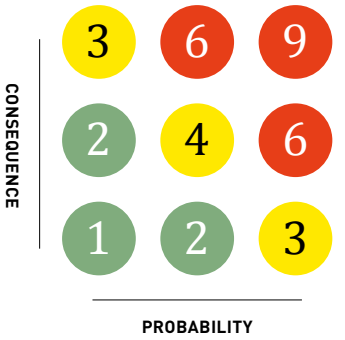
"Hazards" mean all conditions which could lead to loss of or harm to people, the natural environment or material assets.

Several factors may prompt an SJA. Hazards may arise, for example, which have not been adequately covered by the overall HSE risk assessment. Other occasions could be deviations from routines and work instructions or when unforeseen events occur, the introduction of new equipment or jobs, infrequent operations or complex work calling for collaboration between several disciplines.

The analysis is carried out before work starts with the people who are going to do the job. It involves reviewing all elements of the assignment and defining sub-operations in order to identify risk – establishing the consequences of a possible incident or accident and the probability that it might occur. Once the SJA has been done, measures are put in place to eliminate or reduce the hazard.

A risk matrix is used to categorise consequences and probability.

- low risk
- medium risk
- high risk



This calculation indicates which barriers should be in place, and how many, before a job is done. A barrier is intended to prevent errors from developing into an accident, and can be organisational (course certificates, procedures, signs and so forth) or physical (cordons, hard hats, locks and the like).

When prioritising measures, the first step is to try to eliminate the risk, then to lower it and finally to reduce the consequences if something happens.

23

MINIATURE PROBE FOR OIL WELLS CAN BE USED TO HALT BLEEDING

Physical injury – or trauma – is the commonest cause of death on a global scale, particularly among young people. But a microsonde developed for the petroleum sector could help to save lives.

Half of trauma fatalities are caused by uncontrollable internal haemorrhage – in other words, bleeding inside the body which cannot be stopped by external compression. These deaths could be avoided if it was possible to halt the blood loss before the patient leaves an accident site or a hospital casualty department.

A new method of achieving this utilises an occlusion balloon catheter, and is known as resuscitative endovascular balloon occlusion of aorta (Reboa). The procedure involves inserting a balloon-tipped catheter into an artery in the groin and guiding it up to the aorta – the main artery from the heart.

When the balloon is inflated, bleeding from damaged blood vessels behind it will cease immediately. That safeguards blood supply to vital organs such as the heart and brain, and thereby saves lives.

Despite the obvious benefits of this treatment method, it is unfortunately little used. The main reason is

that existing equipment has not been adapted for pre-hospital use.

A tailormade Reboa package is now being developed which will make the procedure simple and safe, either at the injury site or in a hospital emergency. To measure the effect of Reboa and monitor the treatment, a further development of the product will involve equipping the catheter with sensors which register various important parameters, such as blood pressure and oxygen content.

The International Research Institute of Stavanger (Iris) and Sintef ICT have jointly come up with microsondes (μSondes) to measure the condition of oil wells. Experience and knowledge from this project will now be applied to the Reboa work.

Support is being provided by Norway Pumps & Pipes, an initiative aimed at creating a meeting place for expertise transfer between the oil and health sectors in order to promote innovation and value creation. Strengthening education in science, technology, engineering and mathematics will be another goal.

24

FROM RISER ANALYSIS TO TURBINE MONITORING

Software widely used in such applications as drilling operations is now being installed in wind turbines.

The finite element dynamics in elastic mechanisms (Fedem) programme has been developed since the 1980s for dynamic analysis of structural integrity and mechanical systems. Precise analysis and rapid simulation run-time with complex numerical models are among Fedem's strengths. It has been much used over the years in the early phase of offshore projects for calculations, including such aspects as risers and drilling operations.

With time, the software has developed so that Fedem can now analyse complex structures in real time and with high frequency. During 2015, Fedem Technology AS investigated opportunities for using the underlying simulation engine in online and real-time structural monitoring. This involves installing a small number of motion sensors, connecting them to the structural model and "stimulating" it with measurement data. Real-time calculations of structural response are then carried out to provide constantly updated knowledge of the condition. An updated model is constantly available on the internet.

This technology was further developed in 2016 with a full-scale wind demonstrator, where sensors were installed in an onshore turbine to monitor the tower structure. This presentation took place at the Havøygavlen wind farm owned and operated by Arctic Wind AS, and was partly financed by Innovation Norway through its environmental technology scheme.

The goal is to provide the wind farm operator, for example, with a detailed overview of turbine condition. This includes historical information, the present condition, expected loads and calculation of structural life. One application of the analysis results is to adapt maintenance plans and thereby reduce downtime. At the same time, the technology makes it possible to tailor control systems to the actual structural loads by increasing energy output, for example, under conditions which are otherwise restricted by standard control systems.

Fedem occupies a key place in this monitoring concept, with its fast-working engine permitting real-time simulation of complex systems. Positioning virtual sensors in the structural model makes it possible to monitor the general behaviour of the tower structure and to log response data in terms of extreme and fatigue loads. The latter capability results in updated calculations of useful life based on actual loads, which could form the basis for extending the period in operation.

The advantages of virtual rather than physical sensors are that the former can measure several different parameters simultaneously, and that they are located in places where installing physical devices would be difficult or impossible.

25

RoomSketcher was founded in 2007 as a spin-off from Xvision, which has specialised in three-dimensional visualisation for the offshore sector. The technology used to visualise big oil structures under water is now being applied to presenting homes in 3D.

FROM VISUALISING OIL PLATFORMS TO DESIGNING HOMES ON THE WEB

Xvision's history stretches back to 1999, when the big oil companies began to migrate technology down to the depths of the sea. That presented big challenges which called for solutions nobody had seen before, and demand for visualisation became greater than ever before. Since then, the company has produced images, animations and interactive experiences for clients large and small in most sectors of Norwegian industry.

Results from the RoomSketcher Home Designer programme for floor plans and house planning are often to be found in prospectuses and online in advertisements, at residential development companies, and on sites about renovation and interior design.

High-quality floor plans play an important role in the property sector as well as for interior designers and related service providers. Three-dimensional visualisation from RoomSketcher provides a proper "feel" for a property and gives potential buyers a good impression of it.

Two-dimensional floor plans from the company create a simple and professional image of a home's layout. This is perfect when putting a residence on the market, in valuation or sale reports, or for refurbishment or renovation projects. The plans can be supplied either as black-and-white drawings or in colour, with or without furniture, and with or without measurements. In other words, the 2D floor plans can meet the user's exact requirements.

In principle, the same underlying data structure developed in 2007 is used for all the various presentations and applications.

ONE MILLION CUSTOMERS

RoomSketcher has over a million customers and users today, in more than 178 countries. In excess of three million projects have been created with its Home Designer software. Most of the current users are in the USA. The main areas of application are planning of various room solutions and house sales. Room plans are used in such areas as interior design, refurbishment, rehabilitation, office layouts and events. Where house sales are concerned, Home Designer is particularly useful for home photographers, valuers, estate agents, developers and housebuilders.

26 DEVELOPING SENSORS FOR AIRCRAFT ENGINES

ScanSense has won contracts from the international aviation industry by applying technology and lessons learnt from the oil and gas sector.

Established in 1986, the company has spent the past 30 years delivering sensors for safety functions in valves. These are carefully tested and adapted to tough conditions in the offshore, maritime and subsea sectors. High oil prices over the decade up to 2014 had slowed the pace of innovation in ScanSense and, by the time these conditions changed, about 90 per cent of its turnover came from the petroleum sector. The company was then strongly motivated by the oil price slump to renew and further develop its sensors.

The oil and gas industry sets extreme standards for accuracy, safety and verification, making delivery to it a demanding business. Equipment produced for the sector is accordingly very robust, with a design life of more than 25 years. That opens opportunities for transferring technology from the petroleum industry to other demanding sectors, such as health, telecommunications and aviation.

In the autumn of 2015, ScanSense began a dialogue with a medium-sized aviation-industry player in the USA on developing sensors for jet engine turbines to optimise fuel consumption. The US company was interested in collaborating to create a new sensor portfolio which met very stringent demands for temperature tolerance and long-term stability.

In collaboration with the Sintef Mina laboratory and with partial funding from Innovation Norway, ScanSense has transferred knowledge from oil and gas to develop sensors for the aviation sector. Materials know-how, bonding techniques, packing technology, signal processing and ultimately the overall sensor grasp acquired from the petroleum sector equip the company to move boundaries related to weight and temperature ranges for pressure sensors.

Since these devices from ScanSense are able to cope with temperatures above 200°C, they can be positioned closer to the core where fuel pressure in jet engines is measured. That can reduce fuel consumption, providing both financial and environmental benefits. The client has great faith in the products now under development, and has signed a partnership agreement worth well over NOK 250 million, with big and realistic incentives to increase this amount. ScanSense estimates that aviation will account for 25-30 per cent of its turnover in 2017, and plans call for continued growth.

In parallel with its continued commitment to the aviation sector, the company also wants to transfer expertise from this industry back to the offshore business. That will allow its sensors to be used in entirely new areas for oil and gas as well – including well flow metering and downhole applications for process optimisation during production.

DEVELOPERS: Development engineer Sara Kolberg (right) and product design manager André Jacobsen are working to develop sensors at ScanSense.

KNOW OF OTHER TECHNOLOGIES? LET US KNOW

Send your tip-off about technology transfer to editor Kolbjørn Andreassen at Norwegian Oil and Gas: ka@norog.no

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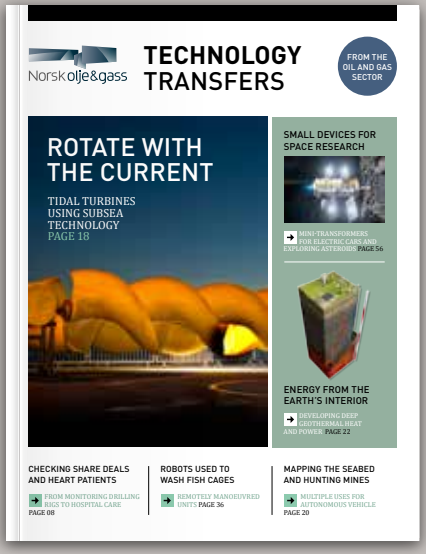

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The Norwegian petroleum industry is advanced, adaptable and forward-looking. It is working to make the difficult feasible, the complicated easier and the impossible possible.

Karl Eirik Schjøtt-Pedersen

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